The relationship between the home environment and children's physical activity and sedentary behaviour at home

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Abstract

Increasing children's physical activity (PA) and reducing their sedentary behaviour are considered important preventative measures for obesity and several other health risk factors in children. Given children spend significant time at home, an improved understanding of these behaviours in the home environment would provide invaluable insight for interventions. Therefore, the overarching aim of this thesis was to provide new insight into how the home environment is related to children's home-based PA and sedentary behaviour.

Study 1 investigated the relationship between sufficient moderate-to-vigorous physical activity (MVPA) ($\geq$60 min·day^{-1}) and excessive screen-time ($\geq$2 h·day^{-1}) with lifestyle factors in children, and found they were associated with healthy and unhealthy factors, respectively. This study highlighted the importance of meeting PA and screen-time recommendations in relation to important health-related lifestyle factors, which is of concern, as few children were shown to meet such recommendations. Identifying the correlates of children's behaviours is an important stage in intervention development, therefore studies 2-5 focussed on improving understanding of children's PA and sedentary behaviour at home. Study 2 demonstrated the validity and reliability of HomeSPACE-II, a novel instrument for measuring physical factors that influence children's home-based PA and sedentary behaviour. Using HomeSPACE-II, study 3 showed that the physical home environment is related to children's home-based PA and sedentary behaviour. Given the established influence of social and individual factors on children's behaviour and their confounding effects in study 3, study 4 investigated the influence of social and individual factors on: (i) children's home-based PA and sedentary behaviour, and; (ii) the home physical environment. Study 4 revealed that parental and child activity preferences and priorities, as well as parental rules were associated with children's home-based PA and sedentary behaviour and the physical home environment. Study 5 found clusters of social and physical factors at home, which were associated with

children's home-based PA and sedentary behaviour as well as background characteristics in the expected directions.

Scientific outputs

Publications

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Presentations

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Sheldrick, M.P.; Maitland, C.; Mackintosh, K.A; Rosenberg, M.; Stratton, G. Validity and reliability of the HomeSPACE-II instrument to assess the influence of the home physical environment on children's physical activity and sedentary behavior. 1st Annual Pan-Wales Postgraduate Conference in Sport and Exercise Sciences, Swansea, UK. April 2017. Poster Presentation.

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Declarations and statements

1. I, Michael Sheldrick, hereby declares that the work presented in this thesis has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

2. I, Michael Sheldrick, hereby declare that the thesis is the result of my own investigations, except where otherwise stated and that other sources are acknowledged by footnotes giving explicit references and that a bibliography is appended. In chapter 5, data from the 2015 Swan-linx project was analysed. In this chapter, I analysed the data and wrote the manuscript. I was not involved in collecting data for that year's project, but I have participated in data collection for later editions. In chapter 6-9, I was the sole person responsible for recruitment, data collection, analysis and the writing of the manuscripts.

3. I, Michael Sheldrick hereby gives consent for the thesis, if accepted, to be available for photo copying and for inter-library loan, and for the title and summary to be made available to outside organisations.

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20 MSFT	20 metre multi-stage fitness test
β	Standardised regression weight
A-STEM	Applied Sport Technology Exercise and Medicine
ABP	AddressBase Premium
AYP	Active young people
BMI	Body mass index; weight (kg) divided by height (m2)
BMI z-scores	Measure of relative body mass adjusted for child age and sex with use of reference data
BLE	Bluetooth low energy
CFA	Confirmatory factor analysis
CHAT	Child Health and Activity Tool
CI	Confidence interval
CKC	Cohen’s Kappa coefficients
CPM	Counts per minute
CRF	Cardiorespiratory fitness
EMA	Ecological momentary assessment
FMS	Fundamental movement skills
GPS	Global positioning system
GIS	Geographic information system
HBSC	Health Behaviour in School-Aged Children survey
HR	Heart rate
ICAD	International children’s accelerometery database
ICC	Intraclass correlation coefficients
K	Kappa Coefficient
Kg	Kilogram
KMO	Kaiser-Meyer-Olkin
LPA	Light physical activity
LPL	Lipoprotein lipase
METS	Metabolic equivalents
MPA	Moderate physical activity
NHANES	Health and nutrition examination survey
OSMM	Ordnance Survey Mastermap
P	Levels of significance
PA	Physical activity
PAMI	PA and media equipment inventory

PCA	Principal component analysis
r	Coefficient of correlation
r2	Coefficient of determination; statistical measure that represents the proportion of the variance for a dependent variable that is explained by an independent variable
RCT	Randomised controlled trial
REE	Resting energy expenditure
RFIS	Radio-frequency identification
ROC	Receiver operating curve
RTLS	Real time locating systems
s	Seconds
SES	Socioeconomic status
SD	Standard deviation
TPA	Total physical activity
TV	Television
UK	United Kingdom
USA	United States of America
VA	Vertical axis
VM	Vector magnitude
VPA	Vigorous physical activity
WHO	World health organisation
WIMD	Welsh index of multiple deprivation

1. Introduction

1.1. Rational and background

The high prevalence of physical inactivity in children is considered a key contributor to the global childhood obesity epidemic [1–3]. The significant time children spend in sedentary behaviours nowadays, particularly screen-based media, is another likely contributing factor [1,4]. In addition, sedentary behaviour, often characterized as screen-based behaviours, and PA are associated with a wide range of other health and well-being outcomes in children [5]. Physical activity of moderate-vigorous intensity has been shown to have potent health benefits in children including improved fitness, better bone health, improved cardio metabolic profile, aiding motor skill development and mental health benefits [6]. Even light physical activity has been shown to have beneficial associations with health outcomes in children [7,8], albeit not all the time [9,10]. While sedentary time, specifically screen-time, has been unfavourably associated with cardiometabolic risk factors, social behaviour problems, fitness, self-esteem and academic achievement [5,11]. There is also some evidence that overall sedentary time [12], particularly in obese and overweight children [13], and infrequent interruptions in sitting time [14] are also associated with adverse health outcomes in children. However to date findings are inconsistent [5,13].

The detrimental health effects of inactivity is particularly significant in adults [15]. In fact, physical inactivity is considered the fourth leading risk factor for mortality worldwide, accounting for 16.9% of deaths in the UK and for 6% of all deaths globally [16]. This may be because regular PA has been shown to reduce adult's' risk of developing several serious health outcomes including metabolic syndrome [17], hypertension, stroke [18], type 2 diabetes [19], depression and anxiety [20], breast, colon and endometrial cancer [21], coronary heart disease [22]. Although the evidence for the harmful effects of sedentary behaviour is less convincing, partly due to methodological issues [23], research has shown serious health consequences of daily sedentary behaviour in adults and it is estimated to be responsible for 3.8% of deaths globally [24]. Specifically, daily sedentary behaviour has been linked with non-fatal cardiovascular disease, metabolic syndrome and to a lesser degree cancer (ovarian and endometrial) as well as type 2 diabetes [25]. Screen-based sedentary behaviours (i.e., screen-time) appear to have unique detrimental effects on health. Indeed, screen-time, particularly TV viewing, unlike daily sedentary time, has been strongly associated with type 2 diabetes and colon cancer [25]. In adults, the way sedentary time is accrued may be also be relevant, with recent studies showing that prolonged sitting may be particularly harmful [26]. In fact, more frequent interruptions in sitting time have been associated with a better cardio-metabolic profile [27,28], a lower waist circumference [28] and even all-cause mortality [29]. It has been shown that PA [30] and sedentary habits [31] can track into adulthood. Thus, inactivity and sedentary time may have direct health effects in children, as well as indirect effects whereby habits track into adulthood putting them at risk for a plethora of health problems [32]. In fact, children get less active [33] and more sedentary with age [34], with the change most pronounced between 9 and 12 years [34]. Given the evidence, there is a pressing need for effective evidence-based PA and sedentary time interventions in children, particularly among children aged 9-12 years.

When designing and implementing effective interventions targeting sedentary time and PA, it is important to understand their correlates [35]. Ecological models highlight environmental influences on PA and sedentary behaviour [36,37]. Aside from school, children spend most of their time at home [38,39]. As a result, a large proportion of children's overall sedentary time and PA is accumulated at home [40]. Therefore, the home environment has a particularly important role in influencing children's PA and sedentary behaviour.

To date, although there is an emerging evidence base on the influence of the home environment on children's PA and sedentary behaviour, many aspects of the home environment remain unexplored, with the physical environment in particular receiving little attention [41,42]. Despite a qualitative study identifying a wide range of potential influences of the home physical environment including the space and size of the house and garden as well as other aspects of home design [43], few studies have assessed the physical environment beyond media and PA equipment. Further, assessment of PA and media equipment has been limited to self-report, which may partly explain why findings have been inconsistent to date [41]. The use of more objective instruments which assess other physical environmental factors is imperative to improving our understanding of influences within the home, however such measures are lacking. Additionally, although a large body of literature exists on social influences, home-specific social factors remain largely unexplored. Another key criticism of past work is that studies have mostly assessed PA and sedentary behaviour across the entire day. Since children spend significant time at home [38,39] and that a key tenet of ecological models is that behaviour is most likely influenced by the environment in which it occurs [36,37], research investigating how home-specific physical and social factors relate to home-based behaviours is paramount. Moreover, parents control many elements of the home, however little is known about what influences these choices. Such information would improve our understanding of potentially modifiable correlates of PA and sedentary behaviour within the home. Further, few studies have examined clustering of activity related factors within the home. Indeed, identifying which social and physical factors cluster could lead to more efficient interventions, through targeting several factors simultaneously.

Addressing the discussed gaps in the literature would afford new insight and an improved understanding of the relationship between the home environment and children's PA and sedentary behaviour. Such information could inform intervention development with the objective to promote children's PA and reduce sedentary behaviour within the home.

1.2. Problem statement

Despite inactivity and sedentary behaviour being associated with detrimental physiological and psychological effects, few children meet the PA and sedentary behaviour guidelines. Children become even less active [33] and more sedentary with age [34], with the change particualry pronounced between 9 and 12 years [34]. This suggests the importance of research into the correlates of PA and sedentary behaviour in this particular age group. Although ecological models recognise the environment as an important sphere of influence on behaviour and children spend significant time at home, little is known about its influence, particularly the physical environment, on children's PA and sedentary time at home. An improved understanding of the correlates of these behaviours among children aged 9-12 years at home will be imperative for informing interventions.

1.3. Thesis aims

The overall aim of the thesis was to improve researchers' understanding of the correlates, particularly within the home environment, of children's aged 9-12 years PA and sedentary behaviour. This PhD thesis is comprised of 5 chapters;

Study 1; The first study aimed to explore relationships between multiple lifestyle factors and sufficient physical activity (≥60 $\text{min}\cdot\text{day}^{-1}$) and excessive screen-time (≥2 $\text{h}\cdot\text{day}^{-1}$) in children.

Study 2; The purpose of study two was to assess the validity and reliability of the HomeSPACE-II instrument, for use in two-storey homes and with the added measure of accessibility, to measure parameters of the home physical environment hypothesized to influence children's PA and sedentary time at home.

Study 3; The aim of the 3rd study was to investigate relationships between physical home environmental factors and children's sitting, PA, standing and sitting breaks at home.

Study 4; The aim of study 4 was to investigate the influence of parental and child activity preferences and priorities, as well as parental rules on: (i) children's sitting time, PA and sitting breaks at home, and: (ii) the creation of the home physical environment.

Study 5; The last study aimed to examine clustering of parental and physical factors within the home, whether they are related to child and parental characteristics, and children's sitting, sitting breaks and PA at home.

2. Literature review

Regular PA is associated with numerous health benefits in children [6], yet PA levels among children remain low worldwide [44]. Children also spend a large proportion of their discretionary time sedentary, particularly engaged in screen-based behaviours [45], which have been associated with poor health outcomes [5,46]. Additionally, much of children's sedentary behaviour occurs in prolonged bouts ($\geq$ 30 mins) [47,48]. This is a concern, since more frequent sitting breaks have been associated with lower diabetes and cardio-metabolic indicators in adults [28,49] and short-term improvements in metabolic indicators in children [50]. Whilst reviews have found limited and inconsistent evidence for a relationship between health and both patterns of sedentary behaviour and overall amounts in children, authors have noted that this is, in part, due to methodological issues and the infancy of the research [13,23]. Nevertheless, given the emerging evidence in adults [25] and that sedentary habits appear to track into adulthood [31], interventions are needed to both increase children's PA, and reduce their sedentary time, particularly for extended periods.

The identification of correlates is considered a crucial stage of effective intervention development [51]. Given, the recognised influence of the environment [36,37], and that children spend more time at home than anywhere else [39,52], correlates of PA and sedentary within the home are particularly important. However, in order to improve our understanding of how the home influences children's sedentary time and PA, comprehensive measures of behaviour and the environment are imperative [51]. With this in mind, this literature review will provide a rationale for this thesis by demonstrating the prevalence of inactivity and sedentary behaviour in children as well as highlight the health benefits and detriments of PA and sedentary time, respectively. Further, the current literature on physical and social environment correlates of the home and the evidence gaps will be discussed. In addition, measures of behaviours, including novel technologies with largely unknown validity capable of providing broader contextual information, will be reviewed.

2.1. Physical activity

2.1.1. Physical activity and health

Physical activity (PA) is defined as "any bodily movement produced by skeletal muscles resulting in energy expenditure higher than resting" [53]. There are different intensities of PA (light, moderate, vigorous and total) and various sub groups (organised sport, leisure-time activity and occupational activity) [54], and at home may include exercise, chores and active play. In adults, PA has been shown to decrease the risk of several adverse health outcomes including coronary heart disease [22], hypertension, stroke [18], type 2 diabetes [19], metabolic syndrome [17], depression and anxiety [20], breast, colon and endometrial cancer [21] as well as all-cause mortality [55]. Regular PA also provides beneficial health effects in youth, with a recent systematic review reporting consistent and strong favourable associations between total physical activity (TPA) and physical fitness, adiposity, bone health and cardio-metabolic biomarkers and weak favourable associations with quality of life/well-being, psychological distress and motor skill development [6]. The specific intensities of PA had similar beneficial associations with health indicators, however on the whole, higher intensity PA (i.e., moderate-to-vigorous) had the stronger and more consistent relationship with health compared with lower intensity PA (i.e., light). In addition, favourable associations were found with all patterns of PA (bouts, sporadic, continuous) [10].

Moderate-to-vigorous physical activity (MVPA) has a long-standing relationship with health. Accordingly, the UK guidelines, guidelines from other countries (e.g., USA [56], Australia [57], Canada [58] and the World Health Organisation (WHO) [59] recommend that children spend a minimum of 60 mins in MVPA each day. In contrast, the importance of light physical activity (LPA) to health has only been acknowledged recently. Indeed, a review [10] found evidence that LPA is beneficially associated with diastolic BP, BP z-score, insulin resistance, and HDL cholesterol in children. However, compared with MVPA, much less studies have examined the health effects of LPA [6]. This discrepancy may be due to the popularity of subjective PA measures, which unlike objective measures, cannot assess LPA accurately [60]. This may explain why most PA guidelines do not include recommendations on LPA. To the author's knowledge, the Canadian 24-hour movement guidelines [61] were the first set of behavioural recommendations to consider LPA. They recommend that children spend several hours each day in a variety of structured and unstructured LPA. Taken together, despite MVPA being more consistently associated with health, there is evidence to suggest that even lower intensities of PA (i.e., LPA) may be important for health promotion in children, and therefore should be targeted in evidence-based interventions.

2.1.2. Physical activity prevalence in children

Despite the numerous health benefits of MVPA [6], according to survey data, the majority of children do not meet the current public health guidelines ($\geq$60 min$\cdot$day^{-1}) [62]. Nationally representative data in the UK is survey based. In Wales, based on self-reported data from the 2016/17 survey for Wales and the 2017/18 Health Behaviour in School-Aged Children survey (HBSC), 34% of children aged 3-17 met PA guidelines [63]. Slightly worse PA participation rates have been reported in England, with only 22% of children aged 5-15 years meeting PA recommendations based on data from the 2015 health survey for England [64]. Similar low compliance rates have been observed in surveys worldwide [44].

The few studies with nationally representative samples that objectively measured PA also indicate that a high proportion of children do not meet PA guidelines. In a large UK study of 6,497 children aged 7-8 years, 51% of children met the PA guidelines [65]. However, significantly less girls (38%) than boys (63%) achieved the guidelines. There was also considerable variation by gender among 1,223 children aged 8-9 years in another UK study, with 73% of boys and only 54% of girls achieving the PA guidelines [66]. Much lower participation rates were observed in 27,637 participants aged 5-17 years from 10 countries in the international children's accelerometery database (ICAD), with only 9.0% of boys and 1.9% of girls achieving the recommended amount of PA [67]. The significant difference in the proportion of children meeting the PA guidelines in the two samples, may be explained by the fact PA levels have been shown to decline with age [68]. Indeed, in the ICAD study, TPA on average decreased by 4.2% with each additional year of age [67].

While other intensities of PA are also important to health [6], most surveillance studies have only reported MVPA data due to the historical public health focus on it [69]. The 2016/17 Canadian health measures survey collected TPA data on Canadian youth aged 5-17 years [70]. On average, youth spent 4 hours in LPA and 63 mins in MVPA, and 5 hours in total physical activity (TPA). Similar to the MVPA surveillance data, children (4 hrs and 19 mins) had higher LPA compared to adolescents (3 hrs and 35 mins). On the other hand, LPA levels did not differ between girls (3 hrs and 55 mins) and boys (4 hrs and 1 min).

It is clear from both self-reported and objective PA data in the literature that children are not doing enough MVPA, particularly girls. Moreover, PA of all intensities appears to decrease with age. Of note, TPA levels do not seem to differ in girls and boys [70]. This evidence highlights the pressing need for interventions promoting children's PA. To date, interventions solely targeting MVPA have shown limited success [71], thus, increasing LPA may be more feasible, particularly in girls. In addition, since sedentary time has been associated with obesity in children, independent of MVPA levels [12], substituting some of it for LPA may have a beneficial effect on weight outcomes.

2.2. Sedentary time, screen-time and sedentary breaks

2.2.1. Sedentary time and health

The universal definition of sedentary behaviour has been proposed as any waking activity, in a sitting, lying or reclining posture with an energy-expenditure below 1.5 metabolic equivalents (METs) [72], such as television (TV) viewing, using a computer or reading. Although there is clear consensus for the accuracy of this definition in adults [72,73], some argue that the MET threshold characterising sedentary behaviour must be higher in children as they have a higher resting energy expenditure (REE) [74]. Saint Maurice et al. [75] confirmed this notion and concluded that the MET threshold should be 2 METs in children and adolescents, so this value may improve the accuracy of sedentary behaviour classification in this population.

Until recently, sedentary behaviour was often confused with physical inactivity [76], a term used to describe an individual who is not meeting PA guidelines [77]. It is important that sedentary behaviour and physical inactivity are considered separate constructs, as a child can engage in sufficient PA (60 mins/day), but still spend significant time sedentary [78]. Sedentary behaviour research has proliferated in recent years, where there is emerging evidence for an adverse association with health outcomes in adults [32]. Indeed, a review by Rezende et al. [25] found strong evidence for an adverse relationship between sedentary time, including screen-based behaviours (e.g., TV viewing, video games and internet use), and all-cause mortality, cardiovascular disease, type 2 diabetes and metabolic syndrome in adults [46]. They also found moderate evidence for harmful associations with ovarian, colon and endometrial cancer as well as type 2 diabetes [46]. Although the results of more recent studies investigating the relationship between all-cause mortality are relatively mixed, this is, in part, due to methodological issues [79,80]. Specifically, the majority of studies have used accelerometers to assess sedentary behaviour, which are useful for understanding the health effects associated with a lack of movement, however not so much for the health risks of sitting specifically. Therefore, despite the promising findings to date, before we can conclude there is a causal relationship between sedentary behaviour and adverse health outcomes, more studies using posture sensors to measure sedentary behaviour are needed. The relationship between overall sedentary time and health in children is even less understood [5]. This could be because the harmful effects of sedentary time may have not had long enough to manifest themselves. Additionally, although a recent systematic review found limited evidence for an adverse relationship between overall sedentary time and health in children, they noted there were insufficient studies of a randomised controlled trial (RCT) design using valid and reliable measures of sedentary time to draw any conclusions [5]. Although the way by which excessive sedentary time adversely effects health is not fully understood, it has been postulated that the lack of local contractile stimulation when sitting reduces skeletal muscle lipoprotein lipase (LPL) activity (important for regulating triglyceride and HDL-cholesterol concentrations) and glucose uptake [81,82].

Of the sedentary behaviours, screen-time is thought to have a particularly detrimental effect on health [5,46], partially because of its relationship with unhealthy lifestyle behaviours such as shorter sleep duration [83,84], a poorer diet [85–88] and MVPA [89,90], albeit relationships with the latter are inconsistent [91]. In fact, in children excessive screen-time has been unfavourably associated with obesity, cardiometabolic risk factors, social behaviour problems, fitness, self-esteem and academic achievement [5,11]. On the other hand, a review including only prospective studies found insufficient evidence that screen-time was associated with either fitness or cardiometabolic indicators in children [92]. However, the authors did note that there wasn't enough prospective studies investigating such relationships to draw any conclusions. Another limitation of the literature to date is the reliance on self-report measures without reported psychometric properties to assess screen-time [93]. High quality prospective studies using valid and reliable measures of screen-time are clearly needed to better understand the relationship between screen-time and health. However, the evidence thus far is sufficient enough for public health guidelines in the UK [94], Canada [61] and Australia [95] to recommend that children spend no more than 2 hours/day engaging in screen-time and limit their sitting as often as possible. Therefore, given the harmful consequences shown in adults [96], and that children's sedentary habits appear to persist into adulthood [31], reducing overall sitting levels and screen-time in childhood should be a public health priority. Given sedentary time has been shown to have different correlates to low PA [87], it is likely that strategies required to reduce sedentary behaviour and increase PA may differ as well [97]. Consequently, when theories and interventions designed for PA have been applied to reduce sedentary time, they have been unsuccessful [98]. The reason for this may, in part, be due to PA and sedentary time having different motivational factors [99]. The choice to engage in PA is mostly planned and requires effort whereas sitting is often spontaneous and requires minimal effort. Therefore, in order to produce meaningful reductions in sedentary time, future interventions and theories informing them need to consider the pervasive and habitual nature of sedentary time.

2.2.2. Breaks in sedentary time and health

The way sedentary time is accumulated may be important, with recent evidence suggesting that prolonged sitting is particularly harmful to health [100]. As a result, there is an emerging body of evidence on the health effects of increasing sitting breaks [101]. In studies using ActiGraph monitors, breaks have mostly been defined as a transition from a 'sedentary' (<100 counts per minute (cpm)) to an 'active' state (> 100 cpm) over a 60-second epoch in adults [102,103] and youth [104,105]. When using the activPAL, studies have considered breaks in sitting time as transitions from sit/lie to stand or step in adults [102,106] and youth [104,106]. Some studies have shown improvements in metabolic and cardiovascular indicators when periods of sitting are broken up with LPA or MPA [27,28], however findings on the whole are inconsistent [107,108]. On the other hand, experimental studies have consistently shown beneficial effects of breaking up prolonged sitting with light PA on postprandial glucose metabolism [23,109]. Interrupting sitting with LPA was also associated with reduced self-reported fatigue in overweight adults in a small pilot study [110]. Very few studies have investigated the relationship between sedentary breaks and all-cause mortality [23]. However, in one study, longer sitting bouts were associated with a higher all-cause mortality risk over 4 years in 7,985 US middle-aged or older adults [29]. Conversely, the number of sitting breaks were not associated with all-cause mortality over 5 years in a smaller sample of 1655 men [111]. The evidence on the relationship between sedentary breaks and health is scarce and limited to studies that have used waist worn accelerometers, while posture monitors are thought to provide a more accurate measure of sitting time, as they can differentiate between sitting and standing [112]. Despite the limited and inconsistent evidence to date, several national guidelines recommend interrupting sitting with PA as often as possible [94,113].

Although, several studies have shown benefits of breaking up sitting time on health in adults, albeit findings are inconsistent, the evidence in youth is even less clear [13]. Carson et al. [114] reported no association between the frequency of sedentary breaks and cardiometabolic disease risk in children and adolescents. Further, Kwon et al. [115] failed to detect an association between sedentary breaks and fat mass in children. To our knowledge, Belcher et al. [14] is one of the few studies to show that interrupting sitting time may lead to improvements in children’s health as well. This study found that interrupting sitting time with short bouts of moderate intensity walking improved short-term metabolic function in healthy children aged 7-11 years. Despite a review finding limited and inconsistent evidence for a relationship between sitting breaks and health in youth, the authors noted that more experimental research is needed to make a conclusion on the relationship [13]. The inconsistencies in the literature may be attributable to several measurement issues. Specifically, most of the evidence is limited to studies that have used waist worn accelerometers. The only study in the review that used a posture monitor to measure sitting time, found a negative relationship between the frequency of sitting breaks and adiposity in adolescent girls [116]. Such a finding supports the case for using posture monitors to measure sitting time and breaks and raises the possibility that prolonged sitting may also have harmful health effects in youth. Further, given the adverse effects of prolonged sitting in adults [73] and evidence that sitting appears to track from childhood to adulthood [31] , research identifying correlates of sitting breaks in children is important.

2.2.3. Prevalence of total sedentary time, screen-time and sitting breaks in children

Screen-time has become the most popular sedentary activity among children [5], which is of concern given its association with adverse health outcomes [5]. The Office of Communication (Ofcom) measured weekly screen-time in UK children including TV, games console and internet use by parental report [117]. Parents reported an average of over 5 hours/day for children aged 8-11 years, and 6 and half hours/day for children aged 12-15 years. Research on children in Wales reports similar findings. In the 2016/17 National Health Survey for Wales, parents were asked how many hours per day their children aged 3-17 years spent watching TV or using electronic devices [118,119]. While average daily screen-time was not reported, the survey found that 81% spent at least 2 hours in screen-time per weekday and 92% spent at least 2 hours in screen-time per weekend day. The Ofcom 2018 report showed internet use was the most popular screen-based activity among children aged 8-11 years, with 93% going online for 13 and a half hours a week. This was followed closely by watching TV on a TV set, where 94% watched it for 13 hours a week. While still prevalent, video game use was not as common, with 74% playing video games for 10 hours a week [117].

Studies using accelerometers to assess sedentary time have found that youth spend a high proportion of their waking time sedentary. In a large UK representative sample of 6,497 children aged 7-8 years, more than half of the children were sedentary for at least 6.4

hrs/day [65]. In another large UK cohort of 5,429 children aged 12 years, prevalence of sedentary time was also high, with children on average spending 7.1 hrs/day sedentary [120]. Similar findings have been reported in North American children. In a large nationally representative samples of children aged 6-10 years from Canada [121] and aged 6-11 years from the United States [122], children were sedentary for 7.4 hrs/day and 6.1 hrs/day, respectively.

Few large accelerometer studies report the number of sedentary breaks However one study indicated that children aged 9 years have on average 8 sedentary breaks per hour [123]. Overall sedentary time also appears to increase with age. For example, data from National Health and Nutrition Examination Survey (NHANES) in the US showed that sedentary time increased by more than 2 hours per day across three age groups (i.e., 6-12 years, 12-15 years, and 16-19 years) [124]. In a UK longitudinal study [123], where children had their PA measured at age 7 years, 9 years, 12 years and 15 years, the daily proportion of time spent sedentary increased from 51.3% at baseline to 74.2% at 15 years (22.9%). In the same sample, the number of sedentary breaks per hour decreased from 8.6 at 7 years to 4.1 at 15 years. Further, sedentary time increased steadily over each of the three periods, with the most pronounced increase occurring between 9 years and 12 years (9.2%).

Postural-based monitors can distinguish between sitting and standing, and therefore are thought to be a more precise measure of sedentary time, however the few studies using them in children are typically small. One UK study of 79 children aged 9-10 years, which assessed sitting time using the activPAL, found that children sat for over 10 hrs/day (68%) on school days and 11 hrs/day on weekend days (73%) [48]. Similar results were reported from activPAL data on 65 obese Malaysian children aged 9-11 years, with children sitting in excess of 11 hrs/day (68%) on school days and 12 hrs/day (74%) on weekend days [125]. In one of the only studies to report the number of activPAL determined sitting breaks in children, children aged 7-8 years had on average 111 breaks/day [47]. Further, a large proportion of UK children's sitting time is accumulated in prolonged sitting bouts. The Sherry et al., (2018) study demonstrated that 20% and 28% of children's sitting bouts were prolonged ($\geq$ 30 mins) on school and weekend days, respectively. Whilst in the Nagy et al., (2019) study, 24% of total sitting time was generated from prolonged bouts ($\geq$ 30 mins).

Irrespective of the instruments used to assess sedentary time (self-report, activPAL or accelerometery), there is a clear consensus in the literature that youth spend too much of their waking time sedentary. Further, accelerometer data clearly indicates that sedentary behaviour increases with age. The steepest change seems to occur between 9 and 12 years [123], representing the transition from primary to secondary school, suggesting this is a particularly important period to intervene.

A large proportion of children's sedentary time occurs in the after-school period, with one study finding that it accounts for 21% of children's daily levels [126]. Further, a systematic review [127] reported that children are sedentary for a significant amount of this period (41-51%). Additionally, the proportion of children's sitting accumulated in prolonged bouts is highest during this period, particularly in the evening (6 pm-10 pm), as demonstrated among children in Belgium [128] and adolescents in Australia [129]. Therefore, after school hours is a key period for targeting reductions in sedentary time, and it has been recognised as the most feasible time to intervene, as children have greater control over their behaviour choices in comparison to other times of the day [130]. The home is a setting where children spend considerable time during after school hours [52], thus an improved understanding of the correlates of sedentary time in this environment is imperative for informing effective interventions.

2.3. Standing

Standing has been defined as a position which entails maintaining an upright position with support from the feet [131]. Until recently, standing was proposed as a "sedentary behaviour", due to the limited amount of bodily movement and energy expenditure involved [77]. However, findings from ground-breaking work by Hamilton and colleagues [81] suggest that standing, through providing greater muscle contractile activity than sitting, increases lipoprotein lipase (LPL) activity (important for triglyceride uptake and the production of HDL-cholesterol) and glucose uptake. Other studies have also reported improvements in insulin and lipid management as well as energy expenditure (EE) from having the body in a standing position as opposed to a sitting position [132–134]. Indeed, according to the sedentary behaviour research network (SBRN), "passive standing" and "active standing" have energy expenditures of ≤ 2.0 and > 2.0 METs respectively, which makes standing a Light PA (PA) [72]. Indeed, a recent review noted improvements in energy expenditure when standing compared with sitting [135]. Although, some studies comparing the EE of standing versus sitting have noted only negligible improvements [136,137], this may, in part, be due to differences in sample populations and methodologies. Nonetheless, even modest improvements would accumulate over time. Therefore, given the barriers to engaging in MVPA, particularly at home, displacing sitting time with the next lowest form of physical activity (standing) could be a feasible strategy for increasing Energy Expenditure (EE) and improving indicators of metabolic health in children. However, given the infancy of research into the health impact of standing [72], and that early accelerometers were not able to accurately measure standing [138], few studies have examined the correlates of standing.

2.4. Measures of PA, sedentary time and sedentary breaks

The behavioural epidemiology framework, developed to improve understanding of health related behaviours to inform evidence-based interventions, comprises of 5 stages [51]. The development of accurate measurements of behaviours is the second of these [51]. Valid and reliable measurement tools are essential for identifying the determinants of PA, sedentary time and sitting breaks. Although behaviours can be assessed using subjective methods, objective measurement is considered the most accurate measure. Indeed, self-report measures are less robust in measuring PA intensities, and are limited by reporting and recall bias [139,140]. As a result, there is increasing emphasis on objective measures in research. Each measure has advantages and disadvantages, which will be discussed.

2.4.1. Objective measurements of PA

2.4.1.1. Accelerometers

Accelerometers are generally the objective measure of choice in PA research [141]. Accelerometers measure acceleration during movement along three axes (Vertical, longitudinal and lateral axes), from which PA is estimated. There are several accelerometer models available (e.g., Actical, GENEActiv), however ActiGraph monitors have the most evidence supporting their use and are therefore the most commonly used in the literature [142]. Until recently, accelerometers were always attached to the hip [143]. This was because it was thought that the trunk location, near the centre of the body's mass, would provide the most accurate estimate of whole-body PA [144]. Although this is still largely the consensus [145], some studies have shown wrist-worn accelerometers to have comparable validity [146]. Wrist-worn accelerometers have grown in popularity in recent years due to higher compliance [147,148] because they are perceived as less burdensome to wear [149]. In fact, the NHANES 2011-2012 found a 100% improvement in wear time for wrist-worn accelerometers compared with previous years, when devices were attached to the hip [150]. Higher compliance results in less missing data, which increases researchers chances of obtaining reliable estimates of habitual PA [151], resulting in more accurate findings and better interpretation of the data [152]. Additionally, since children find wrist-worn accelerometers more comfortable to wear [146], participation rates may be better when wrist accelerometer placement is chosen. Therefore, although hip accelerometer placement is considered more accurate [145], researchers are regularly opting for wrist accelerometer placement.

Accelerometers generate activity counts, from which cut points are generally used to classify LPA, MPA, VPA and MVPA. Whilst a multitude of validated cut-points exist for hip-worn accelerometers [153], cut points derived and validated for wrist-worn accelerometers are limited. Crouter et al. [154] developed PA cut-points among a large sample. However, they are inapplicable to most data as they were only validated using the dominant hand. Indeed, accelerometers placed on the dominant wrist may misclassify sedentary activities involving large amounts of hand movement (e.g., video gaming, drawing/colouring) as PA, but when attached to the non-dominant wrist they would detect less movement limiting misclassification. Thus, wrist-worn accelerometers should be worn on the non-dominant wrist to assess PA and sedentary time in fact. Chandler et al. [155] are one of the few to develop and validate PA cut-points for accelerometers placed on the non-dominant wrist, specifically among 8-12 year old children. Similar classification accuracies were observed for axis 1, axis 2 and the vector magnitude (VM). However, the use of the VM has been recommended previously. as it is a sum of all axes, providing a more complete picture of activity compared with one axis alone. The cut-points for the VM are 306-817, 818-1968 and 1969 + per 5s for light, moderate and vigorous intensities, respectively [155].

Activity counts are summed over a pre-set sampling period (e.g., 5s), called an epoch, and then stored by the accelerometer. Epoch length has been shown to significantly influence PA intensity classifications in children [156,157], therefore the choice of epoch length is an important consideration when PA intensity is of interest. Researchers have employed a variety of different epoch lengths, ranging from 1 second to 60 seconds [158]. However, given children’s PA is sporadic, with bouts usually lasting between 3 and 22 seconds [158,159], the use of longer epoch lengths is inappropriate with children as it may lead to an underestimation of their MVPA [160]. 2 s, 5 s, 10 s, 15 s and 30 s epoch lengths have been used previously in children [161]. However it is important that the epoch length does not differ from the one used to validate the chosen cut-points, otherwise misclassification of PA intensities can occur [162].

2.4.1.2. Heart rate monitoring

Heart rate (HR) monitoring is an appealing approach for assessing PA, as it's relatively inexpensive compared with accelerometers, whilst still providing an objective measurement. A major limitation of HR monitors for assessing PA, is that HR can be affected by factors other than PA such as fitness, anxiety, age, sex and the influence is greatest during low intensity activity [163]. Therefore, whilst HR monitors can provide estimates of moderate-vigorous PA, they may introduce measurement error when assessing light or total levels [141]. Another problem with HR monitoring is the HR delay in response to movement, which may limit its ability to detect children's intermittent movement. One method for overcoming these limitations is to adjust for individual differences in resting HR [164]. However, this technique relies on an accurate assessment of resting heart rate and unfortunately there is great variability in how resting HR is defined and measured in the literature [165]. Taken together, whilst HR monitors are inexpensive and can provide an objective assessment of PA, given the discussed limitations as well as the inappropriateness of heart rate monitoring in large scale studies, they are rarely used to assess PA in high quality research studies [141].

2.4.1.3. Pedometers

Pedometers are a low-cost alternative to accelerometers and HR monitors, with a longer battery life. They collect data on the number of steps taken, which can be used as an estimate of PA. Although pedometers have been shown to be a valid and reliable measure of PA (the number of steps taken) [166,167], until recently they were unable to determine whether it is of a light, moderate or vigorous intensity. To overcome this notable limitation, several pedometers have been developed which can assess time spent in MPA and VPA. Saunders et al. [168] evaluated the accuracy of three such devices in assessing MPA and VPA in youth against indirect calorimetry. The SC-StepRx demonstrated the highest validity for assessing MPA and VPA, with estimates comparable to those observed from indirect calorimetry and accelerometers. Although, the SC-StepRX shows potential as being an inexpensive alternative to accelerometers for assessing PA, further studies investigating its validity are needed, before studies prioritise its use over the frequently tested ActiGraph accelerometer.

2.4.1.4. Conclusion

Heart rate monitors, although inexpensive and capable of providing an objective measure of PA, are not suitable for use in this thesis due to their inability to assess LPA accurately. Indeed, due to space constraints [41], children's PA at home is most likely to be of light intensity. Similarly, whilst pedometers show potential for assessing MVPA, their ability to accurately assess LPA is still largely unknown. Therefore, owing to the large body of evidence supporting its ability to provide valid and reliable estimates of PA of all intensities, the ActiGraph accelerometer will be utilised to measure children's PA at home in the present thesis. Specifically, given the better compliance rates, children will wear accelerometers on the non-dominant wrist.

2.4.2. Objective measurements of sedentary time and sedentary breaks

2.4.2.1. Accelerometers

Accelerometers are the most commonly used objective measure of sedentary time in the literature [169]. Accelerometers quantify sedentary time based on a lack of movement, through the accumulation of a number of movement counts below a defined threshold [139]. They are also used to assess breaks in sedentary time, considered as a bout which exceeds a specified cut-off point [170]. ActiGraph monitors have undergone extensive validity testing [139], are considered among the most accurate and reliable devices [171], and are the most widely used brand because of this. A threshold of 100 CPM [172] is considered the most accurate cut point for sedentary time in hip-worn accelerometery [173]. However, it has demonstrated poor classification accuracy, when used on wrist-worn ActiGraph data [173]. Van Loo et al. [171] evaluated the accuracy of nine ActiGraph wrist-based cut points in identifying sedentary time in youth against direct observation. In this study, Kim et al. [173] was shown to have the most accurate cut point (vector magnitude [VM]: ≤3958 counts/60s, vertical axis [VA]: ≤1756 counts/60s), while the Crouter et al. [154] cut point (VM/receiver operating curve [ROC]: ≤ 100 counts, VA/ROC: ≤ 35 counts) performed the best out of the cut points designed for 5 s epochs. The optimum threshold for defining a sedentary break is unclear in children, however studies have often used a transition from a 'sedentary' (<100 counts per minute (cpm)) to an 'active' state (> 100 cpm) over a 60-second epoch [104,105]. Until recently, ActiGraph accelerometers did not have an inclinometer for detecting posture, which meant they were unable to differentiate between sitting and standing, and therefore they would have misclassified some standing as sitting. Although, newer models (GT3X and GT9X Link) include an inclinometer, when worn on the hip and wrist they have been shown to have only moderate accuracy (60.6-74%) for classifying body posture [174–176]. This may be because the ActiGraph outputs for standing still and sedentary are similar, which may lead to some misclassification of standing time as sedentary time [177]. This misclassification may occur with accelerometers worn on the wrist or hip, due to the wear location [178]. While thigh mounted GT3X+ ActiGraph accelerometers have shown promise in providing better accuracy for assessing posture [179,180], the thickness and sharp edges of the devices limit its wearability on the thigh and more research is needed to confirm its accuracy compared with the gold standard activPal posture inclinometer [181].

2.4.2.2. Pedometers

Pedometers are relatively expensive and have a superior battery life compared with other objective measures. Studies utilising pedometers to measure sedentary time, have used a cut point by Tudor Locke et al. [182] of <5000 steps to categorise someone as 'sedentary' [183,184]. However, this method does not give you any information on the amount of sedentary time accumulated and an individual may not achieve 5000 steps/day without having a sedentary lifestyle, particularly if they spend significant time standing. Recently pedometers have become more sophisticated, for example the PiezoRx pedometer (Stepscount Inc, Deep River, Canada) can quantify LPA and MVPA based on the number of steps per minute. From which, providing wear time is known, sedentary time can be determined by subtracting total PA (i.e., LPA + MVPA) from wear time [185]. Given, the PieszoRx pedometer has been shown to yield similar results to the Actical accelerometer [185], it may be viable option for measuring sedentary time when other more researched objective measures are unavailable.

2.4.2.3. Heart rate monitoring

Heart rate monitoring has been used to measure sedentary time in adults [186] and children [163]. In such studies, sedentary time is determined as low energy expenditure, calculated as the heart rate observations below an individually established cut point (threshold separating rest and exercise), called the flex heart point. However, HR monitors have poor accuracy in determining energy expenditure at very low intensities (i.e., sedentary time), because the relationship between HR and energy expenditure is not linear during sedentary time, as factors such as body position, anxiety or caffeine can affect the relationship [187]. The relationship may also be influenced by age, sex, body composition or fitness levels [188]. Because of these limitations as well as compliance issues [165], HR monitors have sparingly been used to measure sedentary time.

2.4.2.4. Posture sensors

Devices with built in inclinometers offer the best opportunity for assessing body posture. The activPAL is the most commonly used posture sensor. The activPAL micro is the latest model, and it detects posture based on thigh acceleration at a sampling frequency of 20 Hz and uses proprietary algorithms to determine body posture (sitting/lying, standing or stepping), transitions between these postures, number of steps and total MET-hours. By default, $\geq$ 10 s of sitting/lying, standing or stepping is required to register an event. Among very young children (mean age of 4.5 years), Algheed et al. [189] found that a 2 s, compared with a 1 s, 5 s and 10 s, minimum event period performed the best at identifying the number of sitting breaks against direct observation. This would suggest that young children transition quickly from postures and therefore the default setting may not be appropriate for quantifying the number of breaks from sitting in all populations. On the other hand, to our knowledge similar studies have not been conducted with older children, so the extent to which the setting would affect the number of breaks calculation in the 9-12 years population is unknown. Therefore, the 10 s setting, recommended by the manufacture, has been used in older children [112] and adolescents [129].

In adults, the activPAL has been shown to have excellent agreement with direct observation for determining sitting/lying time, upright time, sitting breaks and reductions in sitting time [177,190,191]. Although, there has been relatively few studies examining the validity of the activPAL for use among children, the current evidence would suggest that it has a similar classification accuracy in this population. Specifically, Aminian et al. [112] investigated the validity of the activPAL against video observation in 25 children aged 9-10 years. Perfect correlations were observed between activPAL data and video observation for time spent sitting/lying and standing. Correlations for the number of sit-to-stand transitions were also high. It has also been proven to have high validity in a sample of adolescent girls for assessing time spent sitting and upright [192], and acceptable validity and reliability in young children [193,194]. In fact, the activPAL device is considered as the gold standard for measuring sedentary time [181].

The ability of the activPAL device in providing accurate postural information is thought to be due to its wear location, on the midline of the thigh [195]. This location is powerful for distinguishing between standing and sitting/lying. However, the activPAL is not able to distinguish between lying and sitting, which would improve the objective measurement of sleep [196]. On the other hand, according to Edwardson and colleagues [197], methods for differentiating between lying and sitting are in development.

2.4.2.5. Conclusion

There are several technologies which show promise in assessing children's sedentary behaviour, although, to date only accelerometers and posture sensors have sufficient evidence supporting their use. Traditionally, accelerometers were the sedentary behaviour measure of choice [139], However the use of posture sensors for assessing sedentary behaviour has proliferated in recent years [197]. This is likely due to their ability to differentiate between sitting and standing, which is important given the difference in energy expenditure [198]. The activPAL is the most frequently used device, and in fact it is considered the gold standard measurement of sitting time, standing and sitting breaks [181]. Given that children spend most of their time at home sedentary [52], a robust measure of sedentary time is imperative for home environment correlate research. Further, few studies have investigated the correlates of children's standing and sitting breaks, despite increased standing [132,133] and sitting breaks [199,200] being associated with positive health outcomes. Therefore, the activPAL monitor will be utilised in this thesis to study children's sedentary time, standing and sitting breaks at home.

2.4.3. New and emerging technologies that assess the context of PA and sedentary time

The key limitation of the objective measures discussed above, is that they do not provide information on the context of PA and sedentary time such as where the behaviour is being performed, the type of behaviour being performed and with whom [201]. Objective accurate measurement of such contextual information is important for improving researcher's' ability to identify correlates of PA and sedentary time, and thereby informing effective evidence-based interventions based on the social ecological model [202].

2.4.3.1. Technologies for assessing the location of behaviours

The social ecological model recognises that behaviours are most likely influenced by the location in which they occur [36,37]. Identifying where PA and sedentary behaviour occurs will improve our ability to identify their correlates, which will allow interventions to target locations accordingly. The home is a setting where children spend significant time [38,39] , suggesting measuring where behaviour occurs in this environment may be particularly valuable. For location tracking, global positioning system (GPS) monitors are frequently used in behavioural research [203,204], However they require a clean line of sight to orbiting satellites, meaning they are only suitable for measuring outdoor location [205]. Since most of children's time at home is spent indoors [38,39], the ability to assess indoor location is important. Technologies such as radio-frequency identification (RFID), real time locating systems (RTLS) and Bluetooth low energy (BLE) ibeacons may be capable of measuring indoor location [206]. With such systems, a small mobile tag is usually worn which is read by tag beacons located in the area of interest. The indoor location of sedentary time within an office setting has been measured using a RFID system in combination with a posture monitor [207]. However, due to several practical and technical limitations, analogous systems are not yet fit for accurate indoor location monitoring. Additionally, along with RTLS, it is unsuitable for location monitoring in the home, due to a lack of enterprise Wi-Fi, necessary for both technologies to function [208]. BLE ibeacons are comparatively inexpensive but they require a phone to communicate with. This means they are unsuitable for use with children as many do not own a phone, and it is possible that the person may not always be carrying the phone. Some ActiGraph monitors (GT9X and GT3X-BT) have the BLE functionality, allowing proximity based indoor location monitoring [208]. The advantages of this system include, its low cost (providing the monitors are already owned), it does not require enterprise Wi-Fi to function and it measures behaviour and location in one wearable device, making it the most feasible option for measuring children's location in the home. The monitors are initialised as either receivers which are worn by the participant or beacons which are placed around the environment. Beacons and receivers then communicate through BLE to identify location. The BLE functionality of the monitors has been employed for assessing the location of PA and sedentary time within an office [208,209] and an elderly care home [208]. Clark et al. [209] examined the accuracy of the BLE proximity sensing function of the ActiGraph GT9X for determining the location of behaviour in an office setting. Good accuracy was demonstrated for identifying whether workers were in their office, where they spend most of their time and were mostly sedentary. Accuracy was lower for locations where workers spent less time and/or were more active. Magistro et al. [210] created an algorithm to improve the accuracy of BLE proximity sensing of ActiGraph devices, which was shown to reliably infer location within rooms and social areas of an office setting when compared to a criterion measure (i.e., a wearable camera). While BLE proximity sensing using ActiGraph monitors shows promise for inferring the location of adult's behaviour in an office, its accuracy in different environments (i.e., homes) and among other populations (i.e., children) is unknown without further testing [210]. Further research is needed to examine the utility of BLE proximity sensing for assessing the location of children's PA and sedentary time in a home environment and to investigate more advanced data treatment methods to enhance precision.

2.4.3.2. Technologies for assessing the social context of behaviours

Characterising the social context of a behaviour and whether it is performed alone or with someone would provide important information for a home-based intervention. Sociometers are novel devices which include a BLE proximity sensor and an audio recorder, that both contribute to measuring proximities and interactions between individuals [211]. The inclusion of a BLE proximity sensor, is consistent with smartphones and ActiGraph monitors; However, the audio recorder will not only detect when two individuals are in proximity but also why they are in proximity via the audio recording. Indeed, the audio recording may capture verbal clues for why individuals are in proximity with each other. Yu et al. [212] assessed the validity of these devices in a hospital and found they could accurately detect proximity between individuals, but not face-to-face interactions. Further, the continuous audio recording creates an ethical issue, as it may capture private conversations. Wireless proximity sensing using the BLE function in smartphones has been employed to measure social interaction successfully in adults [213,214]. However, the limitations of using phones discussed above for BLE ibeacons, make it unsuitable for measuring children's social interaction with family members in homes.

2.4.3.3. Technologies for assessing the type of behaviour being performed

Being able to determine the type of behaviour being performed will improve the specificity of interventions, as some types of PA and sedentary time have different correlates [37]. In addition, not all types of sedentary time are equal in terms of their relationship with health [93]. While there is no universally used method for assessing the type of behaviour performed objectively, there are emerging technologies which may capable of it in the future. Small BLE stickers (e.g., Estimote in, New York) could be stuck unobtrusively on electronic media (e.g., TV sets, tablet computers, remote controls) and PA (e.g., bats, a trampoline) equipment within a home [208]. They could measure equipment usage as well as indoor location through proximity monitoring between the participant and the item. This technology currently requires the participant to carry a phone, so it is unsuitable for use with children. In future, if these stickers can communicate with other BLE enabled devices such as ActiGraph monitors, they may be a useful measurement tool for measuring item usage in the home. Recently, there has been an emergence of mobile applications which can monitor smartphone and tablet computer usage. Christensen et al. [215] sought to determine the factors associated with smart phone usage, using an application developed by Ginger. io (San Francisco, CA) to measure the time adults spent on smartphones. While the study [215] did not encounter any major problems with the app, the validity of app recorded screen-time is largely unknown. In addition, it may only be suitable for measuring smartphone usage in adolescents or older, as there could be multiple users of a tablet computer.

2.4.3.4. Technologies for collecting broader contextual information

Wearable cameras are increasingly being used in PA and sedentary behaviour research, as they can identify the type of behaviour, its environment and the social context [206]. One of the most frequently used wearable cameras in a research setting is the Microsoft Sensecam. It is worn on the lanyard around the neck, where it automatically captures point-of-view images at pre-determined intervals. They have been used to assess the type and context of PA [216] and sedentary time [217]. Wearable cameras can infer location (providing the captured image has an identifying feature), but unlike RFID and RTLES location monitoring systems, they also provide broader contextual information. Despite the wealth of information provided, there are significant ethical and analytical issues with using wearable cameras. Participants may be wearing the device in situations unsuitable for photography, coding the images is labour intensive and they have a relatively short battery life [218]. Additionally, it may also not be a good measure of all types of activity, specifically TV viewing [208]. For example, due to the camera attachment and the resultant line of sight, if the participant is not sitting upright while watching TV, the camera may point away from the TV. A head mounted wearable camera could address this limitation [219].However so would the more unobtrusive options of wearable gaze camera glasses [220] and smart glasses that measure blue light emission [221]. Gaze cameras and smart glasses would also allow for better quantification of other types of screen time, as the devices' field of view is aligned with participant's eyes. Although, both could be useful measurement tools for detecting the type of behaviour being performed, currently they are too costly for large scale studies and their usability for measuring children's screen time is still unclear. Energy monitors are plugged into electrical power sockets, and when the plug from an electronic device is inserted into it, they permit objective information on whether the device is switched on [222]. Therefore, it could be used to measure TV viewing or playing computer games [223]; However, it does not provide information on when the device is being used, so it would have to be used in conjunction with a wearable camera, which would quantify whether the child is watching TV. This technique has been employed in a small pilot study [208], but the limitations inherent in wearable cameras remain.

Another technology that can provide broad contextual information on a behaviour, is ecological momentary assessment (EMA), which uses a computing device (usually a phone) to record information during or after a behaviour such as TV viewing [224].

Usually in the form of a mobile app, participants are prompted to complete a brief questionnaire at various times during the day to better understand a person's behaviour and its determinants. Using accelerometer data, context sensitive EMA [225] can be used to time prompts with activity to present questions that appear while a person is doing the activity, which would improve participant's ability to recall information about what they were doing. Ecological momentary assessment could provide useful information for an intervention, and it has previously been used as a measure of behaviour in children [226,227]. Although it may be the least burdensome method of collecting contextual information about children's behaviour at home, it is still largely unsuitable for use in this population, as each participant would have to be provided with a smartphone.

2.4.3.5. Conclusion

Whilst some of the above technologies show potential as being capable of providing objective contextual information for PA and sedentary time, at present the issues and limitations of each technology seem to outweigh the strengths. Therefore, further developments are needed before such technologies can be used to improve our understanding of children's behaviours within the home. In particular, the integration of data streams as well as the device's wearability and ability to produce accurate behavioural outcomes require work.

2.5. Ecological models

To inform effective comprehensive interventions, a conceptual model should be used, for understanding the opportunities and barriers for different behaviours, to guide observational studies [35]. Ecological models are often used for contextualising sedentary time and PA [201], characterised by multiple levels of influence which can interact to influence behaviour. Ecological models propose that behaviour is influenced by intrapersonal (e.g., psychological, biological), interpersonal (e.g., social and cultural), organisational, physical, and policy factors [228]. Additionally, these factors are thought to have a cumulative effect. Therefore for the best approach, more than one level should be examined simultaneously [229]. The model posits that the environment is particularly influential, and that behaviour is most strongly influenced by the setting (i.e., the social and physical situations) in which it occurs [36,228]. Given children spend such a large proportion of their time at home [38–40], this setting may be especially relevant. In this environment, physical factors may include electronic media equipment and a garden, while family members and rules would be social factors. To provide specificity, ecological models need to be designed for each specific behaviour and population, because for example children perform different activities using different equipment to adults. In recent years, there has been an increased interest in ecological models because, unlike psychosocial models which target behaviours at the individual level, they hold more promise for guiding population wide-approaches due to their emphasis on the environment [228]. Ecological models are commonly used in PA research, perhaps because PA occurs in specific settings and many studies have shown associations with a plethora of environmental factors [230]. The socioecological model has been used to guide successful school and community-based interventions which use a combination of environmental and individual strategies [231,232]. Therefore, given its widespread use, ability to target population changes in behaviour and appropriateness for the home environment, an ecological model of health guides this thesis.

Figure 1. Ecological model of health behaviour

2.6. Correlates of children's physical activity and sedentary time within the home environment

Given the current childhood obesity epidemic [233], the development of interventions designed to increase children's PA and reduce sedentary time is important, especially in light of the lack of successful PA [234] and sedentary behaviour [98] interventions to date. Identifying correlates of behaviours is considered an important stage in the development of evidence-based interventions [51]. Children's sedentary time [235,236] and PA [236,237] are influenced by individual, environmental, socio-cultural and socio-economic factors. Ecological models emphasise the influence of the environment on children's PA and sedentary time [36,37]. Of particular interest is the home environment where children spend more time than anywhere else [38,39] and accumulate a large proportion of their daily PA and sedentary time [40]. Since reduced PA and increased sedentary time are major contributors to the current obesity epidemic [238], the home environment plays an important role in obesity prevention. Within the home, both physical and social environmental factors have been shown to influence children's PA and sedentary time [41,42].

2.6.1. The home physical environment

In recent years, there has been a small evidence base emerging on the influence of the home physical environment on children's PA and sedentary behaviour. Children spend most of their time at home indoors [38,39], which is of concern as this is where they are most exposed to harmful screen-based sedentary pursuits (i.e., TV viewing and playing computer). Indeed, media equipment and its placement in the bedroom are consistently positively associated with screen-time [41,236]. Regarding media equipment, the most frequently investigated factor is the presence of a TV in the child's bedroom, which has been associated with screen-time [41,236]. Whilst there seems to be consistent evidence suggesting that media equipment in the home has an important relationship with children's screen-time, there is limited evidence for an association with objectively measured sedentary time [41]. This is interesting and may suggest that when opportunities for screen viewing are limited, children simply engage in other sedentary behaviours. On the other hand, media equipment, specifically in the bedroom, may be inversely related to children's PA [41]. Specifically, one particularly robust international study by Harrington et al. [239] among 5,859 children aged 9-11 years from 12 countries, showed that the presence of at least one electronic media device in the bedroom was associated with less MVPA.

Unlike the convincing evidence for the relationship between home media equipment and children's screen-time, relationships between PA equipment and children's PA are mixed [41], with some finding an association [240–242] and others not [243–245]. Of note, most previous studies have used surveys to measure PA equipment [41] which can be problematic, especially when many PA items exist in the house. Interestingly, the only not to use a survey found a positive relationship between PA equipment and children's PA [240]. Indeed, this study used an audit to measure the home environment, which allows for a more objective assessment. Whilst, the influence of PA equipment on PA is inconclusive, a review found enough evidence to suggest that it may be inversely related to sedentary time [41], supporting the case for increasing PA equipment availability in homes. Moreover, specific PA items may have differential effects on PA depending on the country. For example, in Australia the presence of a bike has been associated with MVPA [246], whilst the presence of a basketball hoop has been associated with PA in the USA [40]. Although research conducted in the UK is limited, given the popularity of football in the country, football nets might represent an important cue to engage in PA in UK homes. Therefore, as countries have different environments and cultures, it is important studies measure equipment most relevant to the country of interest.

Accessibility is related to "ease of use and cueing of behaviour" [247] and may therefore act as an important prompt to participate in behaviours. Indeed, studies investigating accessibility have reported positive relationships between PA equipment accessibility and PA related outcomes [240,248], as well as media equipment accessibility and screen-time in girls [240]. Despite this, most studies have only assessed the accessibility, and not the availability of equipment. Reinforcing the importance of measuring an item's accessibility, Hales et al. [248] found that portable PA equipment accessibility, but not availability was associated with increased outdoor play time. Similarly, another study of children aged 8-12 years found that only the accessibility, and not the availability, of PA equipment/space to play was positively correlated with PA [249]. Restricting children's access to media equipment and making PA equipment more accessible present avenues for limiting children's screen-time and promoting their PA, respectively. It also seems parents are aware of the utility of this strategy, with one study finding that the accessibility, not availability, of media equipment, was a stronger correlate of parents' energy balance related knowledge [250]. These findings suggest that an item's accessibility should be considered in addition to its availability and will be important to examine in the future.

To date, research exploring the influence of the home physical environment on children's sedentary time and PA has focussed on PA and media equipment, with few assessing other physical environmental factors [41]. Moreover, most factors have not been studied frequently enough to draw any conclusions on their influence. Although PA at home is most likely to take place outdoors [251], a review concluded that there was limited evidence to suggest garden space promotes PA [41]. This is curious, given several qualitative studies have identified garden space as a determinant of PA [43,252,253]. On the other hand, there is some indication that the presence of a garden [254–256] and its size [248] may be associated with less time spent in screen-based sedentary behaviours, which is consistent with studies that have found a negative association between outdoor time and sedentary behaviours [257,258]. The inconsistent findings may be attributable to the limited and categorical nature of garden variables, therefore, an objective measure such as geographic information systems (GIS) should be utilised to measure garden space/size in future studies.

Only one previous study investigated house size, which reported no association between self-reported house size and sedentary time among Spanish children aged 9-18 years [254]. This study also found that children who lived in an apartment compared with a house spent more time in sedentary behaviours such as cognitive hobbies, using motorised transport and sitting to rest. In agreement, Roberts et al. [259] did find that children living in apartments/condominiums compared with houses, spent four times as much time using electronic media leisurely (although not significant). It is worth noting that the Roberts et al. [259] study had a particularly small sample size (n=144), therefore with a larger sample the relationship may have reached significance. Although, more studies are needed to explore this relationship, the garden space available in houses may be promoting alternatives to sedentary behaviours through the provision of a safe space to play. Such a mechanism is consistent with studies that have shown outdoor play [260,261] and garden space [248,255] to be negatively associated with children's sedentary behaviours.

Household crowding (e.g., number of people per room) has been associated with obesity in adults [262]. One study by Bafna et al. [263] found adults in houses with greater integration between rooms (higher interconnectedness) engaged in more social sedentary activities, particularly TV viewing. The proposed mechanism for this is that the greater interconnectedness between rooms encourages social interaction which in turn leads to more time spent in socially susceptible sedentary activities. Therefore, the greater interconnectedness in crowded homes [263] may be prompting participation in social sedentary activities, and particularly watching TV, which has consistently been associated with obesity in children [5] and adults [46]. Whilst to our knowledge no studies have assessed the relationship between household crowding and sedentary time, one study did assess for an association with PA, and found no relationship [264]. However, given the limited exploration to date and the results from Bafna et al. [263] and Chambers et al. [262], the influence of household crowding on children's sedentary time and PA warrants further investigation.

2.6.2. The home social environment

Whilst the physical environment of the home has received little attention, there has been a plethora of studies investigating the home social environment [41,235,236]. Additionally, social environmental factors are more consistently associated with children's PA and sedentary time [41,236].

Parents play a significant role in their children's health behaviours, through numerous pathways. Parental attitudes and beliefs are thought to be particularly influential [265,266], and have been shown to directly influence children's PA and screen-based behaviours, respectively [236]. Additionally, such beliefs and attitudes also influence children's behaviour indirectly through parenting practices and behaviour [265,266]. An important parenting practice for PA is parent support in various forms and is frequently associated with increased PA [41,236,237,267]. Parents may support PA through encouragement to be physically active, by providing transport to places where their child participates in PA and financial assistance for clubs and equipment [236,237,267]. Parents also influence children's behaviour through role modelling of behaviours. For example, parental PA has been shown to influence children's PA [236,268], but not always [269,270]. One possible explanation for the mixed findings is that PA has mostly been measured across the entire day, including during school hours, which is less likely to be influenced by parental PA. In support of this explanation, parents' screen-time behaviours are consistently associated with children's screen-time sedentary behaviours [41,236], which mostly occur at home [52]. Further, although higher overall sedentary time in parents has also been associated with children's overall sedentary time [271,272], much less studies have assessed this relationship, most likely due to the difficulties in assessing parents' sedentary time objectively. Additionally, through role modelling of behaviours and/or reciprocal reinforcement, parent-child co-participation in sedentary behaviours [41,236] and PA [236,270] has also been associated with increased time spent in such behaviours in children.

Restrictive practices related to screen-time and PA, such as rules limiting usage and monitoring/supervising children's behaviour represent strategies parents use to limit their children's screen-time and increase their PA. Whilst, parental supervision of PA and screen-time have been associated with increased PA [273] and less screen-time [274,275], respectively, findings are mixed [275,276]. However, the evidence to date is too scarce to draw any conclusions from. On the other hand, the enforcement of screen-time rules by parents is frequently investigated and has consistently been associated with reduced screen-time in children [41,236]. Conversely, despite limited evidence, studies have predominately shown no association between rules limiting screen-time and overall objectively measured sedentary time [277,278] or PA [278,279]. However, it is worth noting that most studies have assessed behaviours over the whole day, including significant time away from parents [52]. It is likely, that away from parents, rules restricting screen-time have little influence. In support of this, the one study that measured sedentary time at home, found a positive association with screen-time rules [40] Due to the historical popularity of TV viewing [117], rules on TV have received considerable attention and are typically related with less TV viewing [41,236]. The presence of TV limiting rules has also been associated with more favourable home environments, including less electronic media and no TV in the child's bedroom [280,281]. Parental TV rules have been shown to have a particularly strong influence when there is a TV in the child's bedroom [274]. This may be because TV rules have a greater influence when the child has more control over the TV. Indeed, when the TV is in a communal area, a child has less accessibility over its use, which limits the utility of TV rules. Nonetheless, taken together, these findings suggest that screen rules have an important role in reducing children's sedentary behaviours which mostly occur at home.

Time spent outdoors has been recognised as a key correlate of children's PA [257,258] and is inversely related with sedentary time [257]. However, parental concerns over neighbourhood safety can influence children's independent mobility and therefore their outdoor play [282,283]. For example, parents' concern about crime rates and dangers from strangers and road traffic has been associated with less PA in children [282]. Given these concerns have increased in recent years [284], children's active play is increasingly being performed indoors [285,286]. The home environment may be particularly relevant, with studies finding that parental neighbourhood safety concerns are associated with increased odds of active play at home compared with other locations [287] and increased sedentary time at home [40]. Further, one study found that PA equipment at home was only related to PA in adolescents if their neighbourhood was perceived as dangerous by parents [242]. Given neighbourhood environments are unlikely to change without significant investment, home environments are of increasing importance and therefore further research into the correlates of PA and sedentary time within this environment is needed.

2.6.3. Evidence gaps and limitations of the social and physical home environment literature

Considering the significant amount of time children spend at home [38,39], there has been little exploration into the influence of the home physical environment, compared with the physical neighbourhood environment [41,236,237]. Specifically, investigation of home physical environmental factors outside of equipment is PA and media equipment is lacking [41,235]. Additionally, whilst parental influences on children's PA and sedentary time are well studied [235–237], few have investigated home-specific parental influences [41]. Further, whilst it is known parents have significant control over their home physical environments [43], little is known about what influences its creation [41]. Such information would allow researchers to assist in creating healthy environments with parental input. Moreover, although, a small number of studies have demonstrated that physical and social factors related to activity cluster, these studies have also included dietary measures and activity factors more relevant to behaviours that occur outside the home [288,289]. Examining solely home-specific activity related social and physical factors will allow for more precise identification of the correlates of behaviours, specifically those that occur at home. Lastly, in recent years, there has been some evidence that having the body in a standing position rather than a sitting position [132–134] and more frequent sitting breaks are associated with improvements in metabolic indicators [50,199,200]. Despite this evidence, research into the correlates of children's standing and sitting breaks is scarce, and non-existent within the home environment, as far as the authors are aware.

There are also several criticisms of past work which limit researchers' ability to draw conclusions from the findings and may explain the inconsistent findings to date. Specifically, to our knowledge, all but one study [40] using objective measures, measured behaviours across the entire day. Given behaviours are most likely influenced by attributes of the environment in which they occur [36,228], objective measurement of sedentary time and PA at home is required. Reinforcing the importance of this approach, aspects of the home physical environment are more consistently associated with screen-based sedentary behaviours, which are likely to occur at home, than with overall outcomes [41,235,236]. Further, objective measurement of the home environment is lacking [41]. For example, GIS could be used to measure house as well as garden size objectively and audits hold potential for collecting more detailed data within the home. Therefore, the authors of this thesis have sought to address these gaps in order to improve researchers' understanding of the relationship between the home environment and children's PA and sedentary time at home.

2.7. Measures of the physical home environment

The home environment, specifically the social and physical environment, is recognised to be an important sphere of influence on children's PA and sedentary time [41,235]. Whilst the social environment has been well studied, the physical environment has received comparatively little attention [41]. This is, in part, attributable to the limited availability of comprehensive measures of the physical environment with strong validity and reliability, which are essential to improving understanding of how physical home environmental factors influence children's PA and sedentary time. However, the small number of comprehensive valid and reliable measures available will be discussed in the following section.

Given children spend considerable time at home [38,39] and that the environment is recognised to have a significant influence on behaviours [37], the home environment is a critical sphere of influence on children's PA and sedentary time. Previous research into the influence of the home environment on children's PA and sedentary time has concentrated on the social environment, with the physical environment receiving little attention in comparison [41,235]. Comprehensive measures of the home's physical environment demonstrating strong validity and reliability are key to improving researchers' understanding of how the physical home space influences children's PA and sedentary time; however, such instruments are lacking [41,42]. Maitland and colleagues' [41] review of studies investigating the influence of the home physical environment on children's PA and sedentary time, noted inconsistent evidence for most physical environment factors, except for media equipment at home which was consistently positively associated with children's screen-time. The review attributed the inconsistent findings in part to several limitations of the evidence base. Specifically, Maitland et al. [41] noted a lack of objective measurement of the physical home environment, limited exploration of the physical home environment factors beyond equipment and few studies that used measures with proven validity and reliability. In fact, Sirard et al. [240] was the only study not to measure the home environment using a survey. Sirard et al. [240] used the PA and media equipment inventory (PAMI), an audit [247] designed to measure the availability and accessibility of PA and media equipment in the home, which included room-level location for most items and underwent validity and reliability testing. Supporting the use of more objective measures, this was the only study to find a relationship between PA equipment, specifically equipment density, and objectively measured MVPA.

Recently, the HomeSTEAD instrument [248] was developed, demonstrating solid validity and reliability, and is a more comprehensive measure than the PAMI [247], as it allows the recording of a larger range of PA and media equipment as well as garden features. In addition, the construct validity of the instrument has been established, with associations being observed between several parameters of the physical home environment and children's self-reported screen-time and outdoor play [248]. However, room-level location was missing for most items, which is a noteworthy limitation. For example, electronic media equipment in the child's bedroom or lounge may be more likely to serve as a visual cue for use, than the same equipment located in a sibling's bedroom or the garage [43]. Moreover, determining the location of equipment when paired with information on where the behaviour is performed will also benefit correlate research [206]. For example, if a child is most sedentary in the lounge, identifying what equipment is in there may help elucidate its influence. This information will be imperative for interventions seeking to create physical home environments, which promote PA and discourage sedentary time.

The HomeSPACE-I instrument [290] includes room-level data and further advances previous instruments, by measuring characteristics of the indoor physical home environment outside of PA and media equipment, including musical instruments, room/area size and furniture. Like the HomeSTEAD instrument, it also assesses garden/yard size and the presence of natural outdoor features (e.g., a grassed area, a tree that can be climbed, etc.). However, despite the HomeSPACE-I instrument being the most comprehensive instrument to date, it was validated in Western Australia where homes are mostly one-storey, which limits its appropriateness for use in countries with typically two-storey homes. Indeed, there are several layout and design differences which may impact the tool's ability to produce the same consistency of measurement in two-storey homes. For example, two-storey homes are less frequently open plan and have more separation between bedroom and living areas which is likely to affect family interaction and how parents monitor children's screen-time. One-storey homes allow families more flexibility in designing the layout to align with their preferences and priorities. On the other hand, the smaller footprint in two-storey homes, usually provides more outdoor space when on a comparably sized plot. Additionally, the HomeSPACE-I instrument only assesses the availability of equipment, and not its accessibility. Accessibility may encourage "ease of use and cueing of behaviour" [247] and may therefore serve as a prompt to engage in specific behaviours. Previous studies have observed positive relationships between the accessibility of PA equipment and objectively measured PA [240,248,249], as well as between the accessibility of media equipment and screen-time in girls [240]. Furthermore, in one study, only the accessibility, and not the availability, of PA equipment and spaces to play was associated with increased PA in overweight children [249]. Therefore, an item's accessibility may have an important influence on behaviours, and thus should be assessed in a measurement tool. Given the limitations of the HomeSPACE-I instrument, study 2 aimed to develop and test the validity and reliability of the HomeSPACE-II instrument, with the added measure of accessibility, to measure the physical environment of two-storey homes in relation to children's PA and sedentary time.

3. General methodology

The following chapter consists of a general methodology, which will outline the methods of data collection employed by each study in the thesis. Specific information (i.e., sample sizes, coding and statistical analyses) for each study can be found in the appropriate chapters and appendices. Only data that was used is covered.

3.1. Ethical approval

Ethical approval for studies 2-5 was sought by the author of the thesis and granted by the Swansea University ethics committee (REC numbers: PG/2014/34; REC:2016-110). Data for study 1 was collected via the Swan-Linx programme which had existing university ethical approval (REC number; PG/2014/020). Prior to participating in the research, all children and parents/guardians received information sheets and completed informed consent and assent forms, respectively. The information sheets and consent/assent forms for studies 2-5 can be found in Appendix XII

3.2. Instruments and procedures

3.2.1. Swan-Linx Fitness Fun Day: Field-Based Fitness

Fitness measures from the EUROFIT fitness test battery [291] were administered with children at fitness fun days using standardised protocols [292]. Just body mass, stature and the 20 multistage fitness test are described in this chapter, as only these were used in the thesis. More detailed information on the complete set of fitness fun day measures and the standard operating procedures for administering them can be found in Appendix I.

Swansea City Council active young people (AYP) officers and sport science postgraduates led the fitness fun day testing, with assistance from Sport Wales young ambassadors and undergraduate sport and exercise science students. All of these were trained in administering the measures prior to the fitness fun days commencing. Additionally, protocols for each test were positioned next to the testing stations to ensure the standardised techniques were always followed.

All children participated in 8-10 minutes warm ups prior to completing the measures, after which they were assigned groups. Groups then completed the measures in a timed circuit. Given the size of the testing facility and the varying number of children participating (20-100) in each session, having the children complete the tests in the same order was not possible.

Body mass: Children had their body measured to the nearest 0.01 kg using portable electronic weighing scales (Seca 876, Hamburg, Germany). Children were asked to remove their shoes, any pull overs as well as to empty their pockets.

Stature: The stature of the child was measured to the nearest 0.001 m using a portable stadiometer (Seca 213, Hamburg, Germany). Children removed shoes, looked straight ahead and kept their head level during the measurement. In addition, children also took a deep breath in before the headpiece was lowered to straighten the spine, providing a more consistent measure of height [293].

Body mass index: Body mass index (BMI) was calculated (*BMI = bodymass (kg)/stature*^{2} (m)*)*, from which BMI z-scores were derived using the WHO (World Health Organization) growth reference standard [294].

20m multistage shuttle run test: To complete the 20m multistage shuttle run test (20m MSRT) [295], children ran between two lines 20m apart, within the sound of beeps playing from a CD. It is considered a valid and reliable measure of cardiorespiratory fitness [296]. Consistent with a standardised lap scoring protocol [297], a participant's score was the number of laps completed after not reaching the line for two successive beeps. A researcher ran with the children for pace consistency and to encourage them to run to fatigue.

3.2.2. Child health and activity tool: online questionnaire

The child health and activity tool (CHAT) questionnaire, similar to the paper-based Sportlinx survey [298], was created at Swansea University. The CHAT is an online questionnaire that collects data on a large range of health and lifestyle related behaviours. Only data used in this thesis is discussed in this chapter, this includes time spent in MVPA, homework/reading and screen-time, as well as dietary habits, age and sleep duration. Children were asked how much time they spend in certain activities before (8 categories ranging from "no time at all" to "more than 1 hour") and after-school (10 categories ranging from "no time at all" to "more than 3 hours"). Additionally, children were asked to think about the previous 7 days and say how many days they spent in screen-time (described as watching TV/playing computer games/tablet and internet use) for 2 or more hours a day and how many days they did sports or exercise (defined as "any activity or sport where your heart beats faster, you breathed faster and you felt warmer" for at least 1 hour. Further, participants were asked how many portions of fruit and vegetables they had consumed the previous day, whether they had breakfast, and how many days of the week they had at least one of the following: a takeaway meal, a sugary snack, a full sugar soft drink or a diet soft drink. Participants were also asked the time they went to sleep and woke up. The CHAT was completed at schools and supervised by teachers and postgraduates or AYP officers. A full copy of the questionnaire is presented in Appendix II and the protocol for administering it can be found in Appendix III.

3.2.3. The HomeSPACE-II audit

Parents completed an online version of the validated HomeSPACE-II instrument [299], an audit that assesses the physical home environment in relation to children's home-based PA and sedentary behaviours. Parents walked around their house and garden whilst completing the items for each room/area. The audit permits the presence, quantity and accessibility of 41 equipment items, as well as room size (perceived), to be recorded for up to 14 rooms indoors and eight areas outdoors. Each item's accessibility was rated on scale of (A) 'put away and difficult to get to' to (D) 'in plain view and easy to get to' [247]. The audit also consisted of questions related to home equipment (TV service, smartphones, streaming). Additionally, ten items assessing the presence of outdoor features in the front garden, back garden and verge were included. Lastly, there were also items related to home features (home type, home size, number of storeys, stairs, space to play in front and back garden).

3.2.4. The HomeSPACE-I questions related to family activity priorities and preferences

Three items from the HomeSPACE-I instrument were used to assess family activity priorities and preferences [290]. Firstly, parents were asked how important it was to them for their child to do the following when at home; (1) participate in active play; (2) play electronic games/computer; (3) watch TV/movies; (4) spend time outside; (5) and be physically active. Responses were coded on a scale of (1) 'very unimportant' to (5) 'very important'. Additionally, parents were asked which activities their child preferred at home when given the choice; (1) sitting OR running around; (2) playing indoors OR playing outdoors; (3) playing electronic games/computer OR active types of play; (4) watching TV/movies OR active types of play; (5) quiet activities OR energetic activities. Similarly, parents were asked what activities they preferred to do when at home and given the choice; (1) watching TV/movies with my child OR doing PA with my child; (2) watching TV/movies OR doing something physically active; (3) using the computer/electronic games OR doing something physically active; (4) playing electronic games/computer with my child OR doing PA with my child; (5) indoor activities with my child OR outdoor activities with my child; (6) be indoors OR outdoors; (7) quiet pursuits OR active pursuits.

3.2.5. The question on the enforcement of a screen-time limiting rule from the BEAP Study questionnaire

Parents were asked one question from the BEAP study questionnaire used in the neighbourhood impact on kids projects [259], whether they enforce a maximum number of hours/day of screen-time rule (yes/no).

3.2.6. Objective house and garden size estimates

A combination of different GIS techniques, AddressBase Premium (ABP) [300] and Ordnance Survey Mastermap (OSMM) [301], were used to derive estimates of garden and house size for each home. Participants only provided postcodes, therefore it was only possible to measure house and garden size for each postcode. Due to the variability in the sizes of homes within postcodes, the median, not the mean, value was used. For residences (min 4-max 82), the building area was extracted from OSMM and the non-residential buildings, defined by ABP were filtered out. The same technique was used to calculate garden size for residences (min 2–max 82), defined in OSMM Greenspace dataset [302]. To determine house size, the median building area was multiplied by the number of floors in each house. To test validity, separate analyses was run with the mean and median values, and the median value had the strongest associations with the outcome variables on average.

3.2.7. ActivPAL posture monitor

Children had the activPAL 3 micro secured on the midline of the upper right thigh using a hypoallergenic dressing (3M Tegerderm or Hypafix Transparent), and waterproofed using a nitrile sleeve. Supplementary dressings, sleeves and instructions (see Appendix XII) on correct reattachment were provided. The device determines body posture (i.e., sitting/ lying and upright) and transitions between these postures, based on accelerometer-derived information about thigh position and acceleration via proprietary algorithms [197]. The activPAL posture monitor has demonstrated excellent validity in children [112], and in this thesis was used to measure sitting, standing and sitting breaks.

3.2.8. ActiGraph accelerometer

Children wore the latest monitor from ActiGraph, the ActiGraph GT9X link, on their non-dominant wrist [303], to improve compliance [304]. Wrist-worn accelerometers have demonstrated good validity in comparison to hip-worn accelerometers [305]. The data was collected at a 30 Hz sampling rate [306] and summed over 5-sec epochs. The device captures acceleration, and subsequently produces activity counts, which allows intensity to be inferred using cut-points. Specifically, Chandler wrist-based cut-points [155], applied to the vector-magnitude, were used to categorise LPA (306-817 counts/5 secs), MVPA (≥818 counts/5-secs) and TPA (≥162 counts/5-secs).

3.2.9. Home log

Parents were given a diary to record when the child was at home each day for seven days, to allow for the calculation of home-based behaviours. Instructions were provided, where "Home" was defined as a single location, including the house, garden, driveway and verge of the home, where the child spends most of their time (i.e., excluding homes of other parents). To minimise missing data, children completed the diary when parents were unable to and incomplete diaries were followed up with families. The home log can be found in Appendix XII.

Table 1. A table showing which instruments were used in which studies

Studies	Measures							
	BMI	20 MSRT	CHAT	HomeSPACE-II	HomeSPACE-I	Activity monitors	GIS measures	Home log
Study 1	✓	✓	✓	×	×	×	×	×
Study 2	×	×	×	✓	×	×	×	×
Study 3	✓	×	×	✓	✓	✓	✓	✓
Study 4	✓	×	×	✓	✓	✓	✓	✓
Study 5	✓	×	×	✓	✓	✓	✓	✓

4. Development of the online HomeSPACE-II instrument

Web-based technology has grown in popularity in recent years among the Welsh population, with 97% of two adult families in Wales now being able to access the internet [307]. Therefore, supporting the case for a web-based equivalent of the validated HomeSPACE-II. Additionally, large scale studies would be easier to implement using a web-based instrument compared with a paper-based instrument, due to lower costs and easier logistics [308]. Moreover, a web-based instrument may enhance the user experience through scope for presenting a more visually appealing design [309]. Lastly, web-based instruments are normally quicker and easier to complete, which may improve response rates [310].

4.1. The initial HomeSPACE-II instrument prototype

Despite, the paper-based HomeSPACE-II instrument demonstrating strong validity and reliability [299], feasibility of the web-based version was assessed with parents of children aged 9-13 years. The initial prototype was created via Google forms, chosen for its simplicity and low running costs. When designing this prototype, the goal was to keep the format as similar to the validated paper-based instrument as possible, while addressing items which demonstrated low reliability and validity. This prototype went through multiple drafts, where the clarity of items, design, format and feasibility of administration were reviewed by researchers in pediatric exercise science. When a satisfactory draft was complete, the researcher conducted home visits with a convenience sample of two parents. During the home visits, the researcher accompanied the parents on a tour of their home to complete the audit tool. The parents were guided through the instrument item-by-item with prompts (see Appendix VI) from the researcher to help identify problems with instruction clarity and comprehension. The tour was recorded and transcribed. Both participants completed written informed consent forms.

During the visits, various problems with the instrument were apparent. Firstly, it could only be completed on devices with highly efficient processers (i.e., Apple devices). The web page would either crash or lag when scrolling down the page with other devices. The problem was related to the size of the document, but there was no logical solution. Although, the functionality of the instrument did improve with Apple devices, there was still a lag when scrolling down the drop-down menus. Several other issues, unrelated to the instrument's speed were identified. Firstly, the parents had to complete each room according to its order in the audit, instead of its order on the tour. This was because each drop-down menu (i.e., item, accessibility, quantity) was on a separate line, meaning it took a while to scroll through each room. Further, parents had to scroll through a room even if it was not present in their home. Lastly, the parents found it difficult to navigate off the drop-down menus without assistance. The instrument also included questions from previously validated measures [259,290], and in contrast participants found this section relatively easy to complete, except for a few minor clarity problems. However, because the audit did not function well enough on Google docs for it to be accurately used by parents, an alternative form building tool was needed that addressed the problems encountered.

4.2. Second iteration of the online HomeSPACE-II instrument

After trialing several online form building platforms, Formdesk was chosen to create the second iteration of the instrument. This was because there was no size limit for documents, it had low running costs and it was flexible in terms of format and graphics. Again, the goal was to keep the format as similar to the paper-based instrument as possible, which was relatively easy to do with Formdesk. A prototype went through several iterations, where the clarity of items, design, format and feasibility of administration were reviewed by researchers in pediatric exercise science. When a satisfactory draft was complete, the researcher conducted home visits with a convenience sample of 3 parents. There was representation from each of the socioeconomic status (SES) groups (i.e., low, medium and high). This was important, given home environments have been shown to differ across SES groups [246,311], and comprehension skills may be related to SES [312], which may affect one's ability to complete the audit tool accurately. The Welsh index of multiple deprivation (WIMD), derived from postcodes, was used to calculate SES. The protocol for this trial was identical to the previous one, and again all the participants completed written informed consent.

The consensus of the participating parents was that the Formdesk version of the audit tool was relatively easy to complete, as most of the problems identified with the Google docs version were rectified. Specifically, parents felt the audit tool had excellent instruction clarity, a visually appealing design, and that the item list covered all relevant items. The audit tool could now be completed via any device, without any lag, which improved its speed and functionality. All the drop-down menus for each room were on the same line (i.e., item, accessibility, quantity), which meant scrolling down the page didn't take as long. Participants were also able to complete each room in the order that they came to it on the tour and navigate off the drop-down menus without assistance. These improvements significantly reduced completion time and improved functionality.

One parent said they like the design but felt it could be improved.

"Overall I like how it looks, but it could do with tidying up in parts"

One parent said they would have found an alphabetical coded equipment list easier to use.

However, since there are more than 26 items on the list, such a change wasn't possible.

"I would find it easier to use the equipment list, if the equipment was coded alphabetically. That's just how my brain works".

In addition, some parents were not aware that each room had its own section and one parent was not sure what a verge was.

Another parent commented on the additional questions at the end.

"I think the questions look a little messy; the zig zag design looks untidy".

Lastly, upon looking at the submitted responses, we noticed the parents missed 1 or 2 questions by mistake while completing the audit.

Considering the positive consensus of the participating parents, the audit tool functioned well enough in Formdesk to be completed accurately by parents, providing some modifications were made. Several modifications were made for the final version of the instrument, informed by comments made by the parents as well as researchers in the pediatric exercise field. Changes were made to improve the aesthetics of the instrument. The drop-down menu columns (centered above) were labelled, instead of labeling each drop-down menu. Spaces were also added between each room section and question, to make it look less cluttered. Further, the answer boxes for the sex of the children below 18 years were replaced with check boxes, to increase data entry speed. Taking on board advice from a researcher with experience in creating online surveys (CM), a list of items was included in the instructions. This would give parents an idea of what items to look for during the audit prior to starting. The provision of sub-categories in the drop-down menus was considered, but it wasn't possible with the software. Moreover, room/area was underlined, and the font size was increased to ensure parents were aware that each room/area had its own section. A definition of a verge was provided too. To minimise missing data, the questions were configured so that responses were forced. If a parent fails to answer a question, an error message will appear, and they would have to complete the question before they can proceed. Although, personal questions such as income, education and postcode were not forced. Lastly, the format of the additional questions was also tidied up. The final version can be found in Appendix VII.

4.3. Feasibility testing of questionnaire including questions from validated measures

A questionnaire with items taken from previously validated measures [259,290] was also created and tested for its feasibility with a convenience sample of 2 families. Again, efforts were made to make sure the format of the questions resembled the format of the validated questions as closely as possible. Similar to the protocol used for assessing the audit's feasibility, the parents were guided through the questionnaire with prompts and questions (see Appendix VI) to gauge its usability and functionality. Written informed consent was also received from these parents. Both parents found the questionnaire relatively easy to complete, however several comments were made.

One parent felt it wasn't clear, where the questions start and end.

"Without looking closely, it's difficult to tell where questions start and end".

Another made a comment regarding the wording of the family health climate (FHC) questions.

"I think the examples of activities you have could be better suited to children, my children are definitely too young to go on hikes"

The same parent also commented on the language used.

"I think the wording is quite complicated. I'm not sure what explicitly means?"

Lastly for the activity preferences questions, initially the parents did not notice the activities on the right.

Due to the comments made by the parents, several changes were made to the questionnaire. To make it clearer where each sub-question starts and ends, the separating lines were made more pronounced through giving them darker backgrounds. For the activity preferences section, it was made clearer to the parents that there were activities on the left and right. Lastly, the activity examples in the FHC questions [313] were replaced with activities more common among the age group in question. The final version is provided in Appendix VIII.

4.4. Conclusion

In order to improve researchers' understanding of how the home influences children's PA and sedentary time, it is important to have accurate measures of the environment that have been tested with the target audience. Based on the home visits and feedback from the parents, several improvements were made to the instruments to enhance the user experience, limit participant burden and increase its accuracy. As a result, the final instruments can be accurately used by parents to measure the physical and social environment of the home in relation to children's physical activity and sedentary time.

Thesis Map

Study	Aims	Key findings
1. Relationship between Sedentary Time, Physical Activity and Multiple Lifestyle Factors in Children	To explore associations between multiple lifestyle factors and being sufficiently active ($\geq$60 min·day^{-1}) or engaging in excessive screen-time ($\geq$2 h·day^{-1}) in children.	
2. Validity and reliability of the HomeSPACE-II instrument to assess the influence of the home physical environment on children's physical activity and sedentary behaviour		
3. Associations between the Home Physical Environment and Children's Home-Based Physical Activity and Sitting		
4. Are parental and child activity preferences and priorities, as well parental rules at home associated with children's home-based behaviour and the home physical environment		
5. Clustering of home physical and social environmental factors		

5. Study 1

5.1. Relationship between Sedentary Time, Physical Activity and Multiple Lifestyle Factors in Children

*This chapter is a published manuscript:

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5.2. Introduction

Childhood obesity is a major public health concern [314], particularly in Wales, which has the highest prevalence in the United Kingdom [315], and often tracks into adulthood [316]. Associated lifetime health risks are frequently cited, such as cardiovascular disease [317], type 2 diabetes [318] and other chronic diseases [319]. There is evidence that modifiable lifestyle factors, including physical inactivity [6], poor diet [320], insufficient sleep [93] and excessive sedentary behaviour [5] are key contributors to the obesity epidemic in children and all-cause mortality. Conversely, regular physical activity [6], adequate consumption of fruit and vegetables [321] and sufficient sleep [93] are widely accepted as protective. Of these lifestyle factors, physical activity and sedentary time have been identified as the most strongly associated with obesity and health [1,322].

As well as being shown to have a robust relationship with obesity, regular moderate-to-vigorous physical activity (MVPA) is also considered to be a preventative measure for poor cardiorespiratory fitness (CRF) and several other health risk factors in children [6]. The way by which MVPA improves health is not fully understood [6], but may be partially explained by its relationship with other healthy lifestyle factors [6,89,323]. Indeed, MVPA is associated with healthy dietary habits, such as increased fruit and vegetable consumption [89,324] , breakfast consumption [325] and a lower intake of unhealthy sugary snacks [326]. Additionally, MVPA has been associated with better academic achievement [327] and longer sleep duration [323], however relationships are equivocal [327–329]. Despite this, MVPA levels remain low among children of all ages with less than 20 percent meeting the current UK physical activity (PA) guidelines of at least 60 minutes MVPA every day [330]. Furthermore, even children meeting the PA guidelines [62] spend a large proportion of their discretionary time in sedentary behaviours (up to 9 h daily) [5].

Whilst homework and reading have been identified as prominent sedentary behaviours amongst children [331], screen-time remains the most prevalent [5] and has been associated with obesity, poor CRF, cognitive function and overall cardio metabolic health [5]. Moreover, screen-time is associated with short sleep duration [83,84], less time spent in MVPA [89,90], a poorer diet, such as lower fruit and vegetable consumption [88], greater intake of soft drinks [86] and unhealthful sugary snacks [85]. Conversely, the relationship between overall sedentary time and cardiometabolic risk markers in children is less clear [5,92,332]. Screen-time, which current public health guidelines recommend children spend no more than two hours per day engaged in [61], may therefore have a stronger link with health due to its associations with numerous unhealthy lifestyle factors [89,333].

Previous studies investigating the relationship between screen-time and other lifestyle factors have solely focused on television (TV) viewing [85,334,335], which, given the vast array of available screen-based technologies, is no longer representative of modern society. Moreover, evidence investigating activity behaviours and diet in children has mainly concentrated on screen-time rather than PA, for which data, specifically amongst British children, is limited. Whilst some studies have investigated relationships between lifestyle factors and MVPA or screen-time, these have been conducted in isolation. Assessing both relationships simultaneously will not only enable a better understanding of the associated multiple lifestyle factors, but inform future interventions.

Therefore, the present study sought to explore associations between multiple lifestyle factors and the number of days being sufficiently active (≥60 min·day^{-1}) or engaging in excessive screen-time (≥2 h·day^{-1}) in children.

5.3. Materials and Methods

5.3.1. Participants

Data were captured on children who participated in the Swan-Linx programme, a health and fitness initiative, which is a sister project to Sportslinx [336,337]. In total, 756 children (371 boys, 385 girls) aged 9–11 years (10.4 ± 0.6 years) participated in the study. Data were collected across 13 socio-demographically representative schools (WIMD: Welsh index of multiple deprivation) [338], within the city and county of Swansea between January and May 2015.

5.3.2. Instruments and Procedures

Anthropometric measurements were obtained using standard anthropometric techniques [339], by the same trained researcher. Children had their stature and body mass measured to the nearest 0.001 m and 0.1 kg, using a portable stadiometer (Seca 213 portable stadiometer, Hamburg, Germany) and electronic weighing scales (Seca 876, Hamburg, Germany), respectively. From these measures, Body Mass Index (BMI) was calculated (BMI = body mass (kg)/stature^2 (m)) and BMI *z*-scores were derived using the British 1990 growth reference standard [340]. The 20 metre multi-stage fitness test (20 MSFT) [295], which has been shown to be valid and reliable in similarly-aged children [296], was conducted by the same trained researchers using a standardised lap scoring protocol [297] to assess cardiorespiratory fitness. Both the anthropometric measurements and 20 MSFT were carried out at the indoor training centre at Swansea University.

Participants were asked to complete an online 29-item lifestyle questionnaire (CHAT: Child Health and Activity Tool) akin to the paper-based tool used in Sportlinx [341]. The

CHAT questionnaire assessed time spent in MVPA, homework/reading and screen-time, as well as dietary habits, age and sleep duration. The description of screen-time included time spent watching TV, playing computer games and tablet/internet use, whereas MVPA was defined as "any activity or sport where your heart beats faster, you breathed faster and you felt warmer". Participants were asked to report time spent in each activity before (8 categories ranging from "no time at all" to "more than 1 hour") and after-school (10 categories ranging from "no time at all" to "more than 3 hours"). There were also questions asking the children how many days a week they engaged in excessive screen-time (>2 h·day^{-1}) and were sufficiently active ($\geq$60 min·day^{-1}). Further, participants were asked how many portions of fruit and vegetables they had consumed the previous day, whether they had breakfast, and how many days of the week they had at least one of the following: a takeaway meal, a sugary snack, a full sugar soft drink or a diet soft drink. Participants were asked to report the time they went to sleep and woke up, from which sleep duration was calculated and split into seven groups (<5.5 h; 5.5–6.4 h; 6.5–7.4 h; 7.5–9.4 h; 9.5–11.9 h; 12–12.9 h; 13–14.5 h). Participants postcodes (i.e., zip codes) were collected to calculate a WIMD score, which considers eight domains of deprivation; employment; health; income; housing; community safety; access to services; education and the environment [338].

5.3.3. Statistical Analysis

Missing data were noted for BMI (8 boys (2.2%), 29 girls (7.5%)), CRF (20 boys (5.4%), 22 girls (5.9%)), dietary and activity behaviours (11 boys (3%), 12 girls (3.1%)) and sleep duration (16 boys (4.3%), 18 girls (4.7%)). Statistical analyses were completed using IBM SPSS statistics 22 (IBM SPSS Statistics Inc., Chicago, IL, USA), where significance was set at ≤0.05. Whilst the normality assumption was violated, research suggests that it is not necessary when the sample size is large (>200) [342,343], therefore parametric tests were deemed appropriate. Multi-collinearity diagnostics were applied to all the variables. Linear regression models, were used to examine the extent to which the lifestyle factors

(BMI *z*-scores; CRF; screen-time, homework/reading and MVPA before and after school; fruit and vegetable consumption; breakfast consumption; full sugar soft drink intake; diet soft drink intake; sugary snack consumption; sleep duration and takeaway meal consumption) and potential confounders (i.e., WIMD and age) were associated with the number of days a week in excessive screen-time and in sufficient levels of MVPA. Variables with a significant result ($p < 0.10$) were added to a multiple regression model using the backward elimination approach. Variables that were not significant ($p > 0.10$) were deleted in a stepwise manner, resulting in a model with only significant interactions ($p < 0.05$). Due to preliminary analyses indicating significant sex differences for some variables, regression models were conducted separately by sex, in accordance with previous work [344]. For each sex, the dependent variables were split at the median to form high and low screen-time and MVPA groups. Cut-off points of $\geq$5 and $\geq$4 days in sufficient MVPA for boys and girls respectively, were used to create MVPA groups. To classify screen-time groups, cut-off points of $\geq$4 and $\geq$3 days in excessive screen-time for boys and girls respectively were used. To help facilitate interpretation of the different associations between the independent and dependent variables, differences between the high and low groups were tested post hoc using independent *t*-tests and χ^2 tests for continuous and categorical variables, respectively.

5.4. Results

Descriptive statistics for the original data set are presented in Table 1. On average, boys had a CRF score 11 units higher than girls ($p < 0.01$), and engaged in six more minutes of screen-time before school ($p < 0.01$) and 21 more minutes after school ($p < 0.01$). Furthermore, boys had at least one full sugar soft drink on 0.4 more days a week ($p = 0.01$), spent 12 more minutes in MVPA after school ($p = 0.04$), and consumed 0.4 less fruit or vegetables ($p = 0.02$). Breakfast was consumed by 94.1% of the children (93.6% boys, 94.6% girls). There were no significant sex differences for the number of days a week spent in excessive screen-time [61] or in sufficient levels of MVPA [62].

Models showing significant associations between the lifestyle factors, being sufficiently active and excessive screen-time are shown in Table 2. For boys, the model for the number of days spent in sufficient MVPA accounted for 35% ($R^2 = 0.35$) of the variance. The model for the number of days spent in excessive screen-time explained 41% ($R^2 = 0.41$) of the variance. Boys were sufficiently active for an additional day for every 100 minutes spent in MVPA ($p < 0.01$) and every 100 minutes spent doing homework/reading after school ($p = 0.05$). They were also sufficiently active for an additional day for every 33 unit increase in CRF scores ($p < 0.01$), and for every four fruit or vegetables consumed ($p < 0.01$). Further, boys engaged in screen-time excessively for an additional day for every 50 minutes spent in screen-time after school ($p < 0.01$), and one day less for every 50 minutes spent in MVPA before school ($p = 0.01$). They also engaged in excessive screen-time for an additional day for every nine days they had at least one diet soft drink ($p = 0.03$) and for every six days they consumed at least one sugary snack ($p < 0.01$).

Among girls, the model for the number of days spent in sufficient MVPA contributed 30% ($R^2 = 0.30$) of the variance. The model for the number of days spent in excessive screen-time explained 33% ($R^2 = 0.33$) of the variance. For girls, an additional day was spent being sufficiently active for every 100 minutes spent in MVPA after school ($p < 0.01$), for every 50 unit increase in CRF score ($p = 0.02$) and for every four fruit or vegetables consumed ($p < 0.01$). Girls were sufficiently active one day less for every five days they consumed more than one takeaway meal ($p = 0.01$). Further, every 50 minutes spent in screen-time after school ($p < 0.01$) and every five days consuming at least one sugary snack ($p < 0.01$) was associated with an additional day engaged in excessive screen-time. Additionally, every 50 minutes spent in MVPA before school ($p = 0.01$), three unit increase in sleep duration ($p = 0.03$) and every six fruit and vegetables consumed ($p = 0.01$) were associated with one less day of excessive screen-time.

Descriptive characteristics for the high vs. low groups are presented in Table 3. Post hoc analyses revealed that, girls in the high PA group had a higher CRF score by five units ($p < 0.01$), consumed one more fruit or vegetable ($p < 0.01$) and spent five more minutes in MVPA before school and 36 more minutes in MVPA after school ($p < 0.01$). Similarly, boys in the high PA group had a higher CRF score by ten units ($p < 0.01$), consumed one more fruit or vegetable ($p < 0.01$) and spent nine more minutes in MVPA before school and 52 more minutes in MVPA after school ($p < 0.01$). Girls in the low PA group consumed at least one takeaway meal for 0.4 more days ($p < 0.01$) and spent ten more minutes in screen-time before school ($p = 0.04$). Regarding screen-time, girls in the high group had a lower CRF score by four units ($p = 0.02$), had at least one full sugar soft drink for one more day ($p < 0.01$), at least one diet soft drink for 0.4 more days ($p = 0.02$) and consumed at least one sugary snack for one more day ($p < 0.01$). Boys in the high screen-time group had a lower CRF score by six units ($p = 0.01$, had at least one full sugar soft drink ($p < 0.01$) and diet soft drink for one more day ($p < 0.01$) as well as at least one sugary snack for one more day ($p < 0.01$).

Furthermore, boys in the high screen-time group consumed at least one takeaway meal for 0.3 more days ($p = 0.01$), spent 15 more minutes in screen-time before school and 56 more minutes in screen-time after school ($p < 0.01$) and spent one less minute in MVPA before school ($p < 0.01$) and 20 less minutes in MVPA after school ($p < 0.01$). Girls in the high screen-time group consumed at least one takeaway meal for 0.3 more days ($p < 0.04$), one less fruit or vegetable ($p < 0.01$), spent nine more minutes in screen-time before school and 29 more minutes in screen-time after school ($p < 0.01$) as well as seven less minutes in MVPA before school ($p < 0.01$). Although, the number of takeaway meals ($p < 0.01$) and CRF levels ($p = 0.02$ girls, $p < 0.01$ boys) were significantly associated with excessive screen-time in both sexes when examined separately, the associations were no longer significant in the final regression model after controlling for confounders. In addition, despite diet ($p = 0.01$) and full sugar soft drink intake ($p < 0.01$) being univariately associated with excessive screen-time in girls and boys, respectively, these associations did not remain significant after controlling for other confounders.

Table 2. Descriptive data.

Characteristics	Total Sample (n = 756)		Boys (n = 371)		Girls (n = 385)		
	Mean (SD)	n	Mean (SD)	n	Mean (SD)	n	P
Age (years)	10.4 (0.6)	752	10.4 (0.6)	369	10.4 (0.6)	383	0.96
WIMD	850.1 (571.1)	756	819.5 (578.7)	371	879.7 (562.8)	385	0.15
Height (cm)	142.1 (7.8)	731	141.8 (7.4)	366	142.0 (8.2)	365	0.21
Body mass (kg)	38.6 (10.2)	724	38.0 (10.5)	365	39.3 (9.9)	360	0.78
BMI	18.9 (3.8)	723	18.7 (3.8)	365	19.2 (3.7)	358	0.08
BMI z-score	0.6 (1.3)	719	0.6 (1.3)	363	0.6 (1.3)	356	0.06
CRF (No. of shuttles run)	31.0 (16.4)	700	36.3 (18.2)	351	25.6 (12.4)	349	<0.01 *
No. of days a week being sufficiently active	4.4 (2.2)	733	4.4 (2.3)	360	4.4 (2.0)	373	0.97
No. of days a week in excessive screen-time	3.7 (2.4)	733	3.9 (2.4)	360	3.6 (2.4)	373	0.14
No. of days a week drinking at least one full sugar soft drink	1.9 (2.1)	733	2.1 (2.3)	360	1.7 (2.0)	373	0.01 *
No. of days a week drinking at least one diet soft drink	1.3 (2.0)	733	1.4 (2.0)	360	1.3 (1.9)	373	0.28
No. of fruit and vegetable portions eaten yesterday	3.2 (1.9)	731	3.0 (2.0)	360	3.4 (1.8)	371	0.02 *
No. of days a week eating at least one sugary snack	3.2 (1.9)	733	3.2 (2.2)	360	3.2 (2.0)	373	0.71
No. of days a week eating at least one takeaway meal	1.0 (1.3)	733	1.0 (1.4)	360	1.0 (1.3)	373	0.53
MVPA before school (min)	14.2 (15.5)	733	14.6 (15.7)	360	14.0 (15.2)	733	0.16
MVPA after school (min)	54.1 (55.5)	732	60.3 (60.7)	360	48.0 (49.2)	732	0.04 *
Homework/reading before school (min)	10.4 (13.8)	733	10.4 (13.8)	360	10.0 (13.8)	373	1.00
Homework/reading after school (min)	17.7 (25.8)	732	16.2 (25.9)	360	19.0 (25.6)	372	0.12
Screen-time before school (min)	14.0 (18.7)	733	17.1 (20.2)	360	11.0 (16.6)	373	<0.01 *
Screen-time after school (min)	45.1 (52.1)	732	55.7 (59.0)	360	35.0 (41.9)	372	<0.01 *
Sleep duration (h)	9.8 (1.3)	723	9.8 (1.5)	354	9.9 (1.2)	367	0.35

P-values are based on significance level from the independent *t*-test for continuous variables (non-italics) or the chi-squared test for categorical variables (italics).
* Relationship is significant. BMI: body mass index; CRF: cardio-respiratory fitness; MVPA: moderate-to-vigorous intensity physical activity; WIMD: welsh index of multiple deprivation.

Table 3. Multivariate regression models conducted separately by sex.

Model	**Predictors**	**Boys (*n*=371)**			**Girls (*n*=385)**		
		B (SE)	**β**	***P***	**B (SE)**	**β**	***P***
No. of days being sufficiently active	MVPA before school (min)	-	-	-	0.01 (0.01)	0.09	0.06
	MVPA after school (min)	0.01 (0.00)	0.38	<0.01 *	0.01 (0.00)	0.35	<0.01 *
	Homework/reading after school (min)	0.01 (0.00)	0.09	0.05 *	-	-	-
	CRF (No. of shuttles run)	0.03 (0.01)	0.20	<0.01 *	0.02 (0.01)	0.11	0.02 *
	No. of days a week eating at least one takeaway meal	-	-	-	–0.20 (0.07)	-0.13	0.01 *
	No. of fruit and vegetable portions eaten yesterday	0.27 (0.05)	0.25	<0.01*	0.27 (0.06)	0.24	<0.01 *
	R^2 (adjusted R^2)	0.35 (0.34)			0.30 (0.29)		
No. of days in excessive screen-time	MVPA before school (min)	–0.02 (0.01)	–0.12	0.01 *	–0.02 (0.01)	–0.13	0.01 *
	Homework/reading before school (min)	–0.01 (0.01)	–0.08	0.08	-	-	-
	Screen-time before school (min)	0.03 (0.01)	0.22	<0.01*	0.03 (0.01)	0.18	<0.01 *
	Screen-time after school (min)	0.02 (0.00)	0.35	<0.01*	0.02 (0.00)	0.27	<0.01 *
	No. of fruit and vegetable portions eaten yesterday	-	-	-	–0.17 (0.07)	-0.12	0.01 *
	No. of days a week drinking at least one diet drink	0.11 (0.05)	0.09	0.03 *	-	-	-
	No. of days a week drinking at least one full sugar soft drink	-	-	-	0.12 (0.60)	0.10	0.05 *
	No. of days a week eating at least one sugary snack	0.17 (0.05)	0.16	<0.01 *	0.18 (0.06)	0.15	<0.01 *
	Age	-	-	-	0.37 (0.19)	0.09	0.05 *
	Sleep duration	-	-	-	–0.36 (0.17)	–0.10	0.03 *
	R^2 (adjusted R^2)	0.41 (0.40)			0.33 (0.32)		

CRF: Cardio-respiratory fitness; MVPA: moderate-to-vigorous intensity physical activity. * Relationship is significant

CRF: Cardio-respiratory fitness; MVPA: moderate-to-vigorous intensity physical activity. * Relationship is significant

Table 4. Descriptive statistics for the high and low screen-time and MVPA groups.

Characteristics	**Boys (*n* = 371)**						**Girls (*n* = 386)**					
	Low MVPA (*n* = 165)	**High MVPA (*n* = 195)**		**Low Screen-Time (*n* = 187)**	**High Screen-Time (*n* = 173)**		**Low MVPA (*n* = 137)**	**High MVPA (*n* = 236)**		**Low Screen-Time (*n*= 141)**	**High Screen-Time (*n* = 232)**	
	Mean (SD)	Mean (SD)	*P*	Mean (SD)	Mean (SD)	*P*	Mean (SD)	Mean (SD)	*P*	Mean (SD)	Mean (SD)	*P*
Age (years)	10.4 (0.6)	10.4 (0.6)	0.16	10.4 (0.6)	10.4 (0.6)	0.27	10.3 (0.6)	10.5 (0.6)	<0.01*	10.3 (0.6)	10.5 (0.6)	0.08
WIMD	799.0 (578.9)	834.9 (580.4)	0.56	917.1 (576.6)	771.9 (564.4)	<0.01 *	872.3 (546.5)	885.8 (574.2)	0.82	916.0 (566.4)	859.4 (561.8)	0.35
Height (cm)	141.1 (7.8)	142.4 (7.2)	0.10	141.7 (6.9)	141.9 (8.1)	0.84	140.8 (8.3)	143.4 (8.1)	<0.01 *	141.6 (8.2)	142.9 (8.2)	0.16
Body mass (kg)	37.8 (11.0)	38.4 (10.3)	0.57	37.9 (9.4)	38.4 (11.8)	0.68	38.3 (10.5)	40.1 (9.7)	0.09	38.5 (9.3)	40.0 (10.0)	0.16
BMI	18.7 (3.8)	18.7 (3.8)	0.93	18.7 (3.5)	18.8 (4.1)	0.79	19.2 (4.2)	19.3 (3.5)	0.65	19.0 (3.5)	19.4 (3.9)	0.29
BMI *z*-score	0.6 (1.4)	0.6 (1.3)	0.98	0.7 (1.2)	0.6 (1.4)	0.58	0.5 (1.5)	0.6 (1.1)	0.40	0.5 (1.2)	0.6 (1.3)	0.53
CRF (No. of shuttles run)	30.1 (14.8)	41.1 (19.4)	<0.01 *	38.7 (18.7)	33.2 (17.4)	0.01 *	22.5 (10.4)	27.2 (13.2)	<0.01 *	27.6 (13.7)	24.1 (11.3)	0.02 *
No. of days a week being sufficiently active	2.3 (1.3)	6.3 (0.9)	<0.01 *	4.6 (2.2)	4.3 (2.4)	0.25	2.2 (0.9)	5.7 (1.2)	<0.01 *	4.5 (2.1)	4.4 (2.0)	0.44
No. of days a week in excessive screen-time	4.1 (2.5)	3.7 (2.4)	0.10	1.8 (1.0)	6.2 (1.1)	<0.01 *	3.7 (2.5)	3.5 (2.3)	0.40	1.1 (0.8)	5.1 (1.6)	<0.01 *
No. of days a week drinking at least one full sugar soft drink	2.1 (2.2)	2.1 (2.3)	0.93	1.5 (1.9)	2.8 (2.5)	<0.01 *	1.9 (2.0)	1.6 (2.0)	0.17	1.2 (1.6)	2.0 (2.2)	<0.01 *
No. of days a week drinking at least one diet soft drink	1.4 (2.0)	1.4 (2.1)	0.93	1.1 (1.6)	1.8 (2.4)	<0.01 *	1.3 (1.9)	1.2 (1.9)	0.69	1.0 (1.6)	1.4 (2.0)	0.02 *
No. of fruit and vegetable portions eaten yesterday	2.3 (1.8)	3.7 (2.0)	<0.01 *	3.2 (2.0)	2.8 (2.1)	0.06	2.7 (1.6)	3.8 (1.8)	<0.01 *	3.8 (1.8)	3.1 (1.7)	<0.01 *
No. of days a week eating at least one sugary snack	3.2 (2.3)	3.3 (2.2)	0.56	2.4 (1.8)	4.1 (2.4)	<0.01 *	3.2 (2.0)	3.2 (2.1)	0.93	2.5 (1.7)	3.6 (2.1)	<0.01 *
No. of days a week eating at least one takeaway meal	1.0 (1.4)	1.1 (1.3)	0.51	0.9 (1.1)	1.2 (1.6)	0.01 *	1.2 (1.5)	0.8 (1.2)	<0.01 *	0.8 (1.3)	1.1 (1.3)	0.04 *
MVPA before school (min)	9.6 (12.5)	18.9 (16.9)	<0.01 *	17.7 (17.4)	11.3 (13.1)	0.01 *	10.7 (14.5)	15.4 (15.1)	<0.01 *	17.9 (16.7)	11.1 (13.3)	<0.01 *
MVPA after school (min)	32.2 (42.7)	84.0 (63.5)	<0.01 *	69.8 (62.2)	49.9 (57.4)	0.01 *	25.4 (31.2)	61.5 (53.0)	<0.01 *	55.6 (50.2)	43.7 (48.3)	0.24
Homework/reading before school (min)	8.4 (11.9)	12.2 (14.9)	0.08	11.6 (14.5)	9.2 (12.9)	0.35	8.8 (12.6)	11.3 (14.4)	0.70	12.5 (14.6)	9.1 (13.2)	0.20
Homework/reading after school (min)	12.7 (20.7)	19.1 (29.4)	0.25	16.5 (23.4)	15.9 (28.4)	0.81	14.7 (16.9)	21.8 (29.3)	0.39	19.4 (20.5)	19.1 (28.3)	0.53
Screen-time before school (min)	18.8 (21.0)	15.7 (19.4)	0.72	9.9 (13.9)	24.8 (22.9)	<0.01 *	14.3 (18.9)	9.1 (15.0)	0.04 *	5.4 (11.6)	14.4 (18.4)	<0.01 *
Screen-time after school (min)	61.2 (62.1)	51.0 (56.0)	0.21	28.9 (38.1)	84.6 (63.9)	<0.01 *	41.5 (47.0)	31.1 (38.4)	0.29	17.0 (26.5)	45.9 (45.9)	<0.01 *
Sleep duration (h)	9.7 (1.5)	9.8 (1.4)	0.55	9.9 (1.3)	9.6 (1.6)	0.11	9.9 (1.2)	10.0 (1.2)	0.97	10.1 (1.2)	9.8 (1.2)	0.12

p-Values are based on significance level from the independent *t*-test for continuous variables (non-italics) or the chi-squared test for categorical variables (italics). * Relationship is significant. BMI: body mass index; CRF: Cardio-respiratory fitness; MVPA: moderate-to-vigorous intensity physical activity; WIMD: welsh index of multiple deprivation. The cut-off values for MVPA were ≥5 and ≥4 days in sufficient MVPA for boys and girls respectively. The cut-off values for screen time were ≥4 and ≥3 days in excessive screen-time for boys and girls respectively.

5.5. Discussion

The present study aimed to explore associations between MVPA, sedentary time and multiple lifestyle factors in 9–11 years old children. Of note, there was no inverse relationship between days spent in excessive screen-time and sufficient levels of MVPA or vice versa. Although studies have reported an inverse relationship between sedentary time and MVPA [91], there is insufficient evidence to assume a reciprocal relationship [91]. Whilst both behaviours may directly compete with each other during a specific time period (e.g., after school) [91], the same may not be true for an entire day or across a week [258]. Further, similar to previous research [83,86,89,345], excessive screen-time was associated with unhealthy factors, which were different to those inversely related to sufficient levels of MVPA. Indeed, available evidence suggests that they are two separate entities [93], which are independently associated with health [5].

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While boys were more active than girls after school, both were sufficiently active for the same number of days a week. Consistent with a recent review [10], sufficient levels of MVPA were positively related to CRF independent of sex. Aside from low CRF, low fruit and vegetable intake is another weight-related risk factor [321]. In agreement with previous research [89,324,346], strong positive associations between fruit and vegetable consumption and sufficient levels of MVPA were observed in both sexes. Conversely, Pereira et al. [347] found a negative relationship, whereas Vissers et al. [348] and Jago et al. [344] found a positive relationship in boys and girls, respectively. The equivocal findings may, in part, be a result of different methodologies and sample characteristics; Pereira et al. [347] found active children engaged in more screen-time, and studies have suggested a negative relationship between screen-time and fruit and vegetable consumption [86,345]; in contrast to the present study, Vissers et al. [348] found MVPA to be significantly higher in boys and Jago et al. [344] recorded dietary and PA measures 12 months apart.

Sleep duration is an important component of health in children [93] and has been associated with MVPA, however evidence is scarce and contradictory. In our study, sufficient levels of MVPA were not associated with sleep duration. On the contrary, Stone et al. [323] found MVPA to be higher among children with >10 h of sleep per night compared with those who slept < 9 h per night. However, it is noteworthy that Stone et al. [323] used parental report to assess sleep duration, which is thought to have questionable reliability, as parents tend to overestimate sleep duration [349,350]. Although children can also overestimate sleep duration [351], our finding that sleep duration was not associated with MVPA is in agreement with several studies that measured sleep duration objectively [329,352]. In children of this age, sleep duration may be more susceptible to environmental factors, such as social activities or school arrangements than the actual need for sleep [352], which may explain why MVPA was not directly associated. However, MVPA has been associated with better sleep efficiency [352,353] and shorter sleep latency [352] and is therefore considered beneficial for sleep in children.

Converse to a systematic review [354], this study did not find an association between BMI and sufficient levels of MVPA irrespective of sex. There was a large amount of data missing for BMI in girls (7.5%); although the weight status of these girls is unknown, it is possible that they were overweight or obese. The extent to which this biased results is unclear, however it may provide a reason for why there was no association between BMI and MVPA in girls. Further, this relationship may be more related to the intensity of PA as opposed to total PA [195]; therefore the aggregation of moderate (MPA) and vigorous (VPA) physical activity may, in part, explain this discrepancy.

The lack of association between excessive screen-time and BMI-*z* scores in the present study, may have been due to the low prevalence of reported screen-time in the sample. On average, children engaged in $\geq$2 hours of screen-time for only 3.7 days a week, compared with the average of 3 hours per day reported in studies observing a relationship between screen-time and adiposity in children [1,4]. Therefore, perhaps only higher durations of screen-time are associated with adiposity in children [5]. Although the underpinning mechanisms behind the relationship between screen-time and adiposity are not completely understood [5], the association between screen-time and elements of a less healthy diet is believed to be a contributing factor [86]. Sugary snack consumption was positively associated with excessive screen-time in this study, in agreement with previous research [86,88,345]. As sugary snack consumption has been shown to increase overall caloric intake [320], it may be an important factor in the screen-time and obesity/overweight relationship. Screen-time may influence sugary snack consumption in children in several ways, through exposure to advertisements for sugary snacks on TV or online [355], reduced sensitivity to satiety cues and messages imbedded in TV programmes [356]. Interestingly, diet soft drinks are the most highly advertised product on TV [355], and since boys watch more TV [357,358], they are more exposed to these advertisements which may explain the positive relationship between diet soft drinks and excessive screen-time in boys.

For girls only, low fruit and vegetable consumption was associated with screen time, consistent with a recent review by Pearson and Biddle [345]. It is not clear why the relationship only exists in girls, but it may be partially explained by the positive but non-significant relationship between sufficient levels of MVPA and excessive screen-time in boys (p = 0.08). This suggests a coexistence of high levels of MVPA and screen-time in boys, in line with others [359,360]. Therefore, fruit and vegetable consumption may be higher among boys who engage in excessive screen time as they are also achieving sufficient levels of MVPA, since studies have found a positive relationship between the latter and fruit and vegetable consumption.

In contrast to previous research [83,84], we observed a negative relationship between screen-time and sleep duration only in girls. The reason for this sex difference is not clear, but mobile phone and MP3 player use is higher among girls, whereas watching TV and video gaming is higher among boys [358]. As mobile phones and MP3 players are easier to hide from parents in bed [361], it could be postulated that the more frequent use of these devices by girls before bedtime could reduce sleep time.

The negative relationship observed between MVPA before school and excessive screen-time may reflect findings from Gorely et al. [362] whereby adolescents who commuted to school via motorised transport were more likely to spend their discretionary time watching screens. Since active travel is considered the main source of MVPA before school [336], it is possible that children who engaged in excessive screen-time more regularly commuted to and from school via motorised transport. However, since few studies have investigated associations between active travel to school and screen-time in children to date, more research is needed to confirm the potential relationship between active travel and habitual screen-time.

We found positive associations between MVPA and screen-time after-school and meeting and exceeding their respective recommendations, respectively, which supports the hypothesis that the after-school period is key for the accumulation of MVPA and screen-time [336]. Indeed, Atkin et al. [331] revealed that time spent in both screen-time and MVPA during the after-school period (15:30–18:30) accounted for approximately 30% and 40%, respectively, of daily totals. Further, Olds et al. [90] found that during this period the greatest variation in MVPA levels occurred between high active and low active children.

Although screen-time and MVPA are the most prominent behaviours during the after-school period [126,331], productive sedentary behaviours, such as homework and reading, also occur and are thought to directly compete with MVPA [363]. However, in the present study, there was a positive relationship between homework/reading after school and sufficient levels of MVPA in boys, similar to data reported in adolescents [364]. In accord with Booth et al. [365], this suggests that there is time for both MVPA and homework and reading throughout the day and provides support for the beneficial influence of MVPA on school endeavours in boys at least. In contrast to most types of screen-based sedentary behaviours, these productive sedentary behaviours are considered essential for a child's education and development [93].

The examined lifestyle factors accounted for 35% and 30% of the variance in the number of days boys and girls were sufficiently active for, respectively. Significant proportions of variance were also explained in the number of days spent in excessive screen-time, with 41% and 33% of the variance accounted for in boys and girls, respectively. This suggests that lifestyle factors relating to sleep duration, diet and behavior have an important relationship with children's MVPA and screen-time, particularly among boys. One reason for this discrepancy, may be that the behaviours examined are more common among boys. Perhaps behaviours not included in this study such as arts and crafts, chatting with friends and listening to music are more important for girls. We chose to concentrate on homework/reading, MVPA and screen-time, as these are more consistently associated with health [5,6].

The present study has numerous strengths. Firstly, to the authors' knowledge, it is the first study to investigate the associations of both sufficient levels of MVPA and excessive screen-time with multiple lifestyle factors in children within the same sample. The integration of new types of technology for assessing screen-time advances previous research, which focused solely on television viewing [85,334,335]. This is important as screen-time is constantly changing due to technological advances, and multifunctional devices such as tablets, smartphones and computers are now frequently used by children [358]. Moreover, children regularly engage in two or more forms of screen viewing simultaneously [366]. Therefore, children can over-report screen-time when responding to certain self-report questions, however we were able to address this with our excessive screen-time question. Further, the sample was socio-demographically representative of the area and the detailed information collected enabled us to control for a number of variables. Also, while there is sufficient research investigating associations between diet and MVPA in adults [367] and adolescents [368], there is a paucity of research among children. In addition, the present study established a number of sex differences in relationships, uncommon in the literature. These may be a function of measurement issues, but equally, they may just be sample dependent, differing by cultural environments, age or country of study.

Nonetheless, certain limitations should be acknowledged. Given the cross-sectional nature of the study, it is not possible to infer causal relationships and future research should clarify such complex relationships by examining longitudinal associations. In addition, the time-specific measures used to assess diet, MVPA, screen-time and sleep duration may not have captured habitual behaviour. Future studies should seek to assess diet [88,348] and screen-time [169] using 7 day diary/logs and similarly PA [322] and sleep duration [369] for 7 days by accelerometer. Measuring PA using an accelerometer also allows researchers to quantify intensity, which the questionnaire did not allow as it primarily focused on the frequency and duration of PA. Indeed, MPA and VPA were aggregated, and VPA is more consistently associated with health [10]. Moreover, the comparably low prevalence of excessive screen-time found in the sample may be due, at least in part, to social desirability, inherent in self-reporting [169]. Unfortunately, as the screen-time measure is an aggregate of three behaviours, we could not examine TV viewing, playing computer games and tablet/internet use separately. There is evidence to suggest that internet use for productive purposes, is not related to poor lifestyle habits in adolescents [370]. Even internet use for gaming may have less of an impact on poor lifestyle habits, such as snacking than TV viewing, particularly in boys [371]. Direct comparisons between this cross-sectional study and others are limited by the different study designs and methodologies used to assess behaviours. Whilst, previous studies examining multiple lifestyle factors have used approaches such as cluster and co-occurrence analyses [347,372], this is one of the few to explore the independent associations between MVPA, screen-time and several other lifestyle factors, while simultaneously controlling for potential confounders. The approach utilized in the present study enabled the identification of several important lifestyle factors, which could be beneficially influenced through implementing interventions designed to change MVPA and screen-time. As such, the study is of significant public health interest.

5.6. Conclusions

Taken together, the present study enables researchers to gain a better understanding of other lifestyle factors associated with MVPA and screen-time in children. Specifically, both healthy and unhealthy lifestyle factors, differing by sex, were associated with sufficient levels of MVPA and excessive screen-time respectively. Future interventions seeking to promote health behaviours, should target change in multiple lifestyle factors, with sex-specific strategies.

Thesis map

Study	Aims	Key findings
1. Relationship between Sedentary Time, Physical Activity and Multiple Lifestyle Factors in Children	To explore associations between multiple lifestyle factors and being sufficiently active ($\geq$60 min·day^{-1}) or engaging in excessive screen-time ($\geq$2 h·day^{-1}) in children.	Sufficient MVPA and excessive screen-time were associated with healthy and unhealthy factors, respectively, with relationships sometimes differing by sex. Specifically, fruit and vegetable consumption and CRF were positively associated with sufficient MVPA, irrespective of sex. Excessive screen-time was positively associated with sugary snack consumption in boys and girls, and diet soft drink intake in boys ($p < 0.05$). In addition, excessive screen-time was negatively associated with MVPA before school for both boys and girls, as well as with sleep duration and fruit and vegetable consumption for girls ($p < 0.05$).
2. Validity and reliability of the HomeSPACE-II instrument to assess the influence of the home physical environment on children's physical activity and sedentary behaviour	To test the criterion validity and reliability of the HomeSPACE-II instrument.	
3. Associations between the Home Physical Environment and Children's Home-Based Physical Activity and Sitting		
4. Are parental and child activity preferences and priorities, as well parental rules at home associated with children's home-based behaviour and the home physical environment		
5. Clustering of home physical and social environmental factors		

6. Study 2

6.1. Validity and reliability of the HomeSPACE-II instrument to assess the influence of the home physical environment on children’s physical activity and sedentary behaviour

***This chapter is a publish manuscript:**

Sheldrick, M.P.R; Maitland, C.; Mackintosh, K.A.; Rosenberg, M.; Stratton, G. (2020) Validity and reliability of the HomeSPACE-II instrument to assess the influence of the home physical environment on children’s physical activity and sedentary behaviour. *International Journal of Health Promotion and Education* **2020**.

6.2. Introduction

The importance of physical activity (PA) for disease prevention and health promotion in children is well established [6]. Conversely, time spent sedentary, particularly using screens, has been associated with poor health outcomes [5].

Despite this, few children meet the current PA and sedentary behaviour recommendations [62]. The social ecological model is used to contextualise the determinants of children’s sedentary behaviour and PA [373,374]. This model emphasises the influence of the environment and posits that behaviours are most likely influenced by the setting in which they occur [36,37]. Outside of school, children spend significant time within their home and neighbourhood environments. The influence of the neighbourhood environment on children’s PA levels and sedentary behaviour has been well studied, where proximity to parks and recreation areas has been positively associated with PA [375], and neighbourhood safety has been negatively associated with sedentary behaviour [376]. However, children have less independent mobility [377] and therefore opportunities for active free play [378] in their neighbourhoods compared with previous generations. Given that children spend considerable time at home [38,39], an improved understanding of its influence on PA and sedentary behaviour is imperative for developing effective interventions.

To date, research into the influence of the home environment on children's PA and sedentary behaviour has focused on the social environment, with the physical environment receiving little attention [41,42]. Nonetheless, there is a consistent positive relationship between the quantity of media equipment within the home, its presence within a child's bedroom, and screen-based sedentary behaviours [41,235]. There is limited evidence for an association between PA equipment and PA levels [41]. Moreover, some studies have reported an inverse relationship between media equipment and PA [379,380], and between PA equipment and sedentary behaviour [240,241], but evidence is inconclusive [41]. Similarly, whilst PA at home is most likely to occur outdoors [251], the relationship between garden space and PA remains equivocal [256,381]. Even though the evidence base is growing, there remains a paucity of research investigating the home physical environment, outside of PA and media equipment.

In addition, most home environment measurement tools only assess the availability of equipment, without considering its accessibility, thus limiting investigation. Accessibility is associated with 'ease of use and cueing of behaviour' [247],p.2 therefore, a readily available item posing little barrier to use may act as an important prompt to engage in a behaviour. Studies investigating accessibility have reported a positive relationship between the accessibility of PA equipment and accelerometer-derived PA in children [240,248,249], as well as the accessibility of media equipment and screen-time in girls [240]. Hales et al. [248] also found that only the accessibility, and not availability, of portable play equipment was positively associated with children's outdoor play [248]. Taken together, these findings demonstrate the potential utility of accessibility in influencing behaviour, and accordingly the need to include a measure of accessibility in a measurement tool.

Reviews [41,42] recommended that more objective measurement tools are needed to improve our understanding of how the home physical environment influences children's PA and sedentary behaviour. Sirard et al. [247] developed a valid and reliable PA and media equipment inventory (PAMI), a room-level home audit which records the availability and accessibility of PA and media equipment in homes. Similarly, Pinard et al. [382] created a parent-report instrument to measure PA and media equipment in low-income family homes; however, in-home observation was not used to assess criterion validity. Lastly, the HomeSTEAD instrument [248] underwent rigorous validity and reliability testing and it provides a more comprehensive .assessment of the home physical environment, including a large range of PA and media items as well as garden characteristics, although it did not include room-level location for most items. Whilst these provide valid and reliable assessments of media and PA equipment at home, they lack detailed measures of other physical environmental factors.

The HomeSPACE-I instrument [290] advanced previous instruments by measuring previously unexplored characteristics of the physical home environment such as musical instruments, room/area size and furniture, as well as providing room-level data, assessing garden size and outdoor features. Thus, the HomeSPACE-I instrument allows a more detailed assessment of the physical home environment than previous instruments [247,248]. The HomeSPACE-I instrument was designed and validated for use in Western Australia (WA) where homes are typically onestorey, thereby potentially limiting its appropriateness for use in countries with predominantly two-storey homes. Specifically, one-storey homes are often open plan and have less separation between the bedroom and living areas, and therefore likely to impact family interaction as well as parents' ability to monitor children's electronic media usage. One-storey homes can offer families more freedom to design the layout to suit their preferences and priorities, which may or may not be aligned to the promotion of healthy behaviours. In contrast, two-storey homes have a smaller footprint, which generally allows more outdoor space when on a similar-sized plot. Such inherent layout and design differences highlight the necessity for the HomeSPACE instrument to be validated for use in two-storey homes.

The HomeSPACE-II instrument was developed for use in two-story homes with the added measure of accessibility, to measure parameters of the home physical environment that may influence children's PA and sedentary behaviours. The construct validity of the measure has been established previously, with significant associations between several home physical environmental factors assessed by the instrument and children's objectively measured home-based sitting and PA in the expected directions being found [383]. Specifically, home-based sitting time was negatively associated with musical instrument accessibility and availability, perceived house size, and an open-plan living area, and positively associated with media equipment accessibility and availability. Total physical activity (TPA) levels at home were also positively associated with the number of floors in the home and an open-plan living area. The present study aimed to test the criterion validity and test-retest reliability of the HomeSPACE-II instrument.

6.3. Method

6.3.1. Participants

A convenience sample and parents of children participating in the Swan-Linx school health, fitness and wellbeing project [384] were provided with information about the study. Thirty-one families, 22 via Swan-Linx and nine from the convenience sample, living in the two largest conurbations in South Wales (Cardiff and Swansea) agreed to participate. Families had at least one child aged 9 to 13 years and a parent or guardian prepared to complete the audit on two separate occasions. Family passes for a local water park were offered as an incentive for participating in the study. The institutional ethics committee approved the study.

6.3.2. HomeSPACE-II instrument

The HomeSPACE-II instrument measures the physical environment of the home space in relation to children’s PA and sedentary behaviour, and was based on the audit section of its Australian counterpart [290]. However, the instrument was adapted to include equipment most relevant to home-based activity in the UK, and to assess the accessibility as well as the availability of each item and where appropriate questions were adapted to the UK context. A draft instrument was reviewed by researchers with over 10 years of experience in the field of children’s PA and sedentary behaviour (GS and CM). The instrument and full study procedure were then pilot tested with a convenience sample of two families. At the end of the home visits, parents provided verbal feedback on the audit and home visit data collection protocol. Based on their feedback the audit was refined to improve instruction clarity, the magazine item was moved to the questions section, and items commonly found in UK households such as a football net, frisbee, skipping rope, hula hoop, table football and swing ball were added, and a spa was removed.

The final instrument incorporated 39 equipment items, and allowed the presence, amount and accessibility of each item, as well as room size (perceived), to be recorded for up to 14 rooms indoors and eight areas outdoors (see instrument provided as a supplementary file). Accessibility was rated on a scale of A-D, using developed and validated scores [247]. The response options were; A: put away and difficult to get to; B: put away and easy to get to; C: in plain view and difficult to get to; D: in plain view and easy to get to. The accessibility options were designed to also account for the condition of an item. For example, a punctured football in plain view should be given a C rating, while a tennis racquet in usable condition and in plain view should be given a D rating. Instructions and examples were provided on the first page of the instrument. There were 10 items assessing the presence of outdoor features in the front garden, back garden and verge. Items related to home features (home type, home size, number of storeys, stairs, fencing and adjacency to public open space) were also included. In addition, there were questions for home equipment (books, magazines, DVDs, TV channels, electronic games, active electronic games, smartphones, internet service) and dogs and other pets) that could not be assessed by the room-level audit.

6.3.3. Procedures

Participant home visits were conducted during February to May 2016. Parents were provided the study information prior to the visit. Under ethical guidelines, written informed consent was received upon arrival and all family members provided verbal permission for the home visit. One parent/guardian was required to walk around their home and complete the instrument, while a criterion-trained researcher simultaneously, but independently, completed the instrument. Parents were asked not to communicate with the researcher during the audit. If items were hidden, such as underneath furniture, parents were asked to make them visible. At the end of the visit, parents were given a second copy of the instrument, which they were asked to complete one week later and return via a pre-paid envelope. All the data collected were kept private and confidential.

6.3.4. Data Reduction

Individual items, features and the number of items within each accessibility group were collated into category summary scores (Table 1). Density measures were calculated by dividing the category summary scores by the total number of indoor rooms, outdoor areas or total rooms/locations in the house. Summary scores that accounted for the accessibility and availability of the media equipment, PA equipment, musical instrument and seated furniture items were also created by multiplying each item by their accessibility scores

(A = 1; B = 2; C = 3; D = 4). The higher the score, the greater the overall ‘presence’ of the type of item in the home. Further, an overall home environment score was calculated to assess whether a home was more conducive to physical activity or sedentary behaviour. The score was calculated as the ratio of PA equipment summary score to media equipment summary score (activity: media ratio score). A higher score would reflect a home more likely to facilitate PA and discourage sedentariness.

6.3.5. Demographics

Parents reported their age, place of birth, sex, educational status, as well as the postcode, sex and age of the primary child, family situation, homeowner status and the main language spoken at home. Additionally, postcodes (i.e. zip codes) were used to generate Welsh Index of Multiple Deprivation (WIMD) scores, using the National Statistics Postcode Directory database, as an indication of socioeconomic status (SES). The WIMD scores consider eight domains of deprivation; employment; health; income; housing; community safety; access to services; education and the environment [338]. Small areas in Wales are ranked from 1 to 1909, with 1 being the most deprived and 1909 being the least deprived. Tertiles of SES were formed: Low (1–636), medium (636–1272) and high (1272–1909).

6.3.6. Statistical Analysis

For continuous variables, criterion validity was assessed by examining agreement between the “gold standard” trained researcher and the participant using Pearson correlation coefficients and 95% limits of agreement. Mean differences between the researcher and the participant were evaluated using two-tailed paired t-tests. Test-retest reliability between participants at time-points was evaluated using intraclass correlation coefficients (ICC; 95% confidence intervals displayed, recommended for assessing the reliability of measurement scales [385]. ICCs were rated using cut-off points of: < 0.40 (poor); 0.40 to 0.59 (fair); 0.60 to 0.74 (good); and 0.75 to 1.00 (excellent) [386].

For the categorical variables, validity and test-retest reliability were assessed by Cohen’s Kappa coefficients (CKC; 95% confidence intervals displayed). Kappa coefficients were interpreted as follows: < 0.00 (poor); 0.00 - 0.20 (slight); 0.21- 0.40 (fair); 0.41- 0.60 (moderate); 0.61- 0.80 (substantial); and 0.81-1.00 (almost perfect) [387]. Statistical analyses, were conducted using IBM SPSS statistics 22 (IBM SPSS Statistics Inc., Chicago, IL, USA), where significance was set at $\leq$ 0.05.

6.4. Results

Demographic characteristics of the participating families are provided in Table 1. All parents (n = 31) completed the HomeSPACE-II instrument at both time-points, where 87.1% were female, 61.3% held a university degree and 45.2% lived in the highest SES locations. Houses were mostly semi-detached or terraced (61.3%) with two parents (87.1%), and there were most often four occupants per home (48.4%), including two children (51.6%). Most participants reported they had either a medium or large-sized house (45.2% and 41.9%, respectively), and a medium or large-sized garden (42.0% for both).

6.4.1. Validity

The results of the availability validation analysis are shown in Table 2. Pearson correlation coefficients between the researcher and parent were >0.80 for all the room/area summary variables, and ≥0.84 for the availability and density of PA equipment, musical instruments, media equipment and seated furniture. Three of four outdoor features correlations were >0.90, only the 'back garden' summary item fell below 0.70 (r = 0.65). There were significant differences for five PA equipment categories. On average, the researcher recorded two more sports equipment items (p = 0.05), one more PA equipment item indoors (p = 0.01) and three more in total and a higher density of PA equipment indoors by 0.2 units (p = 0.02) and in total by 0.3 units (p = 0.03). Significant mean differences were also noted for three seated furniture categories. Specifically, the researcher on average recorded one more piece of seated furniture indoors (p = 0.03) and in total (p = 0.03) and a higher density of seated furniture indoors by 0.1 units (p = 0.05).

Table 3 contains the results for the accessibility variables. Correlation coefficients between the researcher and participant were ≥0.35 across all four accessibility ratings for PA equipment (total, indoor and outdoor), media equipment and musical instruments. Correlation coefficients for three accessibility ratings for seated furniture (total, indoor and outdoor) fell below 0.18. Correlation coefficients for the number of items recorded as 'in plain view and easy to get to' were most favourable, where six of eight were ≥0.80 (Table 3). Average accessibility ratings for three of eight item categories achieved correlation coefficients ≤0.35. Mean differences were noted between the researcher and participant for four accessibility ratings, with the researcher on average recording one more PA equipment item indoors as 'in plain view and easy to get to' ($p = 0.02$), and five more PA equipment items outdoors and six more in total as 'put away and easy to get to' (both $p = 0.01$), as well as one more media equipment item as 'in plain view and easy to get to' ($p = 0.02$). Further, there were significant differences in average accessibility ratings for two item categories, with the researcher observing fewer PA equipment in total as harder to access ($p = 0.04$) and more PA equipment outdoors as harder to access ($p = < 0.01$).

Correlation coefficients were high for the calculated accessibility and availability summary scores (number of items * accessibility rating) [$r > 0.75$; Table 2] and for the activity: media ratio score (the ratio of PA equipment summary score to the media equipment summary score) [$r = 0.70$; Table 3]. However, the media equipment accessibility and availability summary score was significantly greater for the researcher ($p = 0.02$).

Validation results for the categorical variables are provided in Table 4. All variables assessing adjacent space showed almost perfect agreement ($K > 0.81$) and those assessing home design showed either substantial or almost perfect agreement ($K \geq 0.69$). Validity for seven out of 14 size measures showed either substantial or almost perfect agreement ($K \geq 0.63$), and the remaining seven demonstrated fair or moderate agreement ($K = 0.24$–0.58).

6.4.2. Reliability

For test–retest reliability, ICCs for 28 of the availability variables were excellent ($ICC \geq 0.76$), with the other 6 being either fair or good ($ICC = 0.52$–0.73; Table 2). For the majority of the categorical variables, Cohen's Kappa was either substantial or almost perfect ($K > 0.61$; Table 4). Most other kappa coefficients were moderate ($K = 0.41$–0.60); however, one item, hall size, was fair ($K = 0.28$).

As shown in Table 3, most of the ICCs for the accessibility categories were either good or excellent ($ICC > 0.60$). Across the accessibility summary categories, the highest ICCs were found for the number of items rated as ‘put away and difficult to get to’ and ‘in plain view and easy to get to’, where six of seven and five of eight, respectively, were excellent (ICC ≥ 0.75). Conversely, the lowest ICCs were found for the number of items rated as ‘in plain view and difficult to get to’, with five of eight being poor (ICC = −0.03–0.32). In terms of average accessibility ratings, all but one of the item categories achieved fair to excellent ICCs ≥0.42; the ICC for musical instruments was poor (ICC = 0.15). Reliability was excellent between the parent at Time 1 and Time 2 for all four accessibility and availability summary scores (ICC ≥ 0.84; Table 2), and for the activity: media ratio score (ICC = 0.79; Table 3).

Table 5. Descriptive statistics of the study sample.

		Both validity and reliability and Sample n=31 %	Families from Swansea n=22 %	Families from Cardiff n=9 %
Family Characteristics				
Parent age, mean (SD)		41.67 (4.04)	41.68 (4.20)	41.67 (5.46)
Parent sex	Female	87.1%	90.9%	77.8%
	Male	12.9%	9.1%	22.2%
Parent country of birth	Wales	74.2%	72.7%	77.8%
	England	16.1%	13.6%	22.2%
	Other	9.7%	13.6%	-
Primary child age, mean (SD)		10.15 (0.98)	10.16 (0.78)	10.11 (1.45)
Primary child sex	Girl	48.4%	36.4%	77.8%
	Boy	51.6%	63.6%	22.2%
Main language spoken at home	English	83.9%	77.3%	100%
	Welsh	12.9%	18.2%	-
	Other	3.2%	4.5%	-
Number of children at home	1	12.9%	13.6%	11.1%
	2	51.6%	50%	55.6%
	3	25.8%	22.7%	33.3%
	≥ 4	9.7%	13.6%	-
Number of people at home	≤ 3	12.9%	18.2%	0
	4	48.4%	45.4%	55.6%
	≥ 5	38.7%	36.4%	44.4%
Parental education	≤ Secondary school	12.9%	18.1%	-
	Trade or Diploma	25.8%	18.1%	44.4%
	University degree	61.3%	63.6%	55.6%
SES (based on WIMD scores)	High	45.2%	45.5%	44.4%
	Medium	38.7%	31.8%	55.6%
	Low	16.1%	22.7%	-
Family situation	Single parent	9.7%	13.6%	-
	Two parents	87.1%	86.4%	88.9%
	Other	3.2%	-	11.1%
Home ownership	Rent	12.9%	18.2%	-
	Owner	87.1%	81.8%	100%
Home characteristics				
House type	Detached house	38.7%	40.9%	33.3%
	Semi-detached or terrace house	61.3%	59.1%	66.7%
House size	Small	12.9%	9.1%	22.2%
	Medium	45.2%	45.5%	44.4%
	Large	41.9%	45.5%	33.3%
Garden Size	No	-	-	-
	Small	16%	13.6%	22.2%
	Medium	42%	45.5%	33.3%
	Large	42%	40.9%	44.4%

Table 6. Validity and reliability for home equipment and features–continuous variables.

Home equipment and features	Time 1 (n=31)	Researcher (n=31)	Time 2 (n=31)	Validity Time 1 vs Researcher			Reliability Time 1 vs Time 2
				Pearson's correlation	t-test of means	Limits of agreement (95%)	Intraclass Correlation Coefficient (1.1)
	Mean (SD)	Mean (SD)	Mean (SD)	*r*	P-value		ICC (95% CI)
ROOMS/ AREAS							
Living rooms	4.32 (1.09)	4.29 (1.05)	4.35 (1.31)	0.96	0.57	(0.58, 0.65)	0.86 (0.73, 0.93
Bedrooms	3.52 (0.76)	3.52 (0.76)	3.45 (0.66)	1	Constant	-	0.88 (0.76, 0.94
Total-Indoors	7.84 (1.57)	7.81 (1.51)	7.81 (1.67)	0.98	0.57	(-0.58, 0.65)	0.89 (0.79, 0.95
Total-Outdoors	3.26 (1.05)	3.35 (0.93)	3.45 (1.01)	0.83	0.37	(-1.27, 1.07)	0.53 (0.23, 0.74
Total-Home	11.10 (2.28)	11.16 (2.16)	11.26 (2.37)	0.96	0.60	(-1.40, 1.27)	0.87 (0.75, 0.94)
OUTDOOR FEATURES							
Back garden	5.74 (1.16)	5.71 (1.05)	5.66 (1.40)	0.65	0.85	(-1.83, 1.89)	0.61 (0.32, 0.78)
Front garden	4.16 (2.11)	4.45 (2.06)	4.52 (1.92)	0.93	0.06	(-1.91, 1.33)	0.84 (0.69, 0.92)
Verge	1.23 (2.28)	1.19 (2.16)	1.38 (2.20)	0.97	0.77	(-1.15, 1.22)	0.95 (0.89, 0.98)
Total-Outdoors	11.13 (3.75)	11.35 (3.63)	11.55 (3.73)	0.91	0.45	(-3.41, 2.96)	0.87 (0.74, 0.94)
PA EQUIPMENT							
Sports	13.65 (9.52)	15.87 (10.83)	16.03 (11.25)	0.84	0.05*	(-10.75, 7.91)	0.78 (0.59, 0.89)
Transportation	8.81(5.01)	9.06 (4.63)	8.48 (5.66)	0.94	0.42	(-3.69, 3.69)	0.81 (0.64, 0.90)
Fitness	1.65 (2.01)	1.90 (2.48)	1.94 (2.54)	0.94	0.13	(-2.08, 1.56)	0.86 (0.74, 0.93)
Outdoor play	2.77 (2.09)	2.90 (2.12)	2.90 (2.39)	0.90	0.46	(-2.01, 1.75)	0.86 (0.73, 0.93)
Indoor play	0.35 (0.54)	0.42 (0.75)	0.32 (0.59)	0.90	0.33	(-0.77, 0.64)	0.76 (0.56, 0.87)
Total-Indoors	6.03 (4.70)	7.19 (5.66)	6.71 (6.22)	0.91	0.01*	(-6.02, 3.70)	0.79 (0.61, 0.89)
Total-Outdoors	21.19 (12.69)	22.97 (13.31)	22.97 (14.94)	0.87	0.16	(-15.12, 11.57)	0.85 (0.71, 0.92)
Total-Home	27.23 (13.43)	30.16 (14.93)	29.68 (17.26)	0.88	0.03*	(-17.21, 11.34)	0.83 (0.67, 0.91)
Density-Indoors	0.83 (0.72)	0.98 (0.83)	0.88 (0.85)	0.92	0.02*	(-0.81, 0.52)	0.76 (0.55, 0.88)
Density-Outdoors	6.74 (4.06)	7.13 (4.41)	6.59 (3.81)	0.84	0.39	(-5.28, 4.49)	0.70 (0.46, 0.84)
Density-Home	2.50 (1.29)	2.79 (1.52)	2.62 (1.60)	0.89	0.03*	(-1.68, 1.10)	0.81 (0.65, 0.90)
Summary score [1]	80.26 (45.22)	83 (45.38)	91.16 (61.20)	0.77	0.63	(-62.96, 57.48)	0.84 (0.69, 0.92)
MEDIA EQUIPMENT							
Fixed	8.52 (3.65)	8.58 (3.54)	8.00 (4.29)	0.97	0.69	(-1.81, 1.81)	0.89 (0.78, 0.94)
Portable	5.03 (2.40)	5.46 (2.50)	5.10 (2.79)	0.88	0.07	(-2.83, 2.00)	0.81 (0.63, 0.90)
Bedrooms	3.94 (2.85)	4.00 (2.93)	3.81 (3.04)	0.99	0.49	(-1.07, 0.94)	0.90 (0.82, 0.95)
Total-Home	13.55 (4.88)	14.03 (4.71)	13.10 (5.92)	0.95	0.11	(-3.68, 2.71)	0.91 (0.83, 0.96)
Density-Home	1.22 (0.36)	1.26 (0.37)	1.16 (0.50)	0.90	0.17	(-0.28, -0.37)	0.82 (0.67, 0.91)
Summary score [1]	48.42 (17.40)	51.26 (16.51)	48 (22.32)	0.93	0.02*	(-15.10, 9.42)	0.93 (0.86, 0.97)
MUSICAL EQUIPMENT							
Total-Home	2.68 (2.31)	2.58 (2.37)	2.77 (2.15)	0.97	0.37	(-1.07, 2.14)	0.92 (0.83, 0.96)
Density-Home	0.24 (0.22)	0.23 (0.22)	0.24 (0.20)	0.96	0.38	(-0.11, 0.13)	0.92 (0.84, 0.96)
Summary score [1]	9.42 (8.16)	9.48 (9.00)	9.74 (7.83)	0.95	0.90	(-5.63, 5.50)	0.96 (0.92, 0.98)
SEATED FURNITURE							
Bedroom	2.52 (3.97)	2.58 (3.14)	2.32 (2.83)	0.92	0.78	(-2.54, 2.41)	0.81 (0.64, 0.90)
Total-Indoor	15.39 (8.29)	16.19 (8.74)	15.35 (9.81)	0.97	0.03*	(-4.80, 3.19)	0.91 (0.83, 0.96)
Total Outdoor	3.65 (4.04)	3.90 (4.21)	2.48 (3.99)	0.95	0.28	(-2.84, 2.32)	0.73 (0.49, 0.86)
Total-Home	19.03 (9.06)	20.10 (9.40)	17.84 (9.93)	0.96	0.03*	(-6.30. 4.17)	0.86 (0.74, 0.93)
Density-Indoors	1.90 (0.73)	2.01 (0.76)	1.89 (0.88)	0.93	0.05*	(-0.46, 0.68)	0.78 (0.59, 0.89)
Density-Outdoors	1.23 (1.31)	1.20 (1.18)	0.66 (0.97)	0.81	0.81	(-1.57, 1.57)	0.52 (0.19, 0.74)
Density-Home	1.70 (0.66)	1.78 (0.66)	1.55 (0.67)	0.97	0.46	(-0.38, -0.38)	0.72 (0.47, 0.84)
Summary score [1]	73.83 (35.90)	78.19 (37.23)	68.58 (38.51)	0.94	0.06	(28.63, 19.92)	0.85 (0.71, 0.92)

* Significant difference ($p < 0.05$) between parent at Time 1 and Researcher. [1] Accessibility and availability equipment summary score.

Table 7. Validity and reliability for accessibility of home equipment – continuous variables.

Home equipment and features	Time 1 (*n*=31)	Observer (*n*=31)	Time 2 (*n*=31)	Validity Time 1 vs Researcher: Pearson's Correlation	Validity Time 1 vs Researcher: t-test of means	Reliability Time 1 vs Time 2: Intraclass Correlation Coefficient (1.1)
	Mean (SD)	Mean (SD)	Mean (SD)	r	P-value	ICC (95% CI)
PA EQUIPMENT						
Total-Home accessibility						
A-Put away and difficult to get to	3.26 (6.83)	2.74 (4.38)	2.65 (5.90)	0.51	0.64	0.87 (0.75, 0.94)
B-Put away and easy to get to	8.29 (8.23)	13.90 (10.62)	8.45 (9.73)	0.39	0.01*	0.48 (0.16, 0.71)
C-In plain view and difficult to get	1.65 (4.18)	0.65 (1.98)	1.94 (3.59)	0.43	0.16	0.05 (-0.32, 0.40)
D-In plain view and easy to get to	13.87 (10.94)	12.71 (10.15)	16.45 (14.19)	0.46	0.57	0.74 (0.53, 0.87)
Average accessibility rating (1-4)	3 (0.69)	3.14 (0.71)	2.75 (0.57)	0.55	0.04 *	0.59 (0.31, 0.78)
Total-Indoor accessibility						
A-Put away and difficult to get to	0 (0)	0 (0)	0.03 (0.18)	-	-	-
B-Put away and easy to get to	2.45 (3.50)	2.81 (3.14)	1.97 (3.28)	0.82	0.35	0.85 (0.71, 0.93)
C-In plain view and difficult to get	0.10 (0.30)	0 (0)	0.45 (2.30)	-	0.08	-0.00 (-0.36, 0.35)
D-In plain view and easy to get to	3.39 (3.69)	4.58 (4.79)	4.65 (4.75)	0.84	0.02*	0.75 (0.52, 0.88)
Average accessibility rating (1-4)	3.21 (0.75)	3.17 (0.70)	3.44 (0.61)	0.52	0.76	0.48 (0.15, 0.72)
Total-Outdoor accessibility						
A-Put away and difficult to get to	3.26 (6.83)	2.74 (4.38)	2.61 (5.91)	0.51	0.64	0.87 (0.75, 0.94)
B-Put away and easy to get to	5.84 (8.12)	11.10 (10.46)	6.48 (9.49)	0.39	0.01*	0.43 (0.09, 0.68)
C-In plain view and difficult to get	1.55 (4.20)	0.65 (1.98)	1.48 (2.99)	0.44	0.20	0.08 (-0.29, 0.42)
D-In plain view and easy to get to	10.48 (9.74	8.13 (8.06)	11.81 (11.84)	0.35	0.22	0.73 (0.51, 0.86)
Average accessibility rating (1-4)	3.03 (0.87)	2.59 (0.67)	2.99 (0.83)	0.61	<0.01*	0.53 (0.21, 0.75)
MUSICAL INSTRUMENTS						
Total -Home accessibility						
A-Put away and difficult to get to	0.03 (0.18)	0.06 (0.25)	0.03 (0.18)	0.70	0.56	1.00
B-Put away and easy to get to	0.48 (0.91)	0.32 (0.74)	0.55 (0.98)	0.54	0.45	0.36 (0.00, 0.63)
C-In plain view and difficult to get	0.03 (0.18)	0 (0)	0.03 (0.18)	-	0.33	-0.03 (-0.40, 0.33)
D-In plain view and easy to get to	2.10 (1.86)	2.19 (2.13)	2.13 (1.86)	0.88	0.85	0.92 (0.85, 0.96)
Average accessibility rating (1-4)	3.56 (0.63	3.67 (0.52)	3.56 (0.60)	0.29	0.64	0.15 (-0.29, 0.53)
MEDIA EQUIPMENT						
Total-Home accessibility						
A-Put away and difficult to get to	0.45 (1.29)	0.48 (1.32)	0.35 (1.15)	0.92	0.75	0.95 (0.90, 0.97)
B-Put away and easy to get to	1.94 (2.15)	1.74 (1.83)	1.55 (1.88)	0.57	0.58	0.61 (0.33, 0.79)
C-In plain view and difficult to get	0.29 (0.73)	0.06 (0.35)	0.10 (0.30)	0.43	0.07	0.32 (-0.02, 0.59)
D-In plain view and easy to get to	10.81 (4.34)	11.77 (3.96)	11.06 (5.59)	0.87	0.02*	0.83 (0.67, 0.91)
Average accessibility rating (1-4)	3.62 (0.35)	3.67 (0.30)	3.68 (0.36)	0.55	0.34	0.45 (0.13, 0.69)
SEATED FURNITURE						
Total-Home accessibility						
A-Put away and difficult to get to	0.26 (0.95)	0.19 (0.90)	0.26 (0.95)	0.89	0.79	0.97 (0.93, 0.98)
B-Put away and easy to get to	0.23 (0.79)	0.55 (1.62)	0.35 (1.40)	0.10	0.33	0.34 (-0.02, 0.62)
C-In plain view and difficult to get	0.29 (0.96)	0.26 (1.01)	0.26 (0.95)	0.59	0.90	0.88 (0.76, 0.94)
D-In plain view and easy to get to	18.06 (8.56)	19.03 (9.01	16.71 (9.12)	0.92	0.67	0.83 (0.68, 0.92)
Average accessibility rating (1-4)	3.93 (0.14)	3.91 (0.21)	3.89 (0.22)	0.16	0.64	0.42 (0.07, 0.67)
Total-Indoor accessibility						
A-Put away and difficult to get to	0.03 (0.18)	0.03 (0.18)	0.03 (0.18)	-0.03	1.00	-0.03 (-0.40, 0.33)
B-Put away and easy to get to	0.16 (0.72)	0.06 (0.25)	0.13 (0.71)	0.67	0.49	0.97 (0.94, 0.99)
C-In plain view and difficult to get	0.23 (0.94	0.10 (0.53)	0.19 (0.90)	0.93	0.52	0.91 (0.82, 0.95)
D-In plain view and easy to get to	14.84 (7.88)	16.03 (8.54)	14.74 (9.14)	0.96	0.58	0.92 (0.83, 0.96)
Average accessibility rating (1-4)	3.97 (0.10)	3.98 (0.06)	3.98 (0.07)	0.35	0.34	0.48 (0.16, 0.71)
Total-Outdoor accessibility						

A-Put away and difficult to get to	0.23 (0.94)	0.16 (0.88)	0.23 (0.94)	0.93	0.79	1.00
B-Put away and easy to get to	0.06 (0.35)	0.48 (1.62)	0.23 (1.24)	0.17	0.16	-0.02 (-0.37, 0.34)
C-In plain view and difficult to get	0.06 (0.25)	0.16 (0.88)	0.06 (0.35)	0.70	0.57	0.66 (0.40, 0.82)
D-In plain view and easy to get to	3.23 (3.43)	3.00 (3.41)	1.97 (3.29)	0.80	0.80	0.54 (0.24, 0.75)
Average accessibility rating (1-4)	3.80 (0.63)	3.70 (0.61)	3.63 (0.92)	0.41	0.10	0.80 (0.49, 0.93)
PA: Media ratio score	1.72 (0.91)	1.75 (1.24)	1.94 (1.07)	0.70	0.88	0.79 (0.61, 0.90)

*Significant difference (p < 0.05) between parent at Time 1 and Researcher

Table 8. Validity and reliability for home equipment and features - categorical variables.

Home Equipment and Features	Potential Score	Validity and reliability sample (*n*=31) Time 1 vs Researcher Cohen's Kappa K	Time 1 vs Time 2 Cohen's Kappa K
HOME DESIGN			
Type of home	4 options	1.00	0.92
Number of storeys	3 options	0.69	0.82
Internal stairs	Y/N	constant	1.00
External stairs	Y/N	constant	constant
Front fence	Y/N/Partial	0.79	0.70
HOME SIZE ^			
Entry/Hall/Foyer	S/M/L	0.54	0.28
Open plan living room	S/M/L	0.80	0.69
Kitchen	S/M/L	0.38	0.41
Lounge room (separate)	S/M/L	0.58	0.76
Dining room (separate)	S/M/L	0.92	1.00
Games room	S/M/L	0.94	0.82
Study	S/M/L	0.87	0.67
Bedroom of primary child	S/M/L	0.24	0.64
Garage	S/M/L	0.73	0.64
Garden shed	S/M/L	0.63	0.60
Back garden	S/M/L	0.55	0.52
Front garden	S/M/L	0.81	0.56
Total house size	S/M/L	0.40	0.88
Total garden size	No/S/M/L	0.26	0.83
ADJACENT SPACE			
Next to public open space	Y/N	0.93	0.83
Next to laneway	Y/N	0.86	0.57
Next to vacant block	Y/N	1.00	1.00
Next to pedestrian cut-through	Y/N	0.82	0.51
HOME EQUIPMENT			
Number of books	6 options	N/A	0.60
Number of magazines	6 options	N/A	0.49
Number of DVDs	6 options	N/A	0.64
Number of TV channels	6 options	N/A	0.55
Number of electronic games	6 options	N/A	0.49
Number of active electronic games	6 options	N/A	0.54
Number of smartphones	6 options	N/A	0.89
Type of internet	3 options	N/A	1.00
PET OWNERSHIP			
Dog ownership	Y/N	N/A	0.61
Other pet ownership	Y/N	N/A	0.75

^Not all participant homes included every room/area.

6.5. Discussion

This study assessed the validity and reliability of the HomeSPACE-II instrument, designed to measure parameters of the home physical environment that may influence children's sedentary behaviour and PA at home. Whilst the instrument was primarily based on HomeSPACE-I [290], there are several differences. Specifically, it was tested for use in two-storey homes and modified to include equipment most relevant to home-based activity in the UK and to assess the accessibility, as well as the availability, of each item. The strong criterion validity and test-retest reliability demonstrated in this study for most of the equipment, size, feature and design items and the already established construct validity of the instrument [383], suggest it can be independently used by parents to detect important characteristics of the home physical environment that may impact children's PA and sedentary time.

Most of the continuous variables for availability showed good to excellent reliability; however, reliability results for accessibility were mixed. For items rated as 'put away and difficult to get to' and 'in plain view and easy to get to', ICCs were mostly to good excellent. However, ICCs for the number of items rated as 'put away and easy to get to' and 'in plain view and difficult to get to' were mostly poor to fair. This may be because, the terms 'put away and difficult to get to' and 'in plain view and easy to get to' are less ambiguous and more congruent than 'put away and easy to get to' and 'in plain view and difficult to get to'. Moreover, ICCs for the average accessibility ratings were mostly fair. Between the parent completing the instrument at time one and time two, items may have moved location and therefore the parent's perception of accessibility may have changed which may partly explain the lower reliability estimates. Despite this, the overall summary scores (number of items * accessibility rating) for all four item categories were strong.

Reliability for the categorical variables was generally high, except for home equipment and size. Indeed, hall size was the only variable to fall below acceptable reliability limits, possibly because the parent did not record it at the second time-point as they may not have perceived it as a living area. Moreover, the moderate reliability limits achieved for several of the home equipment variables assessed by questions rather than the walkthrough audit may reflect the difficulty in estimating a number of smaller items from memory, particularly when a large number of that item exists within the home.

Validity was strong for most of the continuous variables, outside of accessibility. Further, validity coefficients for PA equipment, media equipment, seated furniture and musical instrument measures were higher than in the HomeSPACE-I tool [290]. However, the sample size was slightly smaller in this study, which may, at least in part, explain the more favourable validity coefficients [388]. In contrast, validity for the 10 outdoor features across the three areas (front garden, back garden and verge) was better in HomeSPACE-I. It could be postulated that the sample was more familiar with their outdoor space due to the better climate they experience [389], which may partly explain this discrepancy.

While validity coefficients, in general, were strong, several differences between the researcher and the parent were observed. The researcher achieved a higher media accessibility and availability summary score which might reflect the greater number of items recorded as 'in plain view and easy to get to' by the researcher. In addition, the researcher recorded a higher number of seated furniture indoors and in total than the parent, which concurs with Maitland et al. [290]. This could be due to the researcher taking a more thorough walk-through approach recording all types of seated furniture, whereas the parent may have not acknowledged some pieces or identified table and chairs together as one piece of furniture. Further, the researcher recorded more PA equipment items indoors and in total, which would account for the higher total and indoor PA equipment density. This difference is likely driven by the greater number of balls recorded by the researcher in total, indoors and outdoors (result not shown). Perhaps, because the researcher recorded all types of balls irrespective of their condition, while the parents may have missed those either in poor condition or smaller balls as they were less visible. To minimize such error, efforts were made to define what constitutes seated furniture and balls; parents were also instructed to record everything regardless of condition. Nonetheless, these items may need further clarification in future versions of the instrument.

Validity of home size measures was assessed by comparing the parent's estimates against the researcher's. While a number of studies have sought to validate self-reported garden size against a researcher with little success [248,390,391], Maitland et al. [290] are the only other group to validate self-reported size for indoor rooms, non-garden outdoor areas, overall house size and garden size. In general, validity estimates for the home size measures were higher than those reported by Maitland et al. [290], with most showing moderate agreement. The reason for this difference is not clear; however, the average house in Australia is one of the largest in the world [392], which may have influenced parental perceptions in the Maitland et al. [290] study. Although overall house and garden size achieved only fair agreement, compared to the moderate agreement achieved in the Maitland et al. [290] study for the equivalent measures. Whilst the reason for this is unknown, housing type may have influenced perceptions of house and garden size. Specifically, all the houses in this study had two storeys and were mostly semi-detached or terraced (61.3%), converse to the Australian sample where most were single-storey (83%) and detached (90%). Therefore, these discrepancies in parent-researcher agreement are most likely related to the difference in the nature of homes (e.g. layout, type and size). As overall house and garden size may influence children's PA levels and sedentary time [41,383], an objective measurement of size may be necessary. Conversely, if UK homes continue to reduce in size [393], the design and layout of homes may be of greater importance.

Achieving agreement between the researcher and parent for a largely subjective construct, such as accessibility, was challenging. In general, acceptable validity was observed; although results for PA equipment were particularly low, with the researcher observing fewer PA equipment in total as harder to access and more PA equipment outdoors as harder to access. Similar discrepancies were observed in previous inventories that assessed the accessibility of PA equipment within the home [247,248], although the HomeSPACE-II achieved a higher validity estimate for the average accessibility rating of PA equipment than the HomeSTEAD instrument [248]. These results suggest that parents may have different perceptions of accessibility, particularly for PA equipment. However, while trained researchers may provide a more objective assessment of accessibility, it might be just as, or more, important to consider a parent's perception of accessibility. For example, if an item seems hard to access to the researcher, but is frequently made available to the child by the parent, then the parent's perception of accessibility may better indicate how that item influences activity. In support of this, the HomeSTEAD study [248] found a stronger relationship between child BMI and parent-reported accessibility compared with researcher reported accessibility. The child's perception of accessibility may also be important, as they are likely to have a greater awareness of their barriers to using a particular item. For example, a parent may view a tablet computer hidden in a drawer as hard to access, however if the child knows it is there, it poses less of a barrier for use. Taken together, it may be more important for future studies to consider parent's and child's perceptions, when investigating the relationship between equipment accessibility and children's behaviour.

The strengths of this study include its rigorous reliability and validity testing procedure and the extensive nature of the HomeSPACE-II instrument, which covers a wide range of parameters within the home, providing a comprehensive assessment of the physical home space. There were equal representations of boys and girls within the sample, which is important given studies have found a greater density of PA equipment within boys' houses [240] and boys are mor likely to have electronic media in their bedroom [394]. Although measurement tools have been tested in Australia [290] and the USA [247,248,382], this is the first to be tested in a European country. This is important due to several environmental differences; climate differences [389], the average house size is significantly larger in the USA and Australia than in any European country [392], and Europe is less ethnically and racially diverse than the USA[395].

This study also has several limitations. First, the sample was homogenous, as most parents were female, university educated, and houses were mostly semi-detached or terraced with two parents. Although the predominantly female and university-educated sample is similar to that of previous studies [247,248,290]. We sought to validate home size measures against a researcher with mixed success; however, due to the subjective nature of these items, future research should seek to validate them against objective measures (e.g. GIS [Geographic Information System software]). There was low between-subject variation for accessibility ratings in several item categories, which can result in low ICCs [396] and Pearson correlation coefficients [388], which may explain why some accessibility variables had low validity coefficients and ICCs, in spite of their means and standard deviations indicating minimal differences between scores. The sample was comprised of families living in Wales' two largest cites. Whilst Wales is less affluent than the national average [397], its physical geography, home environmental characteristics and cultural traits are comparable with the rest of the UK. Further, data were collected in the spring and winter and therefore seasonality may have influenced accessibility data, particularly for outdoor PA equipment, whereby equipment may be stored away in the winter but made accessible in the spring. Lastly, the large number of statistical tests conducted in this study may have increased the risk of type I error. Given that some of the results may have therefore occurred by chance, the authors considered employing a more stringent alpha value; however, such corrections may have increased the probability of type II error. As the present results are similar to those reported in other studies [247,248,290], an alpha value of 0.05 was retained.

Several modifications should be considered for future iterations of the HomeSPACE instrument. Given that types of seated furniture, balls, electronic games and active games varied greatly, the instrument would benefit from further clarification around what defines these. Secondly, although the importance of considering a parent's perception of accessibility has been discussed, the accessibility ratings may need further investigation. Specifically, although the accessibility ratings were designed to take into account condition [247], this may not have been clear enough to the parents. In addition, the child's perception of accessibility was not considered, which may be equally as important. However, capturing children's perceptions of accessibility for each individual item would be a challenge, when the instrument is completed by the parent. To improve how the accessibility ratings are defined, future research should seek to utilise qualitative methodologies to ascertain the way both parents and children perceive and interpret accessibility. Further work on how to capture both parents and children's perspectives with the instrument is also needed. Thirdly, the number of TV channels question should be replaced with a question concerning the type of TV service as even Freeview offers over 70 channels. Moreover, a question on movie streaming services (e.g. Netflix, Now TV, Amazon Prime, etc.) should be included, due to their growing popularity, essential for a comprehensive assessment of media sources available in the home. Portable types of electronic media (laptops, tablet computers and handheld devices) do not have a fixed location and can therefore be used almost anywhere, meaning they may not always be captured with the instrument. Therefore, future work on how to account for the portable nature of these devices may be needed. Finally, fitness trackers (e.g. Fitbits, apple watches, Garmin) should be explored, as they have the potential to facilitate children's PA in interventions through goal-setting and self-monitoring [398]. The presence of these in a home may reflect a family promotive of being physically active. Due to constant changes in media technology, updating these types of instruments with relevant media equipment will be ongoing.

6.6. Conclusion

The HomeSPACE-II instrument builds upon its Australian counterpart [290] by being tested in two-storey homes and because it includes a wider range of PA equipment, and a measure of accessibility, rather than just availability. The generally strong test re-test reliability and criterion validity demonstrated here and the construct validity established previously [383], suggests HomeSPACE-II, is a useful tool for assessing the home physical environment in relation to children’s PA and sedentary behaviour. Using the instrument will provide researchers with greater insight into the correlates of important health-related behaviours in an environment where children spend a significant amount of time [38,39]. Such insight may also impact future home planning and design to create physical home environments more conducive to healthy behaviours. Additionally, the HomeSPACE-II instrument may also help parents become more aware of how their home environment is influencing their child’s PA and sedentary time, thereby indirectly promoting healthy active living in families. The instrument may be appropriate for use in countries which share similar geographical and home environment characteristics with the UK.

Thesis map

Study	Aims	Key findings
1. Relationship between Sedentary Time, Physical Activity and Multiple Lifestyle Factors in Children	To explore associations between multiple lifestyle factors and being sufficiently active ($\geq$60 min·day^{-1}) or engaging in excessive screen-time ($\geq$2 h·day^{-1}) in children.	Sufficient MVPA and excessive screen-time were associated with healthy and unhealthy factors, respectively, with relationships sometimes differing by sex. Specifically, fruit and vegetable consumption and CRF were positively associated with sufficient MVPA, irrespective of sex. Excessive screen-time was positively associated with sugary snack consumption in boys and girls, and diet soft drink intake in boys ($p < 0.05$). In addition, excessive screen-time was negatively associated with MVPA before school for both boys and girls, as well as with sleep duration and fruit and vegetable consumption for girls ($p < 0.05$).
2. Validity and reliability of the HomeSPACE-II instrument to assess the influence of the home physical environment on children's physical activity and sedentary behaviour	To test the criterion validity and reliability of the HomeSPACE-II instrument.	The study revealed that most items, outside of accessibility and size measures, had strong reliability and validity. Therefore, the HomeSPACE-II is a valid and reliable instrument for measuring physical factors that influence children's physical activity and sedentary behaviour within the home.
3. Associations between the Home Physical Environment and Children's Home-Based Physical Activity and Sitting	To investigate the relationship between characteristics of the physical home environment and children's home-based sitting, PA, standing and sitting breaks.	
4. Are parental and child activity preferences and priorities, as well parental rules at home associated with children's home-based behaviour and the home physical environment		
5. Clustering of home physical and social environmental factors		

7. Study 3

7.1. Associations between the Home Physical Environment and Children’s Home-Based Physical Activity and Sitting

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Sheldrick, M.P.; Maitland, C.; Mackintosh, K.A.; Rosenberg, M.; Griffiths, L.J.; Fry, R.; Stratton, G. Associations between the Home Physical Environment and Children’s Home-Based Physical Activity and Sitting. *Int. J. Environ. Res. Public Health* **2019**, *16*, 4178.

7.2. Introduction

The importance of physical activity (PA) for children’s physiological and psychological health has been well documented [6], yet few meet current moderate-to-vigorous physical activity (MVPA) recommendations [62]. Children also spend most of their discretionary time in sedentary behaviours (7–8 h daily) [45], defined as ‘any waking activity, in a sitting, lying or reclining posture with an energy-expenditure below 1.5 metabolic equivalents (METs)’ [72]. Screen-time is the most prevalent sedentary behaviour, and has been associated with poor health outcomes [5] [92]. However, the relationship between overall sedentary time and health in children is less clear [5]. Nonetheless, there is strong evidence for an adverse association between excessive levels and mortality in adults [96]. Recently, breaks from prolonged sitting have been beneficially associated with markers of body composition and metabolic health in adults [109]. Given the harmful consequences in adults and that children’s sedentary time appears to track into adulthood [31], high levels in children are a public health concern. Therefore, it is important to develop interventions to increase children’s PA and reduce their sedentary time.

Investigating the correlates of PA and sedentary time is essential for informing effective evidence-based interventions [35]. The social ecological model is often used to guide the understanding of children’s PA and sedentary time, recognising the important influence of the environment [37]. This model suggests that behavioural correlates are domain-specific, whereby behaviours are most likely influenced by the environment in which they occur [36,37]. Outside of school hours, children have been shown to spend significant time at home [38,39]. Indeed, there is also evidence indicating that a large proportion of children's sedentary time and PA occurs at home [40,52,226]. Specifically, Tandon et al. [40] found that 48 and 42 % of children's overall sedentary time and MVPA, respectively, was accumulated at home. The home environment, therefore, may be influential in affecting children's PA and sedentary behaviours.

There is a plethora of research demonstrating the importance of the home social environment on children's PA and sedentary time [41,235]. However, much less is known about physical environmental factors at home. Media equipment in the home and bedroom has consistently been positively associated with screen-time, but not overall sedentary time [41,235]. Additionally, there is some evidence that PA equipment is positively associated with PA [40,240] and inversely related to sedentary time [40,41]. Furthermore, whilst PA at home is most likely to occur outdoors [251], whether greater garden space facilitates PA remains unclear, with equivocal findings [256,381]. Even though there is an emerging evidence base, findings have been inconsistent, and research has been limited by the use of self-report instruments to measure the home and through assessing PA and sedentary time across the entire day [41]. Given behaviours are most likely influenced by the setting in which they occur [37], investigating sedentary time and PA at home will enable more precise identification of correlates. The use of objective measures such as audits and geographic information system (GIS) software to assess the home will also improve measurement accuracy. Additionally, greater media equipment accessibility has been shown to be associated with increased screen-time [240]; however, most studies have only assessed equipment availability.

When at home, children spend most of their time indoors [38,39]. This is of concern, because this is where children are most likely to be sedentary [251]. The indoor space may also be relevant for PA, with an ecological momentary assessment study showing that 30% of children's aged 9–13 years leisure time PA occurred at home indoors [226]. Yet, few studies have explored influences on sedentary time and PA within the home indoor physical environment, outside of equipment [41]. A qualitative study identified several previously unexplored indoor physical environmental factors as potential influences on children's sedentary time and PA at home, including multiple indoor living areas designated for screen-time, the presence of an open plan living area, the availability and layout of indoor space, as well as furniture within the home [43]. Additionally, new electronic media technologies such as online TV/movie streaming services may also be relevant, with just over 11 million people in the UK now being subscribed to one, as TV viewing habits shift online [117]. Moreover, playing musical instruments is an activity that commonly occurs at home [399], which can be done while sitting or standing [400]. Furthermore, houses with more than one floor may have a favourable effect on PA via increased stair climbing [401,402]. Exploration of the role of the factors cited by Maitland et al. [43], as well as musical instruments, movie/TV streaming services and the number of floors in influencing children's sedentary time and PA is needed.

The aim of this study was to investigate the relationship between characteristics of the physical home environment and children's home-based sitting, PA, standing and sitting breaks.

7.3. Materials and Methods

7.3.1. Study Design

The HomeSPACE study is a cross-sectional observational study investigating the relationship between the home environment on children's PA levels and sedentary time. Between November 2017 and July 2018, 235 children aged 9–12 years and their parents (n = 228) (response rate 26%) were recruited through primary schools from four of the largest conurbations in South Wales, Swansea (n = 174), Bridgend (n = 37), Cardiff (n = 16) and Newport (n = 8). A target sample size of 235 was set based on a reliable formula [403], while accounting for the possibility of missing data.

7.3.2. Recruitment

Primary schools (n = 23) were invited to participate. Eleven schools (response rate 48%) consented and 890 children aged 9–11 years were provided with information about the study. To be eligible, children had to be aged 9–12 years and without a physical disability. A chance to win a family pass for an outdoor adventure centre and the child's sitting and PA results were offered as incentives. Informed consent and child assent were provided. The Swansea University ethics committee granted ethical approval for the study.

7.3.3. Home Physical Environment

HomeSPACE-II, an updated version of the HomeSPACE-I [290] and the Physical Activity and Media Inventory [247], was administered to the parents. The audit assessed physical home environmental factors hypothesised to influence children's home-based PA and sedentary behaviours [43]. Parents were asked to walk around their house and garden and complete the items for each room/area. Briefly, the audit allowed the presence, amount and accessibility of 41 media (e.g., TV, computer, etc.), musical (e.g., drums, piano, etc.), PA (e.g., balls, trampoline, etc.) and seated furniture (e.g., sofa, desk etc.) items to be recorded for up to 22 room/areas (14 indoor and eight outdoor). Accessibility of each item was rated on a scale of A–D [247]. The response options were; A: put away and difficult to get to; B: put away and easy to get to; C: in plain view and difficult to get to; D: in plain view and easy to get to. There were questions relating to home features (house size, garden size, type of house, number of floors) and electronic media (smartphones, TV service, movie/TV streaming service). In addition, there were questions referring to the space to play inside the house, and in the back and front garden [290]. The audit data were reduced to several independent variables. Three dichotomous variables were generated to reflect the presence of: (1) an open plan living area; (2) a TV in the primary child's bedroom; (3) a detached house. Yes and no responses were coded as 1 or 0, respectively. The number of living areas in the home with a TV was also calculated. In addition, summary scores that accounted for the accessibility and availability of PA equipment, seated furniture, overall media equipment, media equipment in the child's bedroom and musical instruments were created by multiplying each item by its accessibility rating (A = 1, B = 2, C = 3, D = 4). A higher score indicates a greater overall "presence" of that type of item in the home. For descriptive purposes, we also calculated the total number of each type of item and the number of rooms/areas. Active video game systems (e.g., Wii Fit, Xbox Kinect, PlayStation move) were coded as PA equipment. Instruments were checked for missing data and for clarity, and followed up with families when needed.

7.3.4. Home Log Diary

Parents were given a diary to record when the child was at home each day for seven days, to allow for the calculation of home-based behaviours. Instructions were provided, where "Home" was defined as a single location, including the house, garden, driveway and verge of the home where the child spends most of their time (i.e., excluding homes of other parents). To minimise missing data, children completed the diary when parents were unable to and incomplete diaries were followed up with families.

7.3.5. Objectively Measured Home-Based Physical Activity and Postural Behaviours

Children wore the ActiGraph GT9X (ActiGraph, Pensacola, FL, USA) and the activPAL3 micro (PAL Technologies, Glasgow, UK), which measured total physical activity (TPA) and MVPA as well as postural behaviours (i.e., sitting, standing and sitting breaks), respectively, for seven consecutive days. A sitting break was defined as a transition from sitting to standing/stepping [72]. Both were fitted at school, to ensure correct attachment and to provide instructions on how to reattach them. Participants were asked only to remove the monitors for swimming. Parents were also required to record sleep and wake times, device removals and any illness days.

The activPAL has demonstrated excellent validity in children [112], and was placed in a waterproof nitrile sleeve and secured on the midline of the upper right thigh using a hypoallergenic dressing (3M Tegerderm or Hypafix Transparent). Supplementary dressings, sleeves and instructions on correct reattachment were provided. ActivPAL data were downloaded using the manufacturer software (V8.10.8.32, PAL technologies, Glasgow, UK), which generated Event.csv files for each device. These files were processed in ProcessingPAL-V1.1 (Leicester, UK) using a validated algorithm to identify waking hours, extended non-wear periods (≥5 h) and invalid data [404]. Following processing, files were visually checked for plausibility of sleep/non-wear classification using heatmaps. If sleep and wake times looked unfeasible, the diaries were referred to for verification and when times differed by ≥2 h, the diary times were utilised [405]. A predominately objective processing method was used for determining sleep duration, as parent reported sleep and wake time have been shown to have questionable reliability [349,350]. Additionally, removals noted in the diary were inspected against heatmaps and the events window in the PAL analysis software (V8.10.8.32, PAL technologies, Glasgow, UK), and removed using the software if deemed plausible. Bouts were considered as “non-wear/sleep”, if ≥50% of it was within the period reported in the diary [197]. To minimise known errors with self-reported diary data, based on inspections of the data and previously used methods [406], we considered sitting/lying or standing bouts lasting ≥3 h without transitions as non-wear time.

Children wore the ActiGraph GT9X on their non-dominant wrist [303], to improve compliance [304]. Wrist-worn accelerometers have demonstrated good validity in comparison to hip-worn accelerometers [305]. The data was collected at a 30 Hz sampling rate [306] and summed over 5-sec epochs. ActiGraph (ActiLife V6.13.3) software was used to initialise, download and process files. Chandler wrist-based cut-points [155], applied to the vector-magnitude, were used to categorise MVPA (≥818 counts/5-secs) and TPA (≥162 counts/5-secs). Non-wear time, defined as ≥90 consecutive minutes of zero counts [407], was removed using the software.

Periods when children were at home were uploaded into both the ActiGraph and Processing PAL software and matched with time-stamped data, allowing home-based PA and postural behaviours to be generated, respectively. Days were considered valid, when the device was worn for ≥75% of the time at home [408]. In accordance with previous research [409], children with completed home diaries, and at least one valid day with ≥3 h of wear time at home were included in the analyses. Reported illness days were also excluded from the analyses. ActivPAL and ActiGraph data in minutes, were divided by wear time at home and multiplied by 60 to create the dependent variables conveyed as averages/h [410]. The activity data was expressed as average minutes/h to allow for better comparison across studies.

7.3.6. Children Personal Information and Anthropometric Measures

Anthropometric measurements were taken at the children's respective schools. Stature and body mass were measured to the nearest 0.001 m and 0.1 kg, using a portable stadiometer (Seca 213, Hamburg, Germany) and electronic weighing scales (Seca 876, Hamburg, Germany), respectively, using standard anthropometric techniques [339]. Body mass index (BMI), and subsequently BMI z-scores, were derived using the WHO (World Health Organization) growth reference standard [294].

7.3.7. Objectively Measured House and Garden Size

Objective house and garden size for each postcode were measured using GIS techniques, AddressBase Premium (ABP) [300] and Ordnance Survey MasterMap (OSMM) [301].

For residences (min 4–max 82), we extracted building footprints from OSMM and filtered out non-residential buildings, defined by ABP. The process was repeated to determine garden size for residences (min 2–max 82), defined in OSMM Greenspace dataset [302]. To estimate house size, a median of the extracted building footprints was calculated and multiplied by the number of floors in each house. A median garden size was also calculated for each home in the postcode.

7.3.8. Additional Measures

Parents reported their age, gender, whether they own or rent their home, educational status (Some secondary school/Completed secondary school/Trade qualifications or apprenticeship/Diploma or certificate/University degree or higher), the pre-tax annual household income, postcode and the number of children at home. Season of measurement covered four categories: Winter (December–February), Spring (March–May), Summer (June–August) and Autumn (September–November). Due to missing data on income and educational status, Welsh Index of Multiple Deprivation (WIMD) scores, derived from postcodes, were used as an indicator of socioeconomic status (SES). The WIMD scores, consider eight domains of deprivation; employment; health; income; housing; community safety; access to services; education; the environment [338]. Small areas in Wales are ranked 1–1909, where 1 is the most deprived and 1909 is the least deprived. For descriptive purposes, tertiles of SES were generated based on WIMD scores; low (1–636), medium (636–1272) and high (1272–1909). Daylength for the participants' respective cities during each monitoring day was obtained from a valid and reliable online resource [411]. Family preferences and priorities for activity within the home [290], as well as parental media rules [259] were collected via validated questions.

Social and individual factors have been known to influence children's sedentary and activity behaviours at home [43]; therefore, they could play an important role in associations with such behaviours and the home environment. To identify the confounding factors, the coefficients were computed from the statistical models prior to and following adjusting for each variable. Variables with the greatest impact on the coefficients on average were controlled for in the models [412]. These were parent-reported child and parent activity preferences at home, parent perceptions of the importance of active play at home for their child, and whether parents enforce a maximum h/day of screen-time rule.

7.3.9. Statistical Analysis

Consent and assent as well as activPAL, ActiGraph, physical and social environment data were received for 235 (100%), 207 (88%), 214 (91%), 213 (91%) and 207 (88%) children, respectively. Statistical analyses were conducted using SPSS (IBM SPSS Statistics Inc., Chicago, IL, USA; Version 25), where significance was set at ≤ 0.05. Whilst the normality assumption was violated, research suggests that it is not necessary when the sample size is large (>200) [342,343], therefore parametric tests were deemed appropriate. Influential outliers were replaced with the largest or second smallest value in observations [413] for overall media equipment (n = 1) and bedroom media equipment (n = 1) summary scores. The unadjusted associations between each of the physical environment variables and the five home-based outcomes (min/h spent sitting, standing, in TPA and MVPA and the number of sitting breaks/h) were examined using linear regression (Model 1). Model 2 adjusted for home ownership, raw WIMD scores, season of measurement, daylength and the number of siblings at home, as well as the BMI, age and sex of the child. Model 3 further adjusted for social environmental factors associated with children's PA and sedentary time. A final model (Model 4) was run for each of the five outcomes, including all the significant variables ($p \leq 0.10$) [414] from model 3 and adjustment variables to determine independent associations between physical environment factors and the child home-based outcomes. Paired t-tests revealed that the outcomes differed between weekday and weekend days. However, separate analyses had little effect on findings; thus, weekday and weekend days were combined.

7.4. Results

Descriptive statistics are provided in Table 1. The participating children had a mean age of 10.2 ± 0.7, and 55% were girls. Children spent 40.3 ± 5.9 min sitting (67%), 12.3 ± 4.2 min standing, 21.6 ± 4.7 min in TPA, 6.7 ± 2.3 min in MVPA, and had 7.0 ± 1.9 sitting breaks per hour at home. Most parents who completed the audit and questions were female (83%), owned their home (86%), held a university degree (54%) and lived in the highest SES location (59%). Homes (i.e., the overall plot, including house and outdoor space) were perceived to have medium houses (60%) which were not detached (64%) and large gardens (46%), they mostly had two floors (77%), and had on average four occupants, including two children. Most parents enforced a maximum h/day of screen-time rule (69%) and on average thought it was ‘important’ for their child to engage in active play at home, their child and themselves enjoyed sedentary and PA activities at home ‘about equal’ and ‘strongly agreed’ that their child had enough space to play inside the house and in the back garden. Homes had 11.5 ± 2.1 rooms/areas, 57% had an open plan living area and 52% of the children had a TV in their bedroom. Homes averaged 27.7 ± 18.3 PA equipment items, 19.6 ± 8.0 seated furniture items, 2.0 ± 2.1 musical instruments, 11.6 ± 4.7 media equipment items overall and 1.9 ± 1.7 in the primary child’s bedroom. Lastly, homes tended to have digital TV (82%), access to a movie/TV streaming service (77%) and 3–4 smartphones.

Table 9. Participant characteristics and descriptive statistics.

Variable	Mean (SD) or %	*n*
Parental Characteristics		
Parent age	41.5 (5.7)	211
Parent gender (% Female)	83%	213
Parent activity preferences at home [2]	3.4 (0.7)	211
Parent perceived importance of engaging in active play at home for child [3]	4.0 (0.8)	207
Maximum h/day of screen-time rule (% yes)	69%	206
Parental education **		207
Secondary school or lower	12%	
Diploma/Trade	34%	
University degree or higher	54%	
Child Characteristics		
Child age	10.2 (0.7)	233
Child sex (% Girl)	55%	235
Child BMI-z-score	0.6 (1.1)	233
Child activity preferences at home [2]	3.3 (0.8)	207
Family Characteristics		
Number of siblings	1.2 (0.9)	213
Number of people at home	4.1 (1.1)	213
Home ownership		213
Rent	14%	
Own	86%	
SES (based on WIMD scores) **		220
Low	14%	
Medium	27%	
High	59%	
Home Characteristics and Features		
Perceived house size		213
Small	8%	
Medium	60%	
Large	32%	
Objectively measured house size (m^2)	145.0 (52.1)	207
Perceived garden size		213
No garden	1%	
Small	15%	
Medium	38%	
Large	46%	
Objectively measured garden size (m^2)	269.0 (166.7)	214
Type of house		213
Detached	36%	
Not detached (semi-detached, terrace, bungalow, flat)	64%	
Number of floors		213
1	4%	
2	77%	
>2	19%	
Space to play		211
Inside the house [1]	3.6 (0.7)	
Back garden [1]	3.6 (0.7)	
Front garden [1]	2.6 (1.2)	
Audit Variables		
Total number of Rooms/Areas **	11.5 (2.1)	210
Presence of a TV in the child's bedroom (% yes)	52%	212
Number of living areas with a TV at home	1.5 (0.6)	210
Presence of an open plan living area (% yes)	57%	211
Equipment Variables:		
Number of PA equipment items**	27.7 (18.3)	210
PA equipment accessibility and availability score	86.7 (63.1)	209
Number of seated furniture items **	19.6 (8.0)	210
Seated furniture accessibility and availability score	76.5 (31.2)	209
Number of media equipment items **	11.6 (4.7)	210
Media equipment accessibility and availability score	44.2 (18.2)	209
Number of bedroom media equipment items **	1.9 (1.7)	212
Bedroom media equipment accessibility and availability score	6.9 (6.3)	210

Number of musical instrument items **	2.0 (2.1)	210
Musical instrument accessibility and availability score	7.2 (7.5)	209
Electronic Media Equipment		
TV service		213
Digital (e.g., SKY, BT etc.)	82%	
Freeview or other	18%	
Movie/TV streaming (e.g., Netflix, Amazon TV etc.) [% yes]	77%	213
Number of smartphones (mode)	3–4	213
Outcome Variables		
Home-based activPAL outcomes		207
Full days of activPAL wear at home	5.3 (1.1)	
h/full day of activPAL wear at home	5.8 (1.6)	
Min/h spent sitting, % of time at home*	40.3 (5.9), 67%	
Min/h spent standing, % of time at home*	12.3 (4.2), 21%	
Min/h spent stepping, % of time at home**	7.5 (2.8), 12%	
Number of sitting breaks/h	7.0 (1.9)	
Home-based ActiGraph outcomes		214
Full days of ActiGraph wear at home	5.5 (0.9)	
h/full day of ActiGraph wear at home	5.8 (1.6)	
Min/h spent in MVPA, % of time at home	6.7 (2.3), 11%	
Min/h spent in TPA, % of time at home	21.6 (4.7), 36%	

[1] 1 = strongly disagree; 5 = strongly agree; [2] 1 = almost always—sedentary; 5 = almost always—PA; [3] 1 = unimportant; 5 = very important; * % = proportion of time at home; ** Displayed for descriptive purposes only.

7.4.1. Associations between Physical Home Factors and Home-Based Sitting

When all the confounding factors were controlled for, home-based sitting was negatively associated with a detached house (−2 min/h, $p = 0.03$), an open plan living area (−2 min/h, $p = 0.01$), perceived house size (−2 min/h, $p = 0.01$) and musical instruments, and positively associated with the presence of a TV in the child's bedroom (+2 min/h, $p = 0.03$), bedroom media and overall media equipment (Table 2, Model 3). Children spent one additional min/h sitting at home for every 13 media equipment points (I.e., accessibility and availability summary score) ($p < 0.01$) and seven bedroom media equipment points ($p = 0.03$), and one min/h less for every six musical instrument points ($p < 0.01$). In the final model, negative associations with house size (−2 min/h, $p = 0.02$), an open plan living area (−3 min/h, $p < 0.01$), musical instruments and the positive association with media equipment remained (Table 2, Model 4). Children spent one additional min/h sitting at home for every 13 media equipment points ($p < 0.01$) and one min/h less for every seven musical instrument points ($p = 0.01$). The final model accounted for 33% ($R^2 = 0.33$) of the variance in home-based sitting.

7.4.2. Associations between Physical Home Factors and Home-Based Standing

After adjusting for all confounding factors, a detached house (+2 min/h, $p < 0.01$), perceived house size (+1 min/h, $p = 0.02$), an open plan living area (+2 min/h, $p = 0.01$) and musical instruments were positively associated, whereas media equipment was negatively associated with home-based standing (Table 3, Model 3). Children spent one additional min/h standing at home for every eight musical instrument points ($p < 0.01$) and one min/h less for every 17 media equipment points ($p < 0.01$). In the final model, a detached house (+2 min, $p = 0.02$), an open plan living area (+2 min, $p = 0.01$) and musical instruments remained positively associated, while media equipment remained negatively associated with home-based standing (Table 3, Model 4). Children spent one additional min/h standing at home for every 10 musical instrument points ($p = 0.01$) and one min/h less for every 17 media equipment points ($p < 0.01$). The final model contributed 30% ($R^2 = 0.30$) of the variance in home-based standing.

7.4.3. Associations between Physical Home Factors and the Number of Home-Based Sitting Breaks

Following adjustment for all confounding factors, the number of home-based sitting breaks was negatively associated with digital TV (−1 transition/h, $p < 0.01$) and positively associated with objective garden size ($p < 0.01$) (Table 4, Model 3). The number of home-based sitting breaks was still negatively associated with digital TV (−1 transition/h, $p = 0.01$) and positively associated with objective garden size ($p = 0.03$) in the final model (Table 4, Model 4). The final model contributed 30% ($R^2 = 0.30$) of the variance in the number of home-based sitting breaks.

7.4.4. Associations Between Physical Home Factors and Home-Based TPA

When controlling for all the confounding factors, home-based TPA was negatively associated with media equipment and positively associated with an open plan living area (+1 min/h, $p = 0.05$) (Table 5, Model 3). Every 20 media equipment points ($p = 0.01$) was associated with one min/h less in home-based TPA. The number of floors in the house (+1 min/h, $p = 0.04$) and an open plan living area (+1 min/h, $p = 0.04$) were positively associated with home-based TPA in the final model (Table 5, Model 4). The final model explained 28% ($R^2 = 0.28$) of the variance in home-based TPA.

7.4.5. Associations Between Physical Home Factors and Home-Based MVPA

Following controlling for all the confounding factors, home-based MVPA was negatively associated with media equipment, the number of smartphones at home and positively associated with an open plan living area (+1 min/h, $p = 0.04$) (Table 6, Model 3). Every 50 media equipment points ($p = 0.03$) and 1–2 increase in the number of smartphones at home ($p = 0.01$) were associated with one min/h less in home-based MVPA. In the final model, only the positive association between home-based MVPA and an open plan living area (+1 min/h, $p = 0.05$) remained (Table 6, Model 4). The final model accounted for 30% ($R^2 = 0.30$) of the variance in home-based MVPA.

Table 10. Associations between physical home factors and children's home-based sitting.

Variable	Model 1			Model 2			Model 3			Model 4		
	B (SE)	β	*p*	B (SE)	β	*p*	B (SE)	β	*P*	B (SE)	β	*p*
Perceived house size	−1.56 (0.71)	−0.16	0.03 *	−2.24 (0.75)	−0.23	0.01 *	−1.98 (0.77)	−0.20	0.01 *	−1.77 (0.77)	−0.18	0.02 *
Objective house size	−0.01 (0.01)	−0.05	0.52	−0.01 (0.01)	0.07	0.36	−0.01 (0.01)	−0.10	0.24	–	–	–
Detached house	−1.27 (0.89)	−0.10	0.15	−2.31 (0.92)	−0.19	0.01	−2.12 (0.94)	−0.17	0.03 *	−1.29 (0.93)	−0.10	0.17
Number of floors	−0.28 (0.95)	−0.02	0.77	−0.36 (0.96)	−0.03	0.71	−0.53 (0.97)	−0.04	0.59	–	–	–
Open plan living area	−2.39 (0.84)	−0.20	0.01 *	−2.58 (0.85)	−0.22	0.01 *	−2.43 (0.86)	−0.20	0.01 *	−2.62 (0.81)	−0.22	<0.01 *
TV in child's bedroom	1.99 (0.84)	0.17	0.02 *	1.76 (0.88)	0.15	0.05 *	1.92 (0.89)	0.16	0.03 *	0.66 (1.15)	0.06	0.57
Number of living areas with TV	0.67 (0.68)	0.07	0.32	0.38 (0.69)	0.04	0.59	0.75 (0.70)	0.08	0.29	–	–	–
PA equipment [1]	0.00 (0.01)	0.00	0.97	−0.01 (0.01)	−0.03	0.66	−0.00 (0.01)	−0.02	0.83	–	–	–
Seated furniture [1]	0.00 (0.01)	0.01	0.94	−0.01 (0.02)	−0.03	0.74	−0.01 (0.02)	−0.03	0.70	–	–	–
Media equipment [1]	0.08 (0.02)	0.26	<0.01 *	0.08 (0.02)	0.24	<0.01 *	0.08 (0.02)	0.25	<0.01 *	0.08 (0.03)	0.23	<0.01 *
Bedroom media equipment [1]	0.18 (0.07)	0.19	0.01 *	0.14 (0.07)	0.15	0.05 *	0.15 (0.07)	0.16	0.03 *	0.01 (0.01)	0.01	0.90
Musical instruments [1]	−0.11 (0.06)	−0.15	0.04 *	−0.14 (0.06)	−0.18	0.01 *	−0.18 (0.06)	−0.23	<0.01 *	−0.15 (0.06)	−0.19	0.01 *
Digital TV	0.94 (1.08)	0.06	0.39	0.82 (1.05)	0.06	0.44	1.06 (1.08)	0.07	0.33	–	–	–
Movie/TV streaming	1.26 (1.00)	0.09	0.21	1.14 (1.00)	0.08	0.26	0.90 (1.03)	0.06	0.38	–	–	–
Number of smartphones	0.62 (0.65)	0.07	0.34	0.89 (0.68)	0.10	0.19	1.14 (0.73)	0.12	0.12	–	–	–
Space to play inside	−0.87 (0.62)	−0.10	0.16	−0.59 (0.61)	−0.07	0.33	−0.57 (0.62)	−0.07	0.36	–	–	–
Perceived garden size	−0.32 (0.57)	−0.04	0.57	−0.17 (0.56)	−0.02	0.77	0.07 (0.57)	0.01	0.90	–	–	–
Objective garden size	−0.00 (0.00)	−0.10	0.17	−0.01 (0.00)	−0.14	0.08	−0.00 (0.00)	−0.12	0.13	–	–	–
Space to play in front garden	−0.12 (0.35)	−0.02	0.74	−0.01 (0.35)	−0.00	0.99	0.06 (0.35)	0.01	0.88	–	–	–
Space to play in back garden	−0.75 (0.58)	−0.09	0.20	−0.51 (0.57)	−0.07	0.38	−0.49 (0.59)	−0.06	0.41	–	–	–
										R^2 (adjusted R^2) 0.33 (0.25)		

* $p \leq 0.05$ in model 1, 2 and 4; * $p \leq 0.10$ in model 3. 1 Accessibility and availability equipment score. Model 1: Unadjusted models for each physical factor. Model 2: Model for each physical factor adjusting for child BMI, age and sex, and the number of siblings, home ownership, season, WIMD and daylength. Model 3: Model for each physical factor adjusting for child BMI, age and sex, and the number of siblings, home ownership, season, WIMD, daylength, child preferences for sedentary or PA activities, parent preferences for sedentary or PA activities, parent perception of the importance of their child engaging in active play and a maximum h/day of screen-time rule. Model 4: Final model including all significant physical factors from models 3, adjusting for child BMI, age and sex, and the number of siblings, home ownership, season, WIMD, daylength, child preferences for sedentary or PA activities, parent preferences for sedentary or PA activities, parent perception of the importance of their child engaging in active play and a maximum h/day of screen-time rule.

Table 11. Associations between physical home factors and children's home-based standing.

Variable	Model 1			Model 2			Model 3			Model 4		
	B (SE)	β	*p*	B (SE)	β	*p*	B (SE)	β	*p*	B (SE)	β	*p*
Perceived house Size	1.01 (0.51)	0.14	0.05 *	1.40 (0.53)	0.20	0.01 *	1.28 (0.55)	0.18	0.02 *	0.96 (0.54)	0.13	0.08
Objective house size	0.00 (0.01)	0.03	0.67	0.00 (0.01)	0.04	0.66	0.00 (0.01)	0.05	0.54	–	–	–
Detached house	1.36 (0.62)	0.16	0.03 *	1.97 (0.64)	0.22	<0.01 *	2.09 (0.66)	0.24	<0.01 *	1.61 (0.66)	0.18	0.02 *
Number of floors	−0.40 (0.67)	−0.04	0.55	−0.17 (0.68)	−0.02	0.81	−0.16 (0.69)	−0.02	0.82	–	–	–
Open plan living area	1.37 (0.60)	0.16	0.02 *	1.58 (0.61)	0.19	0.01 *	1.54 (0.62)	0.18	0.01 *	1.58 (0.58)	0.19	0.01 *
TV in child's bedroom	−1.19 (0.59)	−0.14	0.05 *	−1.03 (0.62)	−0.12	0.10	−1.01 (0.64)	−0.12	0.12	–	–	–
Number of living areas with TV	−0.55 (0.48)	−0.08	0.25	−0.45 (0.49)	−0.07	0.36	−0.59 (0.50)	−0.09	0.24	–	–	–
PA equipment [1]	−0.00 (0.01)	−0.01	0.88	0.00 (0.01)	0.03	0.69	−0.00 (0.01)	−0.03	0.68	–	–	–
Seated furniture [1]	−0.00 (0.01)	−0.01	0.85	0.01 (0.01)	0.03	0.66	0.01 (0.01)	0.04	0.63	–	–	–
Media equipment [1]	−0.06 (0.02)	−0.27	<0.01 *	−0.06 (0.02)	−0.24	<0.01 *	−0.06 (0.02)	−0.24	<0.01 *	−0.06 (0.02)	−0.24	<0.01 *
Bedroom media equipment [1]	−0.11 (0.05)	−0.17	0.02 *	−0.07 (0.05)	−0.11	0.13	−0.07 (0.05)	−0.11	0.16	–	–	–
Musical instruments [1]	0.09 (0.04)	0.17	0.02 *	0.10 (0.04)	0.19	0.01 *	0.12 (0.04)	0.22	<0.01 *	0.10 (0.04)	0.18	0.01 *
Digital TV	−0.97 (0.76)	−0.09	0.20	−0.78 (0.74)	−0.07	0.29	−0.88 (0.77)	−0.08	0.25	–	–	–
Movie/TV streaming	−1.18 (0.70)	−0.12	0.10	−1.20 (0.71)	−0.12	0.09	−1.04 (0.73)	−0.10	0.16	–	–	–
Number of smartphones	−0.64 (0.46)	−0.10	0.16	−0.67 (0.48)	−0.11	0.16	−0.61 (0.53)	−0.09	0.25	–	–	–
Space to play inside	0.37 (0.45)	0.06	0.41	0.07 (0.43)	0.01	0.87	0.08 (0.44)	0.01	0.87	–	–	–
Perceived garden size	−0.21 (0.40)	−0.04	0.60	−0.33 (0.40)	−0.06	0.41	−0.39 (0.41)	−0.07	0.34	–	–	–
Objective garden size	0.00 (0.00)	0.05	0.48	0.00 (0.00)	−0.06	0.41	0.00 (0.00)	0.07	0.40	–	–	–
Space to play in front garden	0.09 (0.25)	0.02	0.74	−0.04 (0.25)	−0.01	0.89	−0.06 (0.25)	−0.02	0.83	–	–	–
Space to play in back garden	0.31 (0.42)	0.05	0.46	0.10 (0.41)	0.02	0.80	0.11 (0.42)	0.02	0.80	–	–	–
										R^2 (adjusted R^2) 0.30 (0.23)		

* $p \leq 0.05$ in model 1, 2 and 4; * $p \leq 0.10$ in model 3. 1 Accessibility and availability equipment score. Model 1: Unadjusted models for each physical factor. Model 2: Model for each physical factor adjusting for child BMI, age and sex, and the number of siblings, home ownership, season, WIMD and daylength. Model 3: Model for each physical factor adjusting for child BMI, age and sex, and the number of siblings, home ownership, season, WIMD, daylength, child preferences for sedentary or PA activities, parent preferences for sedentary or PA activities, parent perception of the importance of their child engaging in active play and a maximum h/day of screen-time rule. Model 4: Final model including all significant physical factors from models 3, adjusting for child BMI, age and sex, and the number of siblings, home ownership, season, WIMD, daylength, child preferences for sedentary or PA activities, parent preferences for sedentary or PA activities, parent perception of the importance of their child engaging in active play and a maximum h/day of screen-time rule.

Table 12. Associations between physical home factors and children's home-based sitting breaks.

Variable	Model 1			Model 2			Model 3			Model 4		
	B (SE)	β	*p*	B (SE)	β	*p*	B (SE)	β	*p*	B (SE)	β	*p*
Perceived house Size	0.37 (0.23)	0.12	0.10	0.41 (0.23)	0.13	0.08	0.39 (0.23)	0.12	0.10 *	0.05 (0.25)	0.01	0.86
Objective house size	0.00 (0.00)	0.11	0.13	0.00 (0.00)	0.11	0.15	0.00 (0.00)	0.11	0.15	–	–	–
Detached house	0.13 (0.28)	0.03	0.64	0.11 (0.28)	0.03	0.70	0.11 (0.29	0.03	0.72	–	–	–
Number of floors	0.21 (0.30)	0.05	0.49	0.34 (0.29)	0.08	0.23	0.36 (0.29)	0.09	0.23	–	–	–
Open plan living area	0.08 (0.27)	0.20	0.78	0.03 (0.26)	0.01	0.91	−0.10 (0.27)	−0.03	0.71	–	–	–
TV in child's bedroom	−0.73 (0.27)	−0.20	0.01 *	−0.43 (0.26)	−0.12	0.11	−0.37 (0.27)	−0.10	0.18	–	–	–
Number of living areas with TV	−0.25 (0.22)	−0.09	0.24	−0.20 (0.21)	−0.07	0.35	−0.20 (0.21)	−0.07	0.36	–	–	–
PA equipment [1]	0.00 (0.00)	−0.01	0.86	0.00 (0.00)	0.00	1.0	−0.01 (0.00)	−0.02	0.81	–	–	–
Seated furniture [1]	0.00 (0.01)	0.05	0.46	0.01 (0.01)	0.13	0.07	0.01 (0.00)	0.14	0.06 *	0.00 (0.01)	0.05	0.49
Media equipment [1]	−0.02 (0.01)	−0.20	0.04 *	−0.01 (0.01)	−0.08	0.25	−0.01 (0.01)	−0.05	0.46	–	–	–
Bedroom media equipment [1]	−0.04 (0.02)	−0.15	0.04 *	−0.02 (0.02)	−0.06	0.39	−0.01 (0.02)	−0.05	0.51	–	–	–
Musical instruments [1]	0.02 (0.02)	0.09	0.22	0.02 (0.02)	0.07	0.33	0.01 (0.02)	0.05	0.49	–	–	–
Digital TV	−1.08 (0.33)	−0.23	<0.01 *	−1.11 (0.31)	−0.24	<0.01 *	−0.99 (0.32)	−0.21	<0.01 *	−0.86 (0.32)	−0.18	0.01 *
Movie/TV streaming	−0.33 (0.32)	−0.08	0.30	−0.10 (0.30)	−0.02	0.75	0.02 (0.31)	0.00	0.96	–	–	–
Number of smartphones	−0.33 (0.21)	−0.12	0.11	−0.29 (0.21)	−0.10	0.15	−0.24 (0.22)	−0.08	0.29	–	–	–
Space to play inside	0.49 (0.19)	0.18	0.01 *	0.36 (0.18)	0.14	0.05 *	0.35 (0.19)	0.13	0.06 *	0.35 (0.20)	0.13	0.08
Perceived garden size	0.16 (0.18)	0.06	0.39	0.19 (0.17)	0.08	0.26	0.16 (0.17)	0.07	0.35	–	–	–
Objective garden size	0.00 (0.00)	0.22	<0.01 *	0.00 (0.00)	0.23	<0.01 *	0.00 (0.00)	0.22	<0.01 *	0.00 (0.00)	0.16	0.03 *
Space to play in front garden	0.12 (0.11)	0.08	0.29	0.06 (0.11)	0.04	0.56	0.03 (0.11)	0.02	0.77	–	–	–
Space to play in back garden	0.30 (0.18)	0.12	0.10	0.29 (0.17)	0.12	0.09	0.26 (0.18)	0.11	0.14	–	–	–
										R2 (adjusted R2) 0.30 (0.22)		

* p ≤ 0.05 in model 1, 2 and 4; * p ≤ 0.10 in model 3. 1 Accessibility and availability equipment score. Model 1: Unadjusted models for each physical factor. Model 2: Model for each physical factor adjusting for child BMI, age and sex, and the number of siblings, home ownership, season, WIMD and daylength. Model 3: Model for each physical factor adjusting for child BMI, age and sex, and the number of siblings, home ownership, season, WIMD, daylength, child preferences for sedentary or PA activities, parent preferences for sedentary or PA activities, parent perception of the importance of their child engaging in active play and a maximum h/day of screen-time rule. Model 4: Final model including all significant physical factors from models 3, adjusting for child BMI, age and sex, and the number of siblings, home ownership, season, WIMD, daylength, child preferences for sedentary or PA activities, parent preferences for sedentary or PA activities, parent perception of the importance of their child engaging in active play and a maximum h/day of screen-time rule.

Table 13. Associations between physical home factors and children's home-based TPA.

Variable	Model 1			Model 2			Model 3			Model 4		
	B (SE)	β	*P*	B (SE)	β	*P*	B (SE)	β	*P*	B (SE)	β	*P*
Perceived house size	0.33 (0.57)	0.04	0.56	0.48 (0.58)	0.06	0.41	0.30 (0.59)	0.04	0.62	–	–	–
Objective house size	0.00 (0.01)	0.01	0.90	0.00 (0.01)	0.03	0.68	0.00 (0.01)	0.04	0.58	–	–	–
Detached house	−0.91 (0.70)	−0.09	0.20	−0.82 (0.70)	−0.08	0.24	−0.91 (0.71)	−0.09	0.21	–	–	–
Number of floors	1.04 (0.76)	0.10	0.17	1.20 (0.73)	0.11	0.10	1.28 (0.74)	0.12	0.09 *	1.48 (0.73)	0.14	0.04 *
Open plan living area	1.63 (0.67)	0.17	0.02 *	1.57 (0.65)	0.16	0.02 *	1.34 (0.67)	0.14	0.05 *	1.34 (0.66)	0.14	0.04 *
TV in child's bedroom	−1.99 (0.66)	−0.22	<0.01 *	−1.10 (0.67)	−0.12	0.10	−1.04 (0.68)	−0.11	0.13	–	–	–
Number of living areas with TV	−0.83 (0.53)	−0.11	0.12	−0.80 (0.51)	−0.11	0.11	−0.93 (0.52)	−0.13	0.08 *	−0.79 (0.55)	−0.11	0.15
PA equipment [1]	−0.01 (0.01)	−0.07	0.36	0.00 (0.01)	−0.00	0.97	−0.00 (0.01)	−0.02	0.78	–	–	–
Seated furniture [1]	−0.01 (0.01)	0.03	0.63	−0.01 (0.01)	−0.03	0.64	−0.01 (0.01)	0.04	0.61	–	–	–
Media equipment [1]	−0.07 (0.02)	−0.26	<0.01 *	−0.05 (0.02)	−0.19	0.01 *	−0.05 (0.02)	−0.18	0.01 *	−0.04 (0.02)	−0.13	0.10
Bedroom media equipment [1]	−0.11 (0.05)	−0.14	0.05 *	−0.03 (0.05)	−0.05	0.53	−0.03 (0.05)	−0.04	0.56	–	–	–
Musical instruments [1]	0.05 (0.05)	0.08	0.25	0.04 (0.04)	0.07	0.34	0.05 (0.05)	0.07	0.31	–	–	–
Digital TV	−1.06 (0.85)	−0.09	0.22	−1.06 (0.80)	−0.09	0.19	−0.93 (0.83)	−0.08	0.27	–	–	–
Movie/TV streaming	−1.35 (0.80)	−0.12	0.09	−0.78 (0.77)	−0.07	0.31	−0.53 (0.79)	−0.05	0.50	–	–	–
Number of smartphones	−1.21 (0.51)	−0.17	0.02 *	−1.04 (0.52)	−0.14	0.05	−0.96 (0.57)	−0.12	0.09	−0.45 (0.61)	−0.06	0.46
Space to play inside	0.59 (0.49)	0.09	0.23	0.25 (0.47)	0.04	0.59	0.13 (0.48)	0.02	0.79	–	–	–
Perceived garden size	−0.09 (0.45)	−0.02	0.84	−0.04 (0.43)	−0.01	0.93	−0.18 (0.44)	−0.03	0.69	–	–	–
Objective garden size	0.00 (0.00)	0.09	0.19	0.00 (0.00)	0.14	0.06	0.00 (0.00)	0.12	0.12	–	–	–
Space to play in front garden	0.00 (0.28)	0.00	1.00	−0.06 (0.27)	−0.02	0.82	−0.13 (0.27)	−0.03	0.63	–	–	–
Space to play in back garden	0.55 (0.46)	0.09	0.24	0.44 (0.44)	0.07	0.31	0.31 (0.45)	0.05	0.49	–	–	–
										R^2 (adjusted R^2) 0.28 (0.21)		

* $p \leq 0.05$ in model 1, 2 and 4; * $p \leq 0.10$ in model 3. 1 Accessibility and availability equipment score. Model 1: Unadjusted models for each physical factor. Model 2: Model for each physical factor adjusting for child BMI, age and sex, and the number of siblings, home ownership, season, WIMD and daylength. Model 3: Model for each physical factor adjusting for child BMI, age and sex, and the number of siblings, home ownership, season, WIMD, daylength, child preferences for sedentary or PA activities, parent preferences for sedentary or PA activities, parent perception of the importance of their child engaging in active play and a maximum h/day of screen-time rule. Model 4: Final model including all significant physical factors from models 3, adjusting for child BMI, age and sex, and the number of siblings, home ownership, season, WIMD, daylength, child preferences for sedentary or PA activities, parent preferences for sedentary or PA activities, parent perception of the importance of their child engaging in active play and a maximum h/day of screen-time rule.

Table 14. Associations between physical home factors and children's home–based MVPA.

Variable	Model 1			Model 2			Model 3			Model 4		
	B (SE)	β	*p*	B (SE)	β	*p*	B (SE)	β	*p*	B (SE)	β	*p*
Perceived house size	0.24 (0.28)	0.06	0.39	0.31 (0.28)	0.08	0.26	0.18 (0.28)	0.05	0.53	–	–	–
Objective house size	0.00 (0.00)	0.02	0.76	0.00 (0.00)	0.05	0.51	0.00 (0.00)	0.06	0.44	–	–	–
Detached house	−0.56 (0.34)	−0.12	0.10	−0.42 (0.33)	−0.09	0.21	−0.54 (0.34)	−0.11	0.11	–	–	–
Number of floors	0.52 (0.36)	0.10	0.15	0.50 (0.35)	0.10	0.15	0.57 (0.35)	0.11	0.11	–	–	–
Open plan living area	0.88 (0.32)	0.19	0.01 *	0.73 (0.31)	0.16	0.02 *	0.66 (0.32)	0.14	0.04 *	0.63 (0.32)	0.14	0.05 *
TV in child's bedroom	−0.85 (0.32)	−0.19	0.01 *	−0.48 (0.32)	−0.11	0.13	−0.49 (0.32)	−0.11	0.13	–	–	–
Number of living areas with TV	−0.28 (0.25)	−0.08	0.27	−0.23 (0.24)	−0.06	0.36	−0.37 (0.25)	−0.11	0.13	–	–	–
PA equipment [1]	−0.00 (0.00)	−0.03	0.67	0.00 (0.00)	0.03	0.66	0.00 (0.00)	0.01	0.91	–	–	–
Seated furniture [1]	0.00 (0.01)	0.00	0.95	−0.00 (0.01)	−0.02	0.81	−0.00 (0.01)	−0.03	0.73	–	–	–
Media equipment [1]	−0.03 (0.01)	−0.21	<0.01 *	−0.02 (0.01)	−0.15	0.03 *	−0.02 (0.01)	−0.15	0.03 *	−0.01 (0.01)	−0.08	0.28
Bedroom media equipment [1]	−0.05 (0.03)	−0.14	0.06 *	−0.02 (0.03)	−0.06	0.36	−0.03 (0.03)	−0.07	0.31	–	–	–
Musical instruments [1]	0.02 (0.02)	0.08	0.29	0.02 (0.02)	0.06	0.39	0.03 (0.02)	0.09	0.23	–	–	–
Digital TV	−0.43 (0.41)	−0.08	0.29	−0.37 (0.39)	−0.06	0.34	−0.40 (0.40)	−0.07	0.31	–	–	–
Movie/TV streaming	−0.48 (0.39)	−0.09	0.21	−0.36 (0.37)	−0.07	0.32	−0.27 (0.38)	−0.05	0.47	–	–	–
Number of smartphones	−0.63 (0.25)	−0.18	0.01 *	−0.60 (0.25)	−0.17	0.02 *	−0.69 (0.27)	−0.18	0.01 *	−0.49 (0.30)	−0.13	0.11
Perceived garden size	0.25 (0.22)	0.08	0.25	0.26 (0.21)	0.09	0.20	0.17 (0.21)	0.06	0.42	–	–	–
Objective garden size	0.00 (0.00)	0.10	0.16	0.00 (0.00)	0.16	0.03 *	0.00 (0.00)	0.13	0.07 *	0.00 (0.00)	0.09	0.20
Space to play in front garden	−0.12 (0.13)	−0.06	0.38	−0.14 (0.13)	−0.08	0.27	−0.17 (0.13)	−0.09	0.18	–	–	–
Space to play in back garden	0.25 (0.22)	0.08	0.26	0.21 (0.21)	0.07	0.33	0.15 (0.22)	0.05	0.47	–	–	–
										R^2 (adjusted R^2) 0.30 (0.23)		

* $p \leq 0.05$ in model 1, 2 and 4; * $p \leq 0.10$ in model 3. 1 Accessibility and availability equipment score. Model 1: Unadjusted models for each physical factor. Model 2: Model for each physical factor adjusting for child BMI, age and sex, and the number of siblings, home ownership, season, WIMD and daylength. Model 3: Model for each physical factor adjusting for child BMI, age and sex, and the number of siblings, home ownership, season, WIMD, daylength, child preferences for sedentary or PA activities, parent preferences for sedentary or PA activities, parent perception of the importance of their child engaging in active play and a maximum h/day of screen-time rule. Model 4: Final model including all significant physical factors from models 3, adjusting for child BMI, age and sex, and the number of siblings, home ownership, season, WIMD, daylength, child preferences for sedentary or PA activities, parent preferences for sedentary or PA activities, parent perception of the importance of their child engaging in active play and a maximum h/day of screen-time rule

7.5. Discussion

This study demonstrates the importance of the physical environment to children's behaviours at home, with the examined factors accounting for 28%-33% of the total variance in children's sitting, PA, standing and sitting breaks at home. The amount of variance explained was highest for home-based sitting at 33%, suggesting it has the strongest relationship with the physical environment. Moreover, several previously unexplored physical factors within the home were identified as correlates of children's sitting, standing and PA at home. An open plan living area, the number of floors, musical instrument accessibility and availability as well as objective garden size were significantly influential, although, given these relationships have not been investigated before, it is difficult to make comparisons with past work. This is one of the first in the field to use a posture monitor and to examine home-based PA and sedentary time and found that children spent 46% of their time at home, which reinforces the importance of investigating the correlates of PA and sedentary time in this environment.

The layout of the family home as open plan living, compared with a more segmented living space was shown in this study to be independently associated with less sitting, more standing, more TPA and more MVPA irrespective of demographic factors, the social environment and other significant home factors. According to qualitative research [43,415], the lack of dividing walls in open plan living areas enable parents to better monitor electronic media usage and enforce rules. Indeed, electronic media rules have been shown to be associated with lower screen-time in children [41,235]. Furthermore, open-plan design may also provide more space to accommodate alternatives to screen-based pursuits [415].

This study is the first to include a measure of the number of floors in houses, observing a significant positive association with TPA. Additional floors in houses may result in higher TPA via increased stair usage. Indeed, the energy cost of stair climbing in children is between 5.3 and 8.8 METs [400], which is considered moderate-to-vigorous intensity. However, the relationship did not reach significance until the final model, implying the relationship is accounted for by other physical environmental factors associated with

TPA. This would suggest that the number of floors in houses is not uniquely associated with TPA.

Our findings showed that increased perceived, but not objective, house size, was associated with less sitting. This may suggest that perceived and objective house size may be related to sitting differently, yet it may also be because of the way objective house size was measured. It is possible that the objective house size measure may not be a true measure of size, as it was not the exact house size, but instead the median size of houses in the same postcode unit. One previous study [254], reported no association between self-reported house size and sedentary time among Spanish children aged 9–18 years. This discrepancy may be due to the present study measuring home-based sedentary time, and not sedentary time across the entire day. Indeed, it might be that only home-based, not overall, sedentary time is influenced by house size. A study that examined the influence of spatial organisation in homes on activity found adults in houses with higher integration between rooms (greater interconnectedness) spent more time sedentary, particularly watching TV [263]. The mechanism proposed for this was that a greater interconnectedness between rooms encourages social interaction, which in turn can lead to increased time spent in sedentary activities that are susceptible to social life in homes such as TV viewing. Larger houses may have less interconnectedness overall, as they have more rooms, and the average connectivity between rooms does not increase in larger houses [263]. Although speculative, a higher interconnectedness amongst rooms in smaller houses may increase sitting time by prompting participation in social sedentary activities such as TV viewing.

Increased accessibility and availability of musical instruments was associated with less sitting and more standing at home, which is interesting as many musical instruments can be played sitting or standing [400]. Playing musical instruments may displace sitting activities, such as screen-time, studying, socialising, and increase standing periods. Future research should seek to investigate this relationship further, particularly given the cognitive benefits of playing a musical instrument [416].

There was a strong association between greater accessibility and availability of media equipment and reduced standing and increased sitting at home, which was robust to adjustment for social and demographic factors. In one of the few other studies to have a combined measure of the accessibility and availability of media equipment, a positive relationship was found with screen-time in girls, but not with overall sedentary time in either sex [240]. Most studies [240,241], but not all [254], have shown no association between household media equipment and overall sedentary time. Moreover, bedroom media equipment was positively associated with sitting, but not after adjusting for the other significant factors, in contrast to previous studies that have predominantly shown no association [246,417,418]. The present study used a posture monitor, whereas others have used accelerometery [40,418], which is considered a less accurate measure of sitting [196]. Whilst the lack of a relationship between bedroom media equipment and MVPA is congruent with previous research [417,418], some studies found contradictory results [239,419]. Such contradictory findings may be attributable to, at least in part, methodological differences and large inter-individual variation. Nonetheless, our findings highlight the important role the home media equipment environment may have by encouraging sitting and consequently reducing standing through acting as a prompt to engage in screen-time.

Despite the plethora of studies investigating the influence of media equipment, it is worth noting that, to our knowledge, only one previous study has measured home-based behaviour, whereby no relationship was found with bedroom media equipment and either sedentary time or PA in primary school aged children [40]. As behaviours are likely shaped by characteristics of the setting in which they occur, it is important to measure sedentary time and PA at home, to improve the understanding of the factors that influence these behaviours in this environment. Supporting this approach, screen-based behaviours, that most often occur at home [52], have been consistently positively associated with media equipment in the home [241,254] and in the bedroom [246,418]. Therefore, further research measuring home-based sitting and PA objectively may provide some clarity on the role of media equipment in influencing children's PA and sitting.

Children with digital TV at home had fewer sitting breaks. Pay TV/digital TV has been associated with increased TV viewing in adolescents [420], and screen-time in pre-school children [421]. Therefore, a greater choice of TV channels may be compelling to children, keeping them entertained for longer periods, resulting in less frequent sitting breaks. In addition, objectively measured garden size was positively associated with sitting breaks. This would suggest that children with larger gardens have more opportunities for breaking up screen-based sedentary activities. Fittingly, objectively measured garden size was also positively associated with MVPA. However, the association was attenuated with the addition of the social factors to the model. This indicates that factors such as the importance parents place on their children engaging in active types of play and parental restrictions on screen-time explain why some children do more MVPA and have larger gardens.

Despite the inconsistencies in the literature, our findings demonstrate the potential efficacy of removing electronic media from bedrooms and limiting the electronic media presence in homes to reduce children's sitting time. Given the association between greater accessibility and availability of musical instruments and reduced sitting and increased standing, encouraging children to learn a musical instrument requires exploration as a strategy for reducing children's sitting. Considering the potential utility of an open plan living area in allowing parents to better monitor electronic media usage and accommodating alternatives to sedentary activities, moving electronic media to an area that permits parental supervision and reconfiguring furniture to create space hold promise as strategies for reducing children's sitting time and increasing their PA. Our findings also suggest that larger gardens may be important for PA, and particularly for increasing sitting breaks. This is important, given there is emerging evidence that more frequent sitting breaks are beneficially associated with metabolic indicators in children [422], particularly when interrupted with moderate walking [14]. Therefore, strategies which break up prolonged sitting such as encouraging children to take 5-min walking breaks during adverts when watching TV or after completing a level while playing video games should be incorporated into an intervention. The provision of standing or PA breaks is a strategy that has been incorporated into school-based interventions, which successfully increased PA and decreased sitting [423].

More insight into the behavioural type and broader contextual information may lead to a better understanding of the determinants of PA and sedentary time at home. Automated wearable cameras when used alongside accelerometery and inclinometers could provide important information on where the behaviour occurs, as well as the type of behaviour being performed [424]. However, given participants may be wearing the device in situations unsuitable for photography, research involving this technology remains problematic [425]. Radiofrequency identification and open beacon proximity tags hold potential to assess the location of behaviours at home (e.g., bedroom, lounge or kitchen); however, such technology is currently expensive and difficult to implement in homes due to their weak Wi-Fi coverage [206], compared with environments where it has been trialled previously, such as offices [209] and cares homes [208]. Technologies that provide objective contextual information for sedentary time and PA at home will mostly likely be available for use in the imminent future.

This study has numerous strengths, such as the use of the comprehensive audit to measure the physical environment, the assessment of sitting and standing using a posture sensor, the home-based measures of behaviours and the exploration of several previously unstudied physical variables. Furthermore, a wide range of important confounding factors were controlled for and the high response rate increased the representativeness of the findings. We also included both perceived and objective measures of the environment, based on recommendations of several reviews [426], as they are related to behaviours differently [427]. Nonetheless, it is important to acknowledge the limitations. Some degree of misclassification of when the children were at home is likely, as we relied on self-reporting to determine this. However, there are currently no feasible objective alternatives for measuring children's location-specific behaviours. Whilst the sample size was relatively small, it was large enough to provide reasonable statistical power [403]. Although this is one of the first studies to measure house and garden size objectively and investigate how they relate to children's PA and sitting, since full home addresses were not available, we could only obtain measures for each postcode, and not for the specific homes. Thus, the measures may not reflect the true environments, as not all homes with the same postcode are identical. Additionally, total garden and house size may not correspond to usable space where children can be active and play. Whilst we tried to account for this by measuring actual space to play inside and outside via self-reporting, space syntax software could be used in combination with floor plans to measure indoor space [428] and also the degree of integration amongst rooms [263]. Furthermore, although beyond the scope of the current study, future work should also seek to explore these relationships during the school holidays, when children are less active and more sedentary [429]. Due to the cross-sectional nature of the study, causal relationships could not be inferred. Relationships may be complex, and it is likely that social factors work in combination with the physical environment to influence behaviours. Nonetheless, these findings are novel and add valuable knowledge to the evidence base.

7.6. Conclusion

In conclusion, the results suggest that some aspects of physical home environment may have an important relationship with children's sitting, standing and PA at home, even after adjusting for socio-demographic and social environmental factors. Therefore, it is imperative that future interventions target this environment, especially given children in this study spent a large proportion of their time at home sitting (67%) and the lack of previous home-based interventions [41]. Based on the results, strategies such as reconfiguring furniture to increase space, introducing electronic media breaks, promoting time spent in the garden, and housing electronic media in areas which allow parental supervision could be effective. Given the known influence of the social environment [43], and the impact of the physical environment on sitting and PA, interventions that consider both factors hold most promise. Lastly, although several physical factors are not easily modified, the findings could help impact future home and planning design to reduce sitting and increase PA and to help promote healthy active living in families.

Thesis map

Study	Aims	Key findings
1. Relationship between Sedentary Time, Physical Activity and Multiple Lifestyle Factors in Children	To explore associations between multiple lifestyle factors and being sufficiently active (≥60 min·day^{-1}) or engaging in excessive screen-time (≥2 h·day^{-1}) in children.	Sufficient MVPA and excessive screen-time were associated with healthy and unhealthy factors, respectively, with relationships sometimes differing by sex. Specifically, fruit and vegetable consumption and CRF were positively associated with sufficient MVPA, irrespective of sex. Excessive screen-time was positively associated with sugary snack consumption in boys and girls, and diet soft drink intake in boys ($p < 0.05$). In addition, excessive screen-time was negatively associated with MVPA before school for both boys and girls, as well as with sleep duration and fruit and vegetable consumption for girls ($p < 0.05$).
2. Validity and reliability of the HomeSPACE-II instrument to assess the influence of the home physical environment on children's physical activity and sedentary behaviour	To test the criterion validity and reliability of the HomeSPACE-II instrument.	The study revealed that most items, outside of accessibility and size measures, had strong reliability and validity. Therefore, the HomeSPACE-II is a valid and reliable instrument for measuring physical factors that influence children's physical activity and sedentary behaviour within the home.
3. Associations between the Home Physical Environment and Children's Home-Based Physical Activity and Sitting	To investigate the relationship between characteristics of the physical home environment and children's home-based sitting, PA, standing and sitting breaks.	An open plan living area (OPLA), musical instrument accessibility and availability, and perceived house size were negatively and positively associated, whereas media equipment accessibility and availability was positively and negatively associated with sitting and standing, respectively. Additionally, an OPLA was positively associated with total and moderate-to-vigorous PA. Furthermore, sitting breaks were positively associated with objective garden

		size and negatively associated with digital TV. The physical home environment has an important influence on children's sitting, standing and PA at home.
4. Are parental priorities, preferences and rules regarding activity at home associated with children's home-based behaviour and the home physical environment	To investigate the influence of parental priorities, preferences and rules regarding activity at home on: (i) children's home-based overall sitting time, breaks in sitting, and PA, and; (ii) the home physical environment.	
5. Clustering of home physical and social environmental factors		

8. Study 4

8.1. Are parental and child preferences and priorities, as well as parental rules regarding activity at home associated with children's home-based behaviour and the home physical environment?

8.2. Introduction

The health benefits of physical activity (PA) during childhood have been well established [6]. Moderate-to-vigorous physical activity (MVPA) is considered most important for health, however participation rates are low, especially in Wales, where only a third of children are sufficiently active [119]. Recently, light physical activity (LPA) has also been shown to provide health benefits [6], prompting the Canadian 24-hour movement guidelines to recommend children accumulate at least several hours of LPA daily [61]. Furthermore, sedentary time [96], particularly for extended periods [73], is adversely associated with morbidity and mortality in adults and is of particular concern given that sedentary time tracks from childhood into adulthood [31]. Indeed, recent international guidelines recommend children limit their overall sitting time and break up long periods as often as possible [61,94,95]. However, children spend a significant amount of time being sedentary (7-8 hrs daily) [45], particularly undertaking screen-time behaviours [117].

Determining the correlates of PA and sedentary behaviour is central to the development of effective interventions [35]. Children's sedentary behaviour [235,236] and PA[237,430] is strongly influenced by individual, physical and social environmental factors, particularly within the home setting where children spend most of their time [39]. Parents play an influential role in shaping their children's PA and sedentary time [41]. Indeed, parental PA, support and co-participation are positively associated with their children's PA levels [430,431]. In addition, there is a positive relationship between parent and child sedentary behaviour, and a negative relationship between screen-time rules and sedentary behaviour [41,235]. Individual characteristics, such as a child's preference for being sedentary or physically active, has also been shown to be a consistent predictor of children’s PA [258,432] and screen use [399]. Although studies have investigated the influence of individual and social factors on children’s sedentary behaviour and PA [41], few have examined factors specific to the home, and their influence on home-based behaviours. Investigating individual and social factors specific to the home, such as the leisure activity preferences and priorities of parents and children in this physical space [43] is important, given ecological models posit that behaviour is most likely influenced by the environment in which it occurs[36,228], and the amount of time children spend at home [39,40].

The physical environment has been shown to influence children’s PA and sedentary behaviour within the home [41,42]. Specifically, whilst household and bedroom media equipment are consistent positive correlates of screen-time [41,235], PA equipment is associated with being more active [40,240] and less sedentary [40,41]. Furthermore, the availability of musical instruments is also inversely related to sedentary time [383]. The use of overall size, space and living design of the home is largely shaped by family members, particularly parents [43], which in turn influences children’s PA and sedentary behaviour. For example, parental concerns for television (TV) viewing have been associated with fewer TVs and less media equipment at home [433]. Moreover, parents who enforce rules limiting TV viewing are less likely to report the presence of a TV in their child’s bedroom [280].

Whilst many aspects of the home physical environment are chosen by parents, research on what social and individual factors influence their decisions remains limited [43]. Although qualitative data suggest leisure activity preferences and priorities of parents and children, as well as parental rules, influence children’s PA and sedentary behaviour at home directly and indirectly via the physical environment [43], this theory is yet to be supported quantitatively. Such research is imperative for interventions seeking to create activity-promoting home environments and will provide insight into pathways by which parents could positively influence their children’s PA levels and reduce their sedentary time at home.

Therefore, the aim of this study was to investigate the relationship between parental and child priorities and preferences, as well as parental rules regarding leisure activity at home on: (i) children's home-based sitting time, breaks in sitting, and PA: (ii) the home physical environment.

8.3. Materials and methods

8.3.1. Sample

Twenty-three primary schools in South Wales were invited to take part between November 2017 and July 2018, of which 11 consented to participate. Children in years 5 and 6 (*n*=890) and their parents received information about the study. Entry into a prize draw to win a family pass for an outdoor activity centre and the child's sitting and PA results were offered as incentives. In total, 235 children (26% response rate) returned consent and assent forms. Procedures complied with the declaration of Helsinki and ethical approval was obtained from the Swansea University ethics committee.

8.3.2. Physical environment of the home

The home physical environment in relation to children's PA levels and sedentary time was assessed using the HomeSPACE-II instrument [299]. Parents were instructed to walk around their house and garden and audit items in each room/area. The audit, which accounts for the presence, quantity and accessibility of 34 media (e.g., TV, computer), PA (e.g., balls, trampoline) and musical (e.g., drums, piano) for up to 22 room/areas, has been described elsewhere [299]. For each item, accessibility was rated on a scale of (A) 'put away and difficult to get to' to (D) 'in plain view and easy to get to'. Additionally, there were questions referring to TV service (Freeview/Digital TV/Other) and space to play in the back garden and inside the house [290]. Open plan living areas were also noted. Summary scores (reflecting availability and accessibility) for PA equipment, musical instruments, as well as overall, fixed, portable and bedroom media equipment were created by multiplying each item by their accessibility score (A=1; B=2; C=3; D=4). A larger summary score indicates a greater overall "presence" in the home. Physical activity equipment included active video game systems (e.g., PlayStation move, Wii fit, X-box Kinect). The total number of each type of item and the number of rooms/areas were also determined for descriptive purposes only. Missing entries and queries were clarified with families when necessary.

8.3.3. Home-based PA, sitting and sitting breaks

Physical activity (LPA and MVPA) and postural behaviours (i.e., sitting and sitting breaks) were assessed with the ActiGraph GT9X (Pensacola, Florida, USA) and the activPAL3 micro (PAL Technologies, Glasgow, UK), respectively. A sit-to-stand/step transition was considered a sitting break [434]. The monitors were fitted at school to ensure correct attachment and that children knew how to reattach them. Children were asked to wear the monitors continuously (including when bathing, but excluding swimming) for seven consecutive days. Parents completed a diary recording when the child was at home [383], asleep, awake, periods when the device was removed and illness days. "Home" meant one single location, including the house and garden, where the child spent most time (i.e., not including other parent's homes). To minimise missing data, children completed the diaries when parents were unable to. Families were contacted for further information, if the diary was incomplete.

The activPAL has previously been validated in children [112]. A nitrile sleeve was fitted with a hypoallergenic dressing (3M Tegerderm or Hypafix Transparent) on the midline of the upper right thigh to ensure the device was waterproof. Participants received supplementary sleeves, dressings, and instructions for correct attachment. A detailed explanation of how the data was processed can be found elsewhere [435]. Briefly, activPAL data was downloaded using the manufacturer software (V8.10.8.32, PAL technologies, Glasgow, UK) and the subsequent event.csv files were processed in PAL-V1.1 (Leicester, UK) with a validated algorithm that identified waking hours, prolonged non-wear time ($\geq$ 5 h) and invalid data [404]. Diary-reported non-wear periods deemed plausible were removed. Additionally, based on inspections of the data and methods used elsewhere, sitting/lying or standing bouts lasting $\geq$ 3 hours with no transitions were also classified as non-wear and removed in the software [406].

The ActiGraph GT9X was placed on the child's non-dominant wrist [303], which has been shown to improve compliance [304] and have good validity when compared with hip-placement [305]. The device data was collected at a 30 Hz sampling rate [306] and summed over 5-sec epochs. Files were initialised, downloaded and processed using ActiGraph software (ActiLife V6.13.3). Wrist-worn vector-magnitude cut-points [155] were utilised, whereby LPA and MVPA were categorised as 306-817 and $\geq$ 818 counts/5 secs, respectively. An algorithm was used to identify non-wear time ($\geq$ 90 consecutive minutes of zero counts) [436].

Time at home, imported into the ActiLife V6.13.3 and processing PAL software, was paired with time-stamped data, allowing time spent in PA and postural behaviours at home to be calculated, respectively. To be included in the weekday and weekend day analyses, participants needed satisfactory completed home logs, and at least one day with ≥ 3 hours of data at home [437] when the device was worn for ≥ 75% of the time [408] (children without a valid weekend day were only included in the weekday analysis). Sickness days were also excluded from analyses. Minutes in PA and postural behaviours were divided by wear time at home and multiplied by 60, constituting the dependent variables as averages/hr [410].

8.3.4. Children demographic and anthropometric measures

At their respective schools, children's stature and body mass were measured using a portable stadiometer (Seca 213, Hamburg, Germany) and electronic weighing scales (Seca 876, Hamburg, Germany), respectively, and standardised procedures [339]. Body mass index (BMI), and subsequently BMI z-scores, were calculated using WHO growth reference data [294].

8.3.5. House and garden size estimates

For each postcode unit containing homes included in the study, both the house and garden size were assessed using geographic information systems (GIS) techniques, Ordnance Survey MasterMap (OSMM) [301,302] and AddressBase Premium (ABP) [300] [301]. The specific process utilised has been described previously [383]. Due to significant variation in estimates between homes with the same postcode, median values were used.

8.3.6. Additional Measures

Parents reported their age, sex, whether they owned or rented their home, education status (some secondary school/ completed secondary school/trade qualifications or apprenticeship/diploma or certificate/ university degree or higher), family situation (single parent/two parent/other), annual household income before tax, home postcode and how many children lived at home. Season of measurement included four categories: Spring (March-May), Summer (June-August), Autumn (September-November) and Winter (December-February). Due to missing data for education status and income, the

Welsh Index of Multiple Deprivation (WIMD), linked via a postcode lookup table, was used as an indicator of socioeconomic status (SES). Lower Layer Super Output Areas (LSOA) in Wales are ranked 1-1,909, where a higher ranking represents higher deprivation relative to other LSOAs in Wales. The WIMD scores were collapsed into three tertiles of SES; Low (1-636), medium (636-1,272) and high (1,272-1,909) for descriptive purposes only. The number of daylight hours for the participant's respective geographic locations during each monitoring day was also obtained from a valid and reliable online source [411].

8.3.7. Family social and individual factors

Items from the HomeSPACE-I were used to assess parental and child activity priorities and preferences (Maitland et al., 2018). Firstly, parents were asked how important it was to them for their child to do the following when at home: (1) participate in active play; (2) play electronic games/computer; (3) watch TV/movies; and (4) spend time outside. Responses were coded on a scale of (1) 'very unimportant' to (5) 'very important'. Parents were also asked which activities their child preferred at home when given the choice: (1) sitting OR running around; (2) playing indoors OR playing outdoors; (3) playing electronic games/computer OR active types of play; (4) watching TV/movies OR active types of play; and (5) quiet activities OR energetic activities. Similarly, parents were asked what activities they preferred to do when at home and given the choice: (1) watching TV/movies with my child OR doing PA with my child; (2) watching TV/movies OR doing something physically active; (3) using the computer/electronic games OR doing something physically active; (4) playing electronic games/computer with my child OR doing PA with my child; (5) indoor activities with my child OR outdoor activities with my child; (6) be indoors OR outdoors; and (7) quiet pursuits OR active pursuits. The parental and child activity preferences were coded on a scale of (1) 'almost always' to (5) 'almost always', and the mean score was computed for each scale, with a higher score reflecting a preference for PA activities. Lastly, parents reported whether they enforce a maximum number of h/day of screen-time rule (yes/no) [259].

8.3.8. Statistical analysis

ActivPAL, ActiGraph, physical and social environment data were received for 207 (88%), 214 (91%), 213 (91%) and 207 (88%) children, respectively. For all statistical analyses, SPSS version 26 (IBM SPSS Statistics Inc., Chicago, IL, USA) was used, where $p \leq 0.05$ was accepted as significant. The largest or second smallest values in observations replaced influential outliers [413] for overall (n=1) and bedroom (n=1) media equipment summary scores. Linear regressions were conducted to examine the association between social and individual factors and each of the home-based behaviour variables (min/hr spent sitting, in LPA, in MVPA and the number of sitting breaks/hr). Paired t-tests indicated that the behaviour variables differed significantly between weekday and weekend days; as such, analyses were run separately for weekday and weekend days. Separate regression models were conducted to examine the association between social and individual factors and each of the home physical environment variables. Univariate linear regression was used to assess unadjusted associations (Appendix A). Model 1 adjusted for home ownership, family situation, WIMD ranks, parent age and sex, season of measurement, number of daylight hours, number of siblings at home as well as the child's BMI, age and sex. Final model (model 2) included all the variables in model 1 with $p = \leq 0.10$ [414] and all adjustment variables. Final models were not run for house size and digital TV, since no social or individual factors were significant in model 1. Multicollinearity checks were performed using Pearson's correlations. Perceived importance of active play and spending time outside for child at home were strongly correlated ($r \geq 0.60$), therefore the variable more strongly associated with the outcome was included in the final models [438].

8.4. Results

Table 1 contains descriptive statistics. Overall, children (55% girls; mean age 10.2 ± 0.7 years) spent 40.3 ± 5.9 (67%), 14.9 ± 2.9 and 6.7 ± 2.3 minutes sitting and in LPA and MVPA, respectively, and engaged in 7.0 ± 1.9 sitting breaks per hour at home. There were significant differences between weekdays and weekend days for all behaviour variables. Specifically, children spent more time sitting (41.4 vs 39.4 min), less time in LPA (14.2 vs 15.3 min) and MVPA (6.2 vs 7.0 min), and also completed fewer sitting breaks (6.6 vs 7.2) on the weekend per hour at home. Participating parents were generally female (83%), homeowners (86%), with a university degree (54%), living in the highest SES locations (59%). There were usually two parents (81%) and two children at home. Parents mostly had a maximum h/day of screen-time rule (69%) and believed it was 'important' or 'very important' that their child participated in active types of play (75%)

and spent time outside (89%), and ‘un-important’ or ‘very un-important’ for their child to watch TV/movies (68%) and play electronic games/use computer for fun when at home (65%). On average, parents reported that they and their child enjoyed sedentary activities and PA at home ‘about equal’ and ‘strongly agreed’ there was enough space for their child to play indoors in the house and outdoors in the back garden. Houses averaged 11.5 ± 2.1 rooms/areas, and over half (57%) included an open plan living area and a TV located in the primary child’s bedroom (52%). On average, homes included 2.0 ± 2.1 musical instruments, 27.7 ± 18.3 PA equipment items and 11.6 ± 4.7 media equipment items. Median sizes for the house and garden were 145 m^2 and 269 m^2, respectively. Lastly, most families subscribed to digital TV (82%) and had 3-4 smartphones between them.

Table 15. Participant characteristics and descriptive statistics.

Variable	**Mean (SD) or %**	***N***
Parent Characteristics		
Parent age	41.5 (5.7)	211
Parent gender (% female)	83%	213
Parent education**		207
Secondary school or lower	12%	
Diploma/Trade	34%	
University degree or higher	54%	
Child Characteristics		
Child age	10.2 (0.7)	233
Child sex (% girl)	55%	235
Child BMI-z-score	0.6 (1.1)	233
Family Characteristics		
Number of siblings (< 18 yrs) at home	1.2 (0.9	213
Number of people at home	4.1 (1.1)	213
Family situation		213
Single parent/other	19%	
Two parent	81%	
Home ownership		213
Rent	14%	
Own	86%	
SES (based on WIMD scores) **		220
Low	14%	
Medium	27%	
High	59%	
Home Characteristics		
Objectively measured house size ($m^{2)}$	145 (52.1)	207
Objectively measured garden size (i.e., front and back) (m^2)	269.0 (166.7)	214
Space to play [1]		211
Inside the house	3.6 (0.7)	
Back garden	3.6 (0.7)	
Audit Variables		
Total no. of rooms/areas **	11.5 (2.1)	210
Presence of a TV in the child's bedroom (% yes)	52%	212
Presence of an open plan living area (% yes)	57%	211
Equipment variables		
No. of PA equipment items **	27.7 (18.3)	210
PA equipment accessibility and availability score	86.7 (63.1)	209
No. of media equipment items **	11.6 (4.7	210
Media equipment accessibility and availability score	44.2 (18.2)	209
No. of bedroom media equipment items **	1.9 (1.7)	212
Bedroom electronic media accessibility and availability score	6.9 (6.3)	210
No. of musical instrument items **	2.0 (2.1)	210
Musical instrument accessibility and availability score	7.2 (7.5)	209
Electronic Media		
TV service		213
Digital (e.g., SKY, BT etc…)	82%	
Freeview or other	18%	
Number of smartphones (mode)	3-4	213
Social and Individual Factors		207

Child activity preferences at home [2]	3.3 (0.8)	
Parent activity preferences at home [2]	3.3 (0.7)	
Parent perceived importance of active play at home for child [3]	4.0 (0.8)	
Parent perceived importance of time outside at home for child [3]	4.3 (7.3)	
Parent perceived importance of watching TV/movies at home for child [3]	2.2 (0.7)	
Parent perceived importance of playing electronic games or using the computer for fun at home for child [3]	2.3 (0.8)	
Maximum h/day of screen-time rule (% yes)	69%	206
Additional variables		
Daylength (h/day)	13 (3.4)	
Behaviour Variables		
Home-based activPAL outcomes		207
Full days of activPAL wear time at home	5.3 (1.1)	
h/full day of activPAL wear at home	5.8 (1.6)	207
Min/h spent sitting, % of time at home*		
Overall	40.3 (5.9), 67%	207
Weekday	39.4 (6.4), 66%	206
Weekend day	41.4 (6.5), 69%	180
Number of sitting breaks/h		
Overall	7.0 (1.9)	207
Weekday	7.2 (2.0)	206
Weekend day	6.6 (2.1)	180
Home-based ActiGraph outcomes		214
Full days of ActiGraph wear at home	5.5 (0.9)	
h/full day of ActiGraph wear at home	5.8 (1.6)	
Min/h spent in MVPA, % of time at home		
Overall	6.7 (2.3), 11%	214
Weekday	7.0 (2.4), 12%	212
Weekend	6.2 (2.6), 10%	194
Min/hr spent in LPA, % of time at home		
Overall	14.9 (2.9), 25%	214
Weekday	15.3 (3.0), 26%	212
Weekend	14.2 (3.3), 24%	194

[1] 1=strongly disagree; 5=strongly agree
[2] 1=almost always - sedentary; 5=almost always – PA
[3] 1=very unimportant; 5=very important
*%=proportion of time at home
**=Displayed for descriptive purposes only

8.4.1. Associations between social, individual factors and weekday sitting time, sitting breaks and PA

The results for weekday sitting and PA are shown in Tables 3 and 4, respectively. After adjustment for confounding factors (model 1), a greater child preference for PA was positively associated with weekday home-based MVPA (β = 0.23, p = < 0.01) and negatively associated with weekday home-based sitting (β = -0.25, p = < 0.01). Perceived importance of active play for children was also positively associated (β = 0.16, p = 0.02) with home-based weekday LPA. Additionally, a greater parental preference for PA was positively associated with home-based weekday sitting breaks (β = 0.15, p = 0.04). In the final models (model 2), children with a greater preference for PA spent more time in MVPA (β = 0.23, p = < 0.01) and less time sitting at home on weekdays (β = -0.27, p = < 0.01). On weekdays, children with parents who placed more importance on them engaging in active play at home, spent more time in LPA at home (β = 0.18, p = 0.02). Moreover, children whose parents had higher levels of perceived importance of them playing electronic games/using computer spent less time in LPA (β = -0.14, = 0.05) and more time sitting at home (β = 0.15, p = 0.03) on weekdays.

8.4.2. Associations between social, individual factors and weekend sitting time, sitting breaks and PA

Weekend sitting and PA results are presented in Tables 3 and 4, respectively. After adjustment for all confounding factors, the importance parents assign to active play for their child was positively associated with LPA (β = 0.16, p = < 0.03) and sitting breaks (β = 0.16, p = < 0.04) at home on weekends. Only the importance parents place on active play was included in the final models for LPA and sitting breaks, therefore the results remained unchanged from model 1.

8.4.3. Associations between social, individual factors and the physical home environment

Tables 5, 6 and 7 show results for media equipment accessibility and availability, additional physical factors and architecture/home design factors, respectively. After adjusting for the confounding factors, a greater parental preference for PA was negatively associated with overall media equipment (accessibility and availability score) (β = -0.19, p = < 0.01), fixed media equipment (β = -0.19, p = < 0.01) and media equipment in the child's bedroom (β = -0.17, p = 0.02) (model 1). While greater child preference for PA (β = 0.20, p = < 0.01) and perceived importance of children participating in active play (β = 0.21, p = < 0.01) were positively associated, perceived importance of watching TV/movies for children was negatively associated (β = -0.14, p = 0.03) with PA equipment. Perceived importance of children playing electronic games/using computer was also negatively associated with musical instruments (β = -0.18, p = $\leq$ 0.01). A maximum h/day of screen-time rule was negatively associated with portable media equipment (β = *-0.16*, p = 0.02), as well as the number of smartphones at home (β = -0.15, p = 0.03). Additionally, perceived importance of children participating in active play (*β* = 0.17, *p* = 0.02) and spending time outside (*β* = 0.19, *p* = 0.01) were both positively associated with perceived space to play in the back garden, whilst perceived importance of children spending time outside was also positively associated with objectively measured garden size (*β* = 0.18, *p* = 0.01).

In the final models (model 2), a greater parental preference for PA was associated with less accessibility and availability of overall media equipment (*β* = -0.16, *p* = < 0.03), fixed media equipment (*β* = -0.19, *p* = 0.01) and media equipment in the child's bedroom (*β* = -0.15, *p* = 0.05) [Table 5]. Homes with a maximum h/day of screen-time rule also had less portable media equipment accessibility and availability (*β* = -0.16, *p* = 0.02) [Table 5] and fewer smartphones (*β* = -0.14, *p* = 0.04) [Table 6]. Greater perceived importance of spending time outside for children was associated with a larger garden (front and back) (*β* = 0.18, *p* = 0.01) and more perceived space to play in the back garden (*β* = 0.19, *p* = 0.01) [Table 7]. Additionally, a higher level of perceived importance of active play for child (*β* = 0.16, *p* = 0.02) and a greater child preference for PA (*β* = 0.15, *p* = 0.04) was associated with a greater PA equipment accessibility and availability [Table 6]. Lastly, greater perceived importance of playing electronic games/using computer for child was associated with less musical instrument accessibility and availability (*β* = -0.17, *p* = 0.02) [Table 6].

Table 16. Associations between social and individual factors and children's home–based sitting time and breaks.

	Overall				*Weekday*				*Weekend*			
	Model 1		**Model 2**		**Model 1**		**Model 2**		**Model 1**		**Model 2**	
Home-based sitting time	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI
Parental activity preferences	-0.06	-1.73, 0.69	–	–	-0.08	-1.97, 0.66	–	-	-0.05	-1.97, 1.03	–	–
Child activity preferences	-0.22***	-2.60, -0.48	-0.22***	-2.60, -0.48	-0.25***	-3.08, -0.79	-0.27***	-3.18, -0.90	-0.11	-2.10, 0.43	–	–
Max h/day of screen-time	-0.03	-2.18, 1.54	–	–	0.00	-2.01, 2.06	–	–	-0.05	-2.90, 1.54	–	–
Importance of active play [1]	-0.04	-1.34, 0.82	–	–	-0.04	-1.53, 0.83	–	–	0.01	-1.20, 1.33	–	–
Importance of time outside [1]	0.01	-1.20, 1.33	–	–	0.02	-1.26, 1.52	–	–	0.00	-1.44, 1.49	–	–
Importance of watching TV/movies [1]	-0.06	-1.79, 0.80	–	–	-0.04	-1.84, 0.98	–	–	-0.11	-2.57, 0.47	–	–
Importance of using E-games/computer [1]	0.10	-0.36, 1.92	–	–	0.13*	-0.13, 2.39	0.15**	0.10, 0.26	0.04	-1.01-1.66	–	–
Model 2 R^2 (adjusted R^2)			0.14 (0.09)				0.17 (0.11)				–	
	Model 1		**Model 2**		**Model 1**		**Model 2**		**Model 1**		**Model 2**	
Home-based sitting breaks	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI
Parental activity preferences	0.11	-0.07, 0.65	–	–	0.15**	0.02, 0.76	0.11	-0.11, 0.70	0.02	-0.41, 0.50	–	–
Child activity preferences	0.06	-0.19, 0.46	–	–	0.12*	-0.05, 0.61	0.06	-0.22, 0.50	-0.03	-0.47, 0.31	–	–
Max h/day of screen-time	0.03	-0.45, 0.66	–	–	-0.02	-0.66, 0.49	–	–	0.08	-0.31, 1.03	–	–
Importance of active play [1]	0.15**	0.02, 0.65	0.15**	0.02, 0.65	0.11*	-0.05, 0.61	–	–	0.16*	0.02, 0.77	0.16**	0.02, 0.77
Importance of time outside [1]	0.14*	-0.01, 0.74	–	–	0.14*	-0.02, 0.76	0.12*	-0.07, 0.72	0.09	-0.20, 0.69	–	–
Importance of watching TV/movies	-0.07	-0.57, 0.20	–	–	-0.07	-0.62, 0.17	–	–	0.01	-0.43, 0.50	–	–
Importance of using E-games/computer	-0.07	-0.51, 0.17	–	–	-0.03	-0.43, 0.29	–	–	-0.10	-0.66, 0.15	–	–
Model 2 R^2 (adjusted R^2)			0.22 (0.17)				0.28 (0.22)				0.18 (0.12)	

* $p = \leq 0.10$, ** $p = \leq 0.05$, *** $p = \leq 0.01$. [1] Parent perceived importance of activities for their child. Model 1: Model for each social and individual factor adjusting for home ownership, family situation, WIMD, parent age and sex, season, daylength, no. of siblings, as well as the child's BMI, age and sex. Model 2; Model including all significant social and individual factors from model 1, adjusting for home ownership, family situation, WIMD, parent age and sex, season, daylength, no. of siblings, as well as the child's BMI, age and sex.

Table 17. Associations between social and individual factors and children's home–based PA.

	Overall				*Weekday*				*Weekend*			
	Model 1		**Model 2**		**Model 1**		**Model 2**		**Model 1**		**Model 2**	
Home-based LPA	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI
Parental activity preferences	0.05	-0.35, 0.77	–	–	0.06	-0.35, 0.84	–	–	0.00	-0.69, 0.69	-	–
Child activity preferences	0.03	-0.41, 0.61	–	–	0.10	-0.18, 0.89	–	–	-0.06	-0.82, 0.39	–	–
Max h/day of screen-time	0.03	-0.66, 1.08	–	–	-0.05	-1.22, 0.63	–	–	0.11	-0.27, 1.81	–	–
Importance of active play [1]	0.15**	0.04, 1.04	0.17**	0.09, 1.08	0.16**	0.09, 1.15	0.18***	0.14, 1.19	0.16**	0.05, 1.25	0.16**	0.05, 1.25
Importance of time outside [1]	0.09	-0.24, 0.95	–	–	0.09	-0.23, 1.03	–	–	0.10	-0.28, 1.13	–	–
Importance of watching TV/movies [1]	-0.04	-0.78, 0.44	–	–	-0.04	-0.81, 0.48	–	–	-0.01	-0.77, 0.70	–	–
Importance of using E-games/computer [1]	-0.13*	-1.03, 0.02	-0.15**	-1.08, 0.04	0.12*	-1.08, 0.07	-0.14**	-1.14, 0.00	-0.06	-0.90, 0.37	–	–
Model 2 R^2 (adjusted R^2)			0.21 (0.15)				0.21 (0.15)				0.18 (0.12)	
	Model 1		**Model 2**		**Model 1**		**Model 2**		**Model 1**		**Model 2**	
Home-based MVPA	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI
Parental activity preferences	0.00	-0.43, 0.44	–	–	0.04	-0.34, 0.58	–	–	-0.06	-0.74, 0.35	–	–
Child activity preferences	0.19***	0.12, 0.89	0.19***	0.12, 0.89	0.23***	0.25, 1.05	0.23***	0.25, 1.05	0.10	-0.18, 0.77	–	–
Max h/day of screen-time	0.07	-0.31, 1.03	–	–	0.07	-0.38, 1.04	–	–	0.08	-0.35, 1.29	–	–
Importance of active play [1]	0.09	-0.13, 0.65	–	–	0.09	-0.14, 0.69	–	–	0.06	-0.28, 0.68	–	–
Importance of time outside [1]	-0.01	-0.48, 0.44	–	–	0.00	-0.48, 0.50	–	–	-0.02	-0.61, 0.50	–	–
Importance of watching TV/movies [1]	-0.02	-0.56, 0.39	–	–	-0.03	-0.60, 0.40	–	–	-0.02	-0.65, 0.50	–	–
Importance of using E-games/computer [1]	-0.10	-0.72, 0.10	–	–	-0.08	-0.69, 0.20	–	–	-0.10	-0.85, 0.14	–	–
Model 2 R^2 (adjusted R^2)			0.23 (0.17)				0.24 (0.19)				–	

* p = ≤0.10, ** p = ≤0.05, *** p = ≤0.01. [1] Parent perceived importance of activities for their child. Model 1: Model for each social and individual factor adjusting for home ownership, family situation, WIMD, parent age and sex, season, daylength, no. of siblings, as well as the child's BMI, age and sex. Model 2; Model including all significant social and individual factors from model 1, adjusting for home ownership, family situation, WIMD, parent age and sex, season, daylength, no. of siblings, as well as the child's BMI, age and sex.

Table 18. Associations between social and individual factors and the media equipment accessibility and availability summary scores.

Variable	Overall media equipment [1]				Portable media equipment [1]				Fixed media equipment [1]				Bedroom media equipment [1]			
	Model 1		Model 2		Model 1		Model 2		Model 1		Model 2		Model 1		Model 2	
	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI
Parental activity preferences	-0.19***	-8.15, -1.19	-0.16**	-7.48, -0.29	-0.06	-2.46, 0.96	–	–	-0.19***	-6.40, -0.94	-0.19***	-6.40, -0.94	-0.17**	-2.65, -0.24	-0.15**	-2.02, 0.05
Child activity preferences	-0.04	-3.99, 2.47	–	–	-0.06	-2.19, 0.95	–	–	-0.01	-2.72, 2.34	–	–	-0.01	-1.14, 1.07	–	–
Max h/day of screen-time	-0.13*	-10.55, 0.41	-0.09	-9.18, 2.02	-0.16**	-5.72, -0.45	-0.16**	-5.72, -0.45	-0.05	-5.70, 2.90	–	–	-0.11*	-3.42, 0.33	-0.08	-1.10, 0.27
Importance of active play [2]	0.01	-3.08, 3.46	–	–	-0.09	-2.55, 0.60	–	–	0.04	-1.90, 3.20	–	–	0.01	-1.06, 1.18	–	–
Importance of time outside [2]	-0.03	-4.60, 2.90	–	–	-0.12	-3.19, 0.42	–	–	0.01	-2.82, 3.03	–	–	0.02	-1.14, 1.42	–	–
Importance of watching TV/ movies [2]	-0.08	-6.10, 1.54	–	–	-0.06	-2.69, 1.01	–	–	-0.09	-4.87, 1.08	–	–	-0.04	-1.71, 0.91	–	–
Importance of using E-games/computer [2]	0.09	-1.17, 5.54	–	–	-0.01	-1.73, 1.54	–	–	0.10	-0.79, 4.44	–	–	0.04	-0.84, 1.46	–	–
Model 2 R^2 (adjusted R^2)			0.13 (0.07)				0.10 (0.05)				0.12 (0.06)				0.17 (0.11)	

Table 19. Associations between social and individual factors and the additional physical environment factors.

Variable	PA equipment [1]				Musical instruments [1]				Smart phones [1]				TV in child's bedroom [1]				Digital TV	
	Model 1		Model 2		Model 1		Model 2		Model 1		Model 2		Model 1		Model 2		Model 1	
	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI
Parental activity preferences	0.10	-2.82, 20.41	–	–	0.00	-1.43, 1.49	–	–	-0.04	-0.15, 0.08	–	–	-0.13*	-0.18, 0.00	-0.13*	-0.18, 0.00	-0.10	-0.13, 0.02
Child activity preferences	0.20***	4.93, 25.82	0.15**	0.58, 21.79	-0.14*	-2.51, 0.08	-0.12	-2.34, 0.23	0.06	-0.06, 0.14	–	–	-0.03	-0.10, 0.07	–	–	0.07	-0.04, 0.10
Max h/day of screen-time	0.10	-4.23, 32.10	–	–	0.01	-2.14, 2.34	–	–	-0.15**	-0.37, -0.02	-0.14**	-0.36, -0.01	-0.08	-0.23, 0.06	–	–	-0.08	-0.18, 0.05
Importance of active play [2]	0.21***	6.11, 27.17	0.16**	2.33, 23.72	0.05	-0.87, 1.78	–	–	-0.09	-0.17, 0.04	–	–	0.05	-0.12, 0.06	–	–	-0.10	-0.12, 0.02
Importance of time outside [2]	0.14*	-0.30, 24.25	–	–	0.12	-0.27, 2.75	–	–	-0.12*	-0.22, 0.02	-0.11	-0.21, 0.03	0.02	-0.11, 0.09	–	–	-0.11	-0.14, 0.02
Importance of watching TV/ movies [2]	-0.14**	-26.36, -1.33	-0.11*	-22.69, 1.94	-0.09	-2.35, 0.56	–	–	-0.08	-0.20, 0.05	–	–	-0.07	-0.15, 0.05	–	–	0.06	-0.05, 0.11
Importance of using E-games/computer [2]	-0.02	-13.08, 9.19	–	–	-0.18***	-3.10, -0.42	-0.17**	-2.99, -0.31	0.04	-0.08, 0.14	–	–	0.01	-0.10, 0.08	–	–	0.04	-0.05, 0.09
Model 2 R^2 (adjusted R^2)			0.13 (0.07)				0.10 (0.05)				0.12 (0.06)				0.17 (0.11)			–

* $p = \leq 0.10$, ** $p = \leq 0.05$, *** $p = \leq 0.01$. [1] Accessibility and availability equipment summary score. [2] Parent perceived importance of activities for their child. Model 1: Model for each social and individual factor adjusting for home ownership, family situation, WIMD, parent age and sex, season, daylength, no. of siblings, as well as the child's BMI, age and sex. Model 2: Model including all significant social and individual factors from model 1, adjusting for home ownership, family situation, WIMD, parent age and sex, season, daylength, no. of siblings, as well as the child's BMI, age and sex.

Table 20. Associations between social and individual factors and architecture/home design physical environmental factors.

Variable	**House size [1]**		**Garden size [1]**				**Space to play inside the house**				**Space to play in the back garden**				**Open plan living area**			
	Model 1		**Model 1**		**Model 2**		**Model 1**		**Model 2**		**Model 1**		**Model 2**		**Model 1**		**Model 2**	
	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI
Parental activity preferences	-0.00	-9.20, 9.00	0.05	-20.85, 42.37	–	–	-0.09	-0.22, 0.05	–	–	-0.11	-0.25, 0.03	–	–	0.13*	-0.01, 0.18	0.13*	-0.01, 0.18
Child activity preferences	-0.08	-13.08, 3.55	0.03	-23.43, 34.02	–	–	0.04	-0.09, 0.16	–	–	0.04	-0.09, 0.17	–	–	0.06	-0.06, 0.12	–	–
Max h/day of screen-time	0.08	-5.27, 22.63	0.06	-27.83, 68.74	–	–	0.01	-0.19, 0.23	–	–	-0.05	-0.30, 0.14	–	–	0.06	-0.09, 0.22	–	–
Importance of active play [2]	-0.04	-10.60, 6.00	0.07	-15.04, 42.06	–	–	0.13*	-0.01, 0.23	0.13*	-0.01, 0.23	0.17**	0.03, 0.28	–	–	0.09	-0.04, 0.14	–	–
Importance of time outside [2]	-0.05	-13.25, 5.79	0.18***	8.29, 72.66	0.18***	8.29, 72.66	0.10	-0.05, 0.23	–	–	0.19***	0.05, 0.34	0.19***	0.05, 0.34	0.02	-0.09, 0.12	–	–
Importance of watching TV/ movies [2]	-0.03	-12.14, 7.27	-0.05	-45.32, 22.04	–	–	0.04	-0.10, 0.19	–	–	-0.01	-0.16, 0.15	–	–	0.03	-0.09, 0.13	–	–
Importance of using E-games/computer [2]	-0.06	-12.27, 4.78	-0.12	-32.99, 25.99	–	–	0.10	-0.04, 0.21	–	–	-0.01	-0.14, 0.13	–	–	0.02	-0.08, 0.11	–	–
R^2 (adjusted R^2)				0.13 (0.07)			0.10 (0.05)				0.12 (0.06)				0.17 (0.11)			

* p = ≤0.10, ** p = ≤0.05, *** p = ≤0.01. [1] Accessibility and availability equipment summary score. [2] Parent perceived importance of activities for their child. Model 1: Model for each social and individual factor adjusting for home ownership, family situation, WIMD, parent age and sex, season, daylength, no. of siblings, as well as the child's BMI, age and sex. Model 2: Model including all significant social and individual factors from model 1, adjusting for home ownership, family situation, WIMD, parent age and sex, season, daylength, no. of siblings, as well as the child's BMI, age and sex.

8.5. Discussion

This study examined whether social and individual factors specific to the home were associated with: (i) sitting time, breaks in sitting and PA and (ii) the home physical environment. Parental importance of active play for children was significantly associated with increased LPA and sitting breaks, as well as a physical environment conducive to PA. The level of importance that parents placed on children playing electronic games/using computers for fun was associated with less LPA and more sitting on weekdays. Parental preference for being active at home and placing limits on screen-time were both associated with a physical environment less conducive to sedentary activities. Further, child activity preferences had the greatest relationship with behaviour, where children who preferred being sedentary engaged in less MVPA and more sitting on weekdays. The importance parents place on their children watching TV/movies was the only factor not associated with either the physical environment or children's behaviour. In line with previous research that found parental factors to be stronger correlates of children's weekday behaviour [279], stronger associations were identified for weekday behaviour outcomes, suggesting that social and individual factors play a greater role in children's weekday behaviour at home. These findings likely reflect the increased freedom children have to make their own activity choices without parental influence on weekends.

Parental importance of active play for children at home was positively associated with home-based LPA and sitting breaks, which is consistent with studies that have shown parental importance of PA to be positively associated with PA [439] and outdoor play [440]. Parents who perceive active play as important for their child are more likely to allow or encourage active play at home, providing children with more opportunities to engage in LPA and break up their sitting. More importance placed on active play was also associated with greater accessibility and availability of PA equipment at home. Time outdoors is an important predictor of children's active play [257,441], and in this study parents who perceived it as important had larger gardens. Therefore, it appears a higher level of importance assigned to active play and time outside at home translates into a physical environment that better supports active play. However these relationships may be bidirectional, as parents consider outdoor space and PA equipment an essential factor for their children's active play at home [43]. Nonetheless, changing parent's attitudes towards active play seems important for supporting children's PA at home.

Children's computer use, specifically for playing games among boys and social networking among girls, is sharply increasing [442]. In this study, children whose parents placed more importance on them playing electronic games/using computers for fun, accumulated less LPA and more sitting time on weekdays. This is consistent with another study that found an inverse relationship between parents' negative attitudes towards computer use and children's screen-time [443]. Two thirds of parents considered playing electronic games/using computers unimportant or very unimportant for their child. Parents who enforce fewer restrictions on their child's use of games consoles and computers, are less aware of the risks associated with excessive usage or they may perceive them as being important for education and social interaction [43]. Consequently, children's increased use of video games and computers may hinder their participation in PA at home similar to studies that have found children's screen-time [91], and specifically computer use [432], to be inversely related with PA.

Enforcing a screen-time limit was not associated with children's home-based sitting, in contrast with the only other study to objectively measure home-based sedentary time [40]. This discrepancy likely reflects the sharp increase in the use of portable electronic devices over the past decade [40]. Indeed, parents find limiting the use of such devices difficult due to their portability and because of their multi-functionality, hence rules restricting portable device usage may be harder to enforce [43]. This may also explain why homes of parents who enforced screen-time limits on their children had lower accessibility and availability of portable devices as well as fewer smartphones, which is consistent with one study that found parents who limit screen-time have less media equipment at home [444]. Similarly, parents with a preference for being active at home reported a lesser presence of media equipment at home overall and in the child's bedroom, in line with a study that found higher parental screen-time was associated with presence of at least one electronic media device in a child's bedroom [445]. These findings suggest that parental activity preferences and limits on screen-time may be indirectly associated with children's behaviour through the home physical environment, building on previous evidence that has shown direct associations with children's screen-time [41,430].

In agreement with studies that have shown activity preferences to be a strong predictor of children's PA [258,432] and screen use [399], this study found that children with a preference for PA at home engaged in more MVPA and less sitting at home, but only on weekdays. The reason for the lack of a relationship observed with weekend behaviour is unclear, and it is in contrast to another study reporting that children who preferred PA were more likely to play in the garden at home only on weekends [287]. This discrepancy may, in part, be because Veitch et al. [287] found that children played in their garden more at weekends, whereas children in this study engaged in more MVPA on weekdays. Nonetheless, these findings suggest children's activity preferences play an important role in their PA and sedentary time at home.

This study adds to the evidence that social factors are directly associated with children's PA and sedentary time [41,235,269,430], by showing that they may also be indirectly associated through the physical environment at home. Parent's limits on screen-time and their perceived importance of active play, time outdoors or recreational video game/computer use for children were associated with either children's behaviour or predictors of children's PA and sedentary behaviour within the physical environment at home [41] or both. Therefore, strategies which change parent's attitudes towards active play/time outdoors and encourage more restrictions on electronic media use at home are warranted. Educating parents on the importance of regular PA and limiting sedentary time for health as well as how to create healthy home environments may be a promising approach. Since parental rules and priorities for leisure activity are reflected in their home environments, this approach may not only be important for the child but for the entire family, given the associated physical factors are key determinants of sedentary time and PA [383]. Parental activity preferences were also strongly associated with the physical home space, and child activity preferences had the strongest relationship with behaviour. A difficult, but important, challenge for home-based interventions is to develop strategies which reduce both parents and children's preferences for sedentary activities. Specifically, one approach for increasing children's enjoyment of PA is to target improvements in their fundamental movement skills (FMS), since mastery of FMS may lead to increased enjoyment of PA [446]. This combined with restrictions on screen-based sedentary behaviours set by parents, will provide children with opportunities to experience alternatives to activities such as TV viewing and playing electronic games, which they may enjoy just as much. Parental activity preferences may be particularly difficult to change, as they are more ingrained. However, after receiving education on the benefits of PA and detriments of sedentary behaviour, parents may perceive PA as more valuable, which may contribute to the formation of a home environment more conducive to PA.

This study has numerous strengths, including the validated audit used to comprehensively assess the home physical environment [299], the investigation of associations between home-specific social and individual factors and home-based behaviour and the objective measurement of PA, sitting and sitting breaks. The adjustment for a multitude of important confounding factors was also a strength. Nonetheless, some limitations need to be acknowledged, including the reliance on self-report to assess the home-specific individual and social factors and for determining when the children were at home, which may have introduced some measurement error. However, there is no feasible objective alternative for these measures. The cross-sectional nature of the study also means that causal relationships cannot be inferred. Moreover, we did not have data from both parents. Whilst it is likely that the parent who participated is more involved in the formation of the home environment and their child’s behaviour at home, it could be that the other parent has a stronger influence. However, the number of parents at home was controlled for in all analyses. Further, the overrepresentation of university educated parents living in the least deprived locations, may limit the generalisability of the findings. However, the proportion of high SES families is comparable with other studies [240,248]. Lastly, although the use of GIS to objectively measure house and garden size was a strength, full home addresses were not obtained, therefore measures pertain to each postcode and not the specific homes. Thus, the measures only provide estimates of size, given home size is likely to differ between homes in the same postcode.

8.6. Conclusion

In conclusion, parental and child preferences and priorities, as well as parental rules for leisure activity at home, are associated with children’s sitting and PA at home, particularly during weekdays. They are also associated with factors related to leisure activity in the physical environment, providing evidence to support our hypotheses. Such insight is important, given children spend more time at home than anywhere else [38,39]. The findings suggest that interventions seeking to create home environments conducive to PA, should target parental attitudes and the activity preferences of children and parents, alongside adapting the home physical environment. Future home-based interventions should provide support and education to parents on how to make home environments, through the instigation of restrictions on screen-time and physical environmental changes, that hinder engagement in sedentary activities and promote active alternatives. Additionally, changing children's and parent's preferences for home-based activities or replacing sedentary activities with acceptable active alternatives will also be key targets.

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Thesis map

Study	Aims	Key findings
1. Relationship between Sedentary Time, Physical Activity and Multiple Lifestyle Factors in Children	To explore associations between multiple lifestyle factors and being sufficiently active ($\geq$60 min·day^{-1}) or engaging in excessive screen-time ($\geq$2 h·day^{-1}) in children.	Sufficient MVPA and excessive screen-time were associated with healthy and unhealthy factors, respectively, with relationships sometimes differing by sex. Specifically, fruit and vegetable consumption and CRF were positively associated with sufficient MVPA, irrespective of sex. Excessive screen-time was positively associated with sugary snack consumption in boys and girls, and diet soft drink intake in boys ($p < 0.05$). In addition, excessive screen-time was negatively associated with MVPA before school for both boys and girls, as well as with sleep duration and fruit and vegetable consumption for girls ($p < 0.05$).
2. Validity and reliability of the HomeSPACE-II instrument to assess the influence of the home physical environment on children's physical activity and sedentary behaviour	To test the criterion validity and reliability of the HomeSPACE-II instrument.	The study revealed that most items, outside of accessibility and size measures, had strong reliability and validity. Therefore, the HomeSPACE-II is a valid and reliable instrument for measuring physical factors that influence children's physical activity and sedentary behaviour within the home.
3. Associations between the Home Physical Environment and Children's Home-Based Physical Activity and Sitting	To investigate the relationship between characteristics of the physical home environment and children's home-based sitting, PA, standing and sitting breaks.	An open plan living area (OPLA), musical instrument accessibility and availability, and perceived house size were negatively and positively associated, whereas media equipment accessibility and availability was positively and negatively associated with sitting and standing, respectively. Additionally, an OPLA was positively associated with total and moderate-to-vigorous PA. Furthermore, sitting breaks were positively associated with objective garden

		size and negatively associated with digital TV. The physical home environment has an important influence on children's sitting, standing and PA at home.
4. Are parental priorities, preferences and rules regarding activity at home associated with children's home-based behaviour and the home physical environment	To investigate the influence of parental priorities, preferences and rules regarding activity at home on: (i) children's home-based overall sitting time, breaks in sitting, and PA, and; (ii) the home physical environment.	The findings suggest that parental activity preferences, priorities and rules are not only directly associated with children's sitting and PA, particularly during weekdays, but also indirectly via the physical environment within the home. Parental activity preference had the greatest influence on the physical home space and child activity preference was the strongest correlate of children's behaviour at home.
5. Clustering of home physical and social environmental factors	To investigate clustering of social and physical factors within the home, and how these clusters are related to home-based sitting, sitting breaks, MPVA and total physical activity (TPA). Associations of parental, family and child characteristics with the clusters were also examined.	

9. Study 5

9.1. Clustering of home physical and social environmental factors

9.2. Introduction

Physical activity (PA), irrespective of intensity, is important for children's health and well-being [6]. Although moderate-to-vigorous physical activity (MVPA) has been shown to be the most beneficial to health [6], those meeting the government recommended levels of at least 60 minutes of MVPA, on average, every day [62] remain low [44]. Specifically, in Wales, only a third of children have been classified as sufficiently active [63]. Moreover, children also spend a significant amount of time in sedentary behaviours (7-8 h daily) [45], characterised by 'an energy-expenditure below 1.5 metabolic equivalents (METs), while in a sitting, lying or reclining posture' [198]. Screen-time is the most prominent of these (>5 h daily) [117], and has been adversely associated with health [5]. Further, *how* sedentary time is accumulated may also be important, as more frequent sedentary breaks have been shown to improve short-term metabolic indicators in children [50]. While research has shown significant health consequences of excessive sedentary time and infrequent sedentary breaks in adults [96], the health effects are equivocal in children. However, this is likely, at least in part, because chronic diseases do not manifest until later in life. Nonetheless, due to evidence that children's behaviour habits can persist into adulthood [31], high levels of sedentary time, particularly of a prolonged nature [447], are a public health concern.

Ecological models emphasise the influence of the environment on PA and sedentary time [37]. Outside of school, children spend a large proportion of time in their neighbourhood and home environments. While the neighbourhood environment has received much attention [426,427], less is known about the home environment [41]. However, the availability of household and bedroom media equipment are consistent physical environment correlates of screen-time [41,235]. Moreover, PA equipment has been shown to promote PA [40,240] and discourage sedentary time [40,41], whereas qualitative research has identified that house and garden size influences children's PA and sedentary time at home [43]. Furthermore, parents play a key role in influencing their children's PA and sedentary time [41]; parental PA levels, support and co-participation all identified as important correlates of children's PA [430,431], whereas parental screen-time and electronic media rules are consistent correlates of children's sedentary behaviour [41,235]. This evidence supports the notion that both the physical and social home environment have an important influence on children's PA and sedentary time [41,235].

Although studies have assessed individual physical and social related factors, a limited number of studies have examined clustering or the co-occurrence of such factors [288,289]. Understanding which social and physical factors cluster or co-occur is important, as the co-occurrence of influential PA and sedentary behaviour correlates is likely to have a synergistic effect [448]. Moreover, identifying which social and physical factors cluster may enable more efficient interventions, by informing strategies which target multiple factors simultaneously. There is some evidence that physical and social environmental factors cluster [288,289]. Specifically, at least two studies have shown that low parental screen-time and high PA equipment availability cluster [288,289]. Moreover, low media equipment availability and greater family rules have also been found to cluster [289]. However, to date, no study has investigated the clustering of social and physical factors within the home environment. Given that children spend more time at home than anywhere else [38,39], such insights are important. To determine their importance, it is also necessary to assess how home-specific clusters relate to PA and sedentary time at home. Indeed, ecological models posit that behaviour is most likely influenced by the environment in which it occurs [37].

The aim of this study was to investigate clustering of social and physical factors within the home, and whether these clusters are related to home-based sitting, sitting breaks, MPVA and total physical activity (TPA) in children. A secondary aim was to examine whether clusters are associated with parental, family and child characteristics to inform interventions.

9.3. Materials and Methods

9.3.1. Participants

Between November 2017 and July 2018, 11 out of 23 primary schools which were contacted in South Wales provided headteacher consent to participate in the

HomeSPACE project. From these schools, 890 children from school years 5 and 6 (9-11 years old) were provided with project information. Participation was incentivised; families were offered to be entered into a prize draw to win a family pass for an outdoor activity centre and children were offered a sedentary time and PA report. Informed parental/guardian consent and child assent were received from 235 children (55% girls, aged 10.2 ± 0.7 years) and their parents (n=228) [26% response]. Procedures complied with the declaration of Helsinki and ethical approval was obtained from the Swansea University ethics committee.

9.3.2. The physical home environment

Physical factors within the home which are hypothesised to influence children's PA and sedentary behaviours at home [43] were assessed using an integrated version of the HomeSPACE instrument [290] and the PA and media inventory [247]. Parents were asked to walk around each room/area in their house and garden and use the integrated tool to record the presence, amount and accessibility of 34 items, including media equipment (e.g., TV, computer), PA equipment (e.g., balls, trampoline) and musical instruments (e.g., drums, piano), for up to 22 room/areas. Each item's accessibility was rated on a A-D scale, ranging from (A) "put away and difficult to get to" to (D) "in plain view and difficult to get to". There were also additional questions referring to electronic media (smart phones, TV service, movie/TV streaming service). From the audit data, summary scores were calculated measuring the accessibility and availability of PA equipment, overall and bedroom media equipment, and musical instruments. The higher the score, the greater the "presence" of that item type in the home. A binary variable was also created to determine the presence of an open plan living area and a TV in the primary child's bedroom. To aid interpretation, the total number of each item type and rooms/areas were calculated. Physical activity equipment included active video game systems (e.g., Wii fit, X-box Kinect, PlayStation move). Incomplete audits were followed up with families to, where possible, retrieve additional information.

9.3.3. Social and individual factors

Family priorities and preferences for home-based activity [290] and parental media rules [259] were assessed with validated questions. The first question asked "When at home, how important is it to you that your child [plays electronic games/computer]; [does some active play]; [watches TV/movies]?" with responses ranging from (1) 'very unimportant' to (5) 'very important'. The second question asked parents what activities their child prefers to do when at home; (1) sitting OR running around; (2) playing indoors OR playing outdoors; (3) playing electronic games/computer OR active types of play; (4) watching TV/movies OR active types of play; and (5) quiet activities OR energetic activities. Similarly, parents were asked what activities they preferred to do at home; (1) watch TV/movies with their child OR engaging in PA with their child; (2) watch TV/movies OR being physically active; (3) using the computer/electronic games OR being physically active; (4) play electronic games/computer with their child OR PA with their child; (5) indoor activities with their child OR outdoor activities with their child; (6) be indoors OR outdoors; and (7) quiet pursuits OR active pursuits. Child and parental activity preferences were recorded on a five-point scale and ranged from (1) 'almost always' to (5) 'almost always'. For each scale, scores were generated using the mean responses, where a higher score represented a preference for PA activities. Another item assessed the presence of a maximum number of h/day screen-time rule (yes/no).

9.3.4. Objectively measured home-based physical activity and postural behaviours

Children wore an ActiGraph GT9X (Pensacola, Florida, USA) and activPAL3 micro (PAL Technologies, Glasgow, UK) to assess PA (TPA and MVPA) and postural outcomes (sitting and sitting breaks), respectively. Sitting breaks were considered as transitions from sitting to standing/stepping [198]. The monitors were fitted at school to ensure they were attached correctly and that the children knew how to remove and re-attach. Participants were encouraged to wear the monitors at all times, (including when bathing, but excluding swimming, for seven consecutive days). A diary was provided for parents to record child sleep and wake times, device removals, sickness days and when the child was at home. "Home" included one location, covering the house, driveway and verge area of the child's main home (i.e., the home where they spent most of their time, excluding homes of other parents or relatives etc.). To minimise missing data, children were asked to complete the diary if parents were unable to; families were also contacted for further information for incomplete diary entries.

The activPAL, shown to have excellent validity in children [112], was protected by a waterproof nitrile sleeve and positioned on the mid-anterior aspect of the right thigh using a hypoallergenic dressing (3M Tegerderm or Hypafix Transparent). Additional dressings and sleeves, as well as instructions for correct attachment were provided. The activPAL data processing protocol has been described elsewhere [383], but briefly, the data was downloaded in the manufacturer software (V8.10.8.32, PAL technologies, Glasgow, UK) and the resultant Event.csv files were processed in Processing PAL-V1.1 (Leicester, UK) with a validated algorithm that calculates waking hours, extended non-wear time (≥ 5 h) and invalid data. Diary-reported non-wear time considered feasible were also removed. In addition, based on inspections of the data and methods used elsewhere [406], ≥ 3 h bouts of sitting/lying or standing with no transitions were also treated as non-wear time.

Children wore the ActiGraph GT9X on their non-dominant wrist [303], as wrist-worn accelerometers have been shown to improve compliance [39] and have comparable validity to hip-worn accelerometers [305]. Devices were set to collect data at 30 Hz [449], which was summed over 5-sec epochs. ActiLife V6.13.3 (ActiGraph software) was used to initialise, download and process files. Chandler wrist-based cut-points [155], applied to the vector-magnitude, were used to categorise MVPA (≥818 counts/5-secs) and TPA (≥162 counts/5-secs). Non-wear periods, identified as >90 minutes of consecutive zero counts [436], were removed.

To calculate home-based PA and postural outcomes, time at home was imported into both the ActiLife and Processing PAL software, respectively, and matched with time-stamped data. To be included in the analyses, participants were required to have satisfactorily completed home logs, and at least 1 day that had ≥ 3 h of data at home [437] when the device was worn for ≥75% of the time [408]. Sickness days were also removed. ActivPAL and ActiGraph data in minutes, divided by waking wear time at home, were multiplied by 60 to produce outcome variables expressed as averages/h [410].

9.3.5. Children personal information and anthropometric measures

Within school, trained researchers measured children's stature and body mass to the nearest 0.001 m and 0.1 kg [339], using a portable stadiometer (Seca 213 portable, stadiometer, Hamburg, Germany) and electronic weighing scales (Seca 876, Hamburg, Germany), respectively. Subsequently, body mass index (BMI) was determined, and BMI z-scores were calculated using the WHO (World Health Organization) growth reference charts [294].

9.3.6. House and garden size estimates

Using geographic information system techniques (GIS), Ordnance Survey MasterMap (OSMM) [301] and AddressBase Premium (ABP) [300], house and garden size were assessed for each postcode unit. For homes (min – max: 4 - 82), the building footprint area was determined in OSMM and non-residential buildings defined by ABP were filtered out. Using the same process, garden size (front and back combined) for homes (min – max: 2 – 82) defined by OSMM [302] was calculated using the same process. To estimate house size, a median of the building footprints was calculated and multiplied by the number of floors. A median garden size was also computed for each postcode unit.

9.3.7. Additional Measures

Parents reported their ethnicity; those responding with White were coded as 0 and other responses (i.e., Mixed race, Asian or Asian British, Black or Black British, Chinese) were categorised as 1 (defined as ethnic minorities). Parent's also reported their highest level of education, which was collapsed into three categories: (1) some secondary school/completed secondary school; (2) trade qualifications or apprenticeship/diploma or certificate; and (3) university degree or higher. Pre-tax annual household income was also reported using seven categories ranging from (1) < £10, 000 to (7) ≥ £100, 000. Further, parents reported their sex, age, whether they own or rent their home, the number of people at home and their residential postcode. Hours of daylight for the participant's respective location's during each measurement day were determined using the Time and Date sunrise and sunset calculator [411].

9.3.8. Statistical analysis

All analyses were conducted using SPSS version 26 (IBM SPSS Statistics Inc., Chicago, IL, USA). All social and physical home environment variables were converted to standardised z-scores. A principal component analysis (PCA) was performed to examine clustering of activity-related home environmental variables. Oblique rotation was used because of the hypothesised correlation between the extracted components [450]. The scree plot [450] and eigenvalues (> 1) [451] were used to determine the number of components. Items with component loadings of ± 0.4 [452] and no cross loadings above ± 0.50 [453] were retained and considered part of a component. If an item was within ± 0.05 of the applied loading, the decision as to whether they were included was made based on theoretical rationale. The final solution was significant in the Bartlett test of sphericity [450], had a KMO value above 0.5 [451], and components explained ≥ 50% of the total variance [454]. To calculate cluster scores, the home factors were multiplied by their component loadings and summed for each component [288]. Due to the exploratory nature of the analyses, a backwards linear regression was used to assess associations between the cluster scores and child (BMI and activity preferences), parent (income, family situation, age, ethnicity and education) and family (number of people, WIMD scores, home ownership) characteristics. Partial correlation analyses were used to assess associations between cluster scores and the four home-based behaviour outcomes (min/h spent sitting, in MVPA and TPA, and the number of sitting breaks/h). All analyses were corrected for the child, parent and family characteristics, as well as daylight hours, parental age and the age and sex of the child. Paired t-tests showed significant differences between weekdays and weekend days for the behavioural outcomes. However, separate analyses had minimal impact on results; thus, data for the weekday and weekend days were combined.

9.4. Results

Descriptive statistics are presented in Table 1. Children spent 40.3 ± 5.9, 21.6 ± 4.7, 6.7 ± 2.3 mins sitting, in TPA, in MVPA, respectively, and had 7.0 ± 1.9 sitting breaks per hour, at home. Most participating parents were female (83%), owned their home (86%), held a university degree (54%) and lived in the highest socioeconomic status (SES) location (59%). Most parents had a ‘maximum h/day of screen-time’ rule (69%) and considered engaging in active play at home ‘important’ or ‘very important’ for their child (75.4%) and watching TV/movies (68%) and playing electronic games/using computer (65%) at home as ‘un-important’ or ‘very un-important’ for their child. On average, parents also reported that both they and their child enjoyed sedentary and PA activities at home ‘about equal’. Homes had 11.5 ± 2.1 rooms/areas, with a large proportion having an open plan living area (57%). Homes, on average, had 27.7 ± 18.3 items of PA equipment, 2.0 ± 2.1 musical instruments, 11.6 ± 4.7 media equipment items overall, and 1.9 ± 1.7 media equipment items in the primary child's bedroom. Lastly, homes mainly had digital TV subscriptions (82%), 3-4 smartphones and movie/TV streaming service access (77%).

Table 21. Participant characteristics and descriptive statistics.

Variable	**Mean (SD) or %**	***n***
Parent Characteristics		
Parent age	41.5 (5.7)	211
Parent gender (% female)	83%	213
Parent ethnicity		213
White	91%	
Ethnic minority	9%	
Parent education		207
Secondary school or lower	12%	
Diploma/Trade	34%	
University degree or higher	54%	
Pre-tax annual household income **		200
<£10, 000 - £30, 000	22%	
>£30, 000 - £70, 000	55%	
>£70, 000 - >£100, 000	23%	
Child Characteristics		
Child age	10.2 (0.7)	233
Child sex (% girl)	55%	235
Child BMI-z-score	0.6 (1.1)	233
Family Characteristics		
Number of siblings (< 18 yrs) at home	1.2 (0.9	213
Number of people at home	4.1 (1.1)	213
Family situation		213
Single parent/other	19%	
Two parent	81%	
Home ownership		213
Rent	14%	
Own	86%	
SES (based on WIMD scores) **		220
Low	14%	
Medium	27%	
High	59%	
Home Characteristics		
Objectively measured house size ($m^{2)}$	145 (52.1)	207
Objectively measured garden (i.e., front and back) size (m^2)	269.0 (166.7)	214
Audit Variables		
Total no. of rooms/areas **	11.5 (2.1)	210
Presence of an open plan living area (% yes)	57%	211
Equipment variables		
*No. of PA equipment items ** *	27.7 (18.3)	210
PA equipment accessibility and availability score	86.7 (63.1)	209
*No. of media equipment items ** *	11.6 (4.7	210
Media equipment accessibility and availability score	44.2 (18.2)	209
*No. of bedroom media equipment items ** *	1.9 (1.7)	212
Bedroom electronic media accessibility and availability score	6.9 (6.3)	210
*No. of musical instrument items ** *	2.0 (2.1)	210
Musical instrument accessibility and availability score	7.2 (7.5)	209
Electronic Media		

TV service		213
Digital (e.g., SKY, BT etc…)	82%	
Freeview or other	18%	
Number of smartphones (mode)	3-4	213
Social and Individual Factors		207
Child activity preferences at home [2]	3.3 (0.8)	
Parent activity preferences at home [2]	3.3 (0.7)	
Parent perceived importance of active play at home for child [3]	4.0 (0.8)	
Parent perceived importance of watching TV/movies at home for child [3]	2.2 (0.7)	
Parent perceived importance of playing electronic games or using the computer for fun at home for child [3]	2.3 (0.8)	
Maximum h/day of screen-time rule (% yes)	69%	206
Additional variables		
Daylight hours (h/day)	13 (3.4)	
Behaviour Variables		
Home-based activPAL outcomes		207
Full days of activPAL wear at home	5.3 (1.1)	
h/full day of activPAL wear at home	5.8 (1.6)	
Min/h spent sitting, % of time at home*		
Overall	40.3 (5.9), 67%	
Number of sitting breaks/h		
Overall	7.0 (1.9)	
Home-based ActiGraph outcomes		214
Full days of ActiGraph wear at home	5.5 (0.9)	
h/full day of ActiGraph wear at home	5.8 (1.6)	
Min/h spent in MVPA, % of time at home*		
Overall	6.7 (2.3), 11%	
Min/h spent in TPA, % of time at home*		
Overall	21.6 (4.7), 36%	

[1]1=strongly disagree; 5=strongly agree
[2] 1=almost always - sedentary; 5=almost always – PA
[3]1=very unimportant; 5=very important
*%=proportion of time at home
**=Displayed as tertiles for descriptive purposes only

9.4.1. Clustering of activity related social and physical environmental factors

Six home environment clusters were identified in the PCA (Table 2). The first cluster included high parental preference for PA activities at home, low accessibility and availability of media equipment both overall, and in the primary child's bedroom, as well as no access to a movie/streaming service ('low availability and accessibility of electronic media equipment' cluster). Cluster two included larger house and garden sizes and a high accessibility and availability of PA equipment ('favourable PA physical environment' cluster). Cluster three combined low importance assigned to their child watching TV/movies and playing electronic games/computer for fun by parent with the presence of a screen-time rule ('positive screen-time social environment' cluster). Cluster four included high parental preference for PA activities at home, the presence of a screen-time rule, high importance placed on active play for child by parent and a high accessibility and availability of PA equipment ('positive social and physical PA environment' cluster). Cluster 5 combined access to a TV/movie streaming service with the presence of an open plan living area ('open plan living area and streaming service' cluster). The final cluster, cluster 6, consisted of high smartphone availability, low accessibility and availability of musical instruments and access to digital TV ('high smartphones availability and access to digital TV' cluster). As Cluster 5 did not have at least three loading items, it was not included for the remainder of the analyses [454]. The five retained clusters explained 62.9% of the variance in the original items.

Table 22. Component loadings of principal component analysis on social and physical home activity related factors.

Variable	**Cluster 1: Low availability and accessibility of electronic media equipment**	**Cluster 2: Favourable PA physical environment**	**Cluster 3: Positive screen-time social environment**	**Cluster 4: Positive social and physical PA environment**	Cluster 5: Open plan living area and streaming [1]	**Cluster 6: High smartphones availability and access to digital TV**
Media equipment [2]	**-0.788**	0.156	-0.004	0.041	0.023	0.260
Bedroom media equipment [2]	**-0.754**	-0.283	-0.017	0.044	0.067	-0.014
House size	0.103	**0.868**	-0.008	-0.019	0.004	0.063
Garden size	0.062	**0.804**	0.071	-0.016	0.145	-0.190
Importance of using electronic games/computer for fun [3]*	0.188	-0.025	**-0.806**	-0.141	-0.031	-0.034
Importance of watching TV/movies [3]*	-0.140	-0.010	**-0.798**	0.081	0.042	-0.035
Importance of active play [3]	-0.278	-0.126	-0.043	**0.679**	0.011	-0.303
Max hrs/day of screen-time rule	0.149	0.078	**0.370**	**0.656**	0.009	-0.045
Parental activity preferences	**0.406**	0.014	-0.252	**0.584**	0.272	0.287
PA equipment [2]	-0.279	**0.446**	-0.115	**0.470**	-0.319	0.119
Open plan living area	0.027	0.058	-0.059	0.127	**0.779**	-0.133
Streaming	**-0.410**	0.090	0.088	-0.180	**0.577**	0.147
Smartphones	-0.268	0.141	-0.122	-0.050	-0.089	**0.718**
Musical instruments [2]	-0.140	0.321	-0.183	-0.135	-0.054	**-0.546**
Digital TV	-0.049	-0.056	0.055	-0.108	-0.024	**0.416**

[1] Cluster 5 was not considered for further analysis due to it having less than three loading items. [2] Accessibility and availability equipment summary score. [3] Parent perceived importance of activities for their child. *Item reversed.
Data printed **bold** indicate component loadings larger than 0.4 (= part of the component).
Variance explained by component 1= 15.2%; variance explained by component 2 = 13.3%; variance explained by component 3 = 10.5%; variance explained by component 4 = 9.1%; variance explained by component 5 = 7.8% and variance explained by component 6 = 7.0%.

9.4.2. Associations between clusters and child, parental and family background characteristics

The regression analyses assessing associations between the background characteristics and clusters (Table 3) revealed that children who had a greater preference for PA activities at home (β = 0.17, p = 0.02), with ethnic minority (β = -0.21, p = < 0.01) and high-educated parents (β = 0.23, p = < 0.01) scored significantly higher on the 'low accessibility and availability of electronic media equipment' cluster. The 'favourable PA physical environment' cluster was associated with a lower child BMI (β = -0.17, p = 0.01), a non-two parent household (β = -0.15, p = 0.05), more people at home (β = 0.19, *p* = 0.01), a higher income (β = 0.36, *p* = <0.01) and parental age (β = 0.17, *p* = 0.02). Further, children with a preference for PA activities at home scored significantly higher on the 'positive screen-time social environment' cluster (β = 0.16, *p* = 0.03). Children with a greater preference for PA activities at home (β = 0.40, *p* = <0.01) and a lower BMI (β = -0.18, *p* = 0.01) scored significantly higher on the 'positive social and physical PA environment' cluster. Finally, children with more people at home (β = 0.22, *p* = <0.01), in a rented house (β = -0.16, *p* = 0.05), and with a lower WIMD value (β = 0.17, *p* = 0.03) scored higher on high smartphone availability and access to digital TV (Cluster 6).

Table 23. Child, family and parental characteristics associated with cluster scores.

Variable	Cluster 1: Low accessibility and availability of electronic media equipment		Cluster 2: Favourable PA physical environment		Cluster 3: Positive screen-time social environment		Cluster 4: Positive social and physical PA environment		Cluster 6: High smartphones availability and access to digital TV	
	β	*p*	β	*p*	β	*p*	β	*p*	β	*p*
Child characteristics										
Child BMI z-score	–	–	-0.17	0.01*	–	–	-0.18	0.01*	–	–
Child activity preferences	0.17	0.02*	–	–	0.16	0.03*	0.40	<0.01*	–	–
Parental characteristics										
Parent age	-0.13	0.06	0.17	0.02*	–	–	–	–	0.15	0.06
Ethnicity: White (0) vs ethnic minorities (1)	-0.21	<0.01*	–	–	–	–	–	–	–	–
Education	0.23	<0.01*	–	–	–	–	–	–	–	–
Household income	–	–	0.36	<0.01*	–	–	–	–	–	–
Family situation	–	–	-0.15	0.05*	–	–	–	–	–	–
Family characteristics										
Number of people	–	–	0.19	0.01*	–	–	–	–	0.22	<0.01*
Home ownership	–	–	–	–	–	–	–	–	-0.16	0.05*
WIMD	–	–	–	–	–	–	–	–	-0.17	0.03*

Adjusted for age, BMI, activity preferences and sex of the child, the number of people at home, home ownership, household income, family situation, raw WIMD scores, daylight hours as well as the parent's age, sex, ethnicity and educational status; * relationship is significant.[1] R^2=0.18, [2] R^2=0.27, [3] R^2=0.05, [4] R^2=0.26, [5] R^2=0.09.

9.4.3. Correlations between clusters and home-based behavioural outcomes

Partial correlations between the home-based behavioural outcomes and the clusters (Table 4) showed that the low accessibility and availability of electronic media equipment cluster was negatively associated with home-based sitting (*r* = -0.19, *p* = 0.02). The favourable PA physical environment (*r* = 0.22, *p* = 0.01) and the positive social and physical PA environment (*r* = 0.17, *p* = 0.04) clusters were positively associated with the number of home-based sitting breaks. The high smartphones availability and access to digital TV cluster showed negative associations with the number of home-based sitting breaks (r = -0.25, p = < 0.01), TPA (r = -0.20, p = 0.01) and MVPA (r = -0.24, p = <0.01), as well as a positive association with home-based sitting (r = 0.23, p = < 0.01).

Table 24. Associations between cluster scores and home-based behaviours.

Cluster	Home-based sitting time		Home-based sitting breaks		Home-based TPA		Home-based MVPA	
	r	*p*	*r*	*p*	*r*	*p*	*r*	*p*
1: Low availability and accessibility of electronic media equipment	-0.19	0.02*	0.11	0.19	0.12	0.13	0.12	0.14
2: Favourable PA physical environment	-0.11	0.17	0.22	0.01*	0.11	0.16	0.12	0.14
3: Positive screen-time social environment	0.02	0.82	0.06	0.45	0.04	0.59	0.05	0.49
4: Positive social and physical PA environment	0.04	0.60	0.17	0.04*	0.09	0.27	0.02	0.76
5: High smartphones availability and access to digital TV	0.23	<0.01*	-0.25	<0.01*	-0.20	0.01*	-0.24	<0.01*

Adjusted for age, BMI, activity preferences and sex of the child, the number of people at home, home ownership, household income, family situation, raw WIMD scores, daylength as well as the parent's age, sex, ethnicity and educational status. *correlation is significant (2-tailed).

9.5. Discussion

The primary aim of this study was to investigate the clustering of physical and social activity related factors within the home. A secondary aim was to explore whether these clusters were associated with child, parent and family characteristics, and with home-based behavioural outcomes. Whilst the lack of previous studies examining the clustering of activity related social and physical factors, particularly within the home, enhances the novelty of the current research, it precludes comparisons with other studies. As hypothesized, we found evidence for clustering of physical and social factors within the home. These clusters were also shown to be associated with home-based behavioural outcomes, as well as child, parent and family characteristics. Socioeconomic related factors seem to be particularly influential, with three of the five clusters being associated with such variables in the expected directions.

The strong associations observed between the clusters and socioeconomic factors is consistent with other studies which have found socioeconomic indicators to be important factors defining population sub-groups in relation to youth obesity risk [289,455]. Specifically, parental education is thought to point to a broader context in which parental practices are implemented [456]. The low accessibility and availability of electronic media equipment cluster may reflect a supportive parental context, and it was more likely to be found in high-educated parents, but also in ethnic minority groups and children with a preference for PA at home. Another healthy cluster, the favourable PA physical environment, was also more likely to be found in families with a higher income. In contrast, according to the literature unhealthy clusters are more likely to be found in low SES groups [288,289,457]. Our finding that WIMD scores, another commonly used measure of SES, were negatively associated with the occurrence of the high smartphone availability and access to digital TV cluster is consistent with this. These findings may reflect the long-standing relationship between SES and health, whereby those socioeconomically better off generally have healthier lifestyles [458]. Taken together, these findings suggest that low SES households are an important group to target in interventions seeking to create healthier physical and social home environments in relation to children's PA and sitting.

The positive social and physical PA environment cluster, characterised by positive screen-time related social factors and a high PA equipment presence at home, is congruent with studies that have found low parental sedentary behaviour and high PA equipment accessibility to co-occur [288,289]. This type of cluster may arise because the perceptions/strategies exhibited are indicative of a parenting style that reflects a healthy lifestyle based on habits formed in life and health beliefs [459]. The role modelling of a healthy lifestyle may positively influence children's health cognitions and choices [460], and therefore reduce the likelihood of obesity, which may explain why the cluster was more likely to be found in children with a lower BMI. Similarly, to the positive social screen-time cluster, children with a preference for PA were more likely to be found in this cluster. Indeed, the PA and screen-time supportive practices specifically are likely to affect children's understanding of the importance of PA and harmful effects of screen-time and consequently their activity preferences [461]. This combination of increased preference for PA and reduced BMI paired with a healthful physical and social home environment may explain why this cluster was associated with increased sitting breaks at home.

The favourable PA physical environment cluster was more likely to be found in families with older parents and a higher income. It seems these families have sufficient financial resources which they use to provide a physical environment conducive to PA. Similar to the positive social and physical PA environment cluster, this cluster was also associated with increased sitting breaks and a healthier weight status in children. The greater space inside and outside, coupled with more available PA equipment, may provide more opportunities for breaking up screen-based sedentary activities [383]. Again, given the relationship between income and health, this cluster may also denote parents who use health-promoting practices which have been associated with healthier weight status in children [462].

The high smartphone availability and access to digital TV cluster was associated with all four home-based behavioural outcomes in the hypothesised directions, suggesting it is highly relevant. This cluster was most likely to be found in families who lived in a deprived area (based on WIMD), in a rented home. The greater presence of smartphones and digital TV in the households of these families with limited resources, whilst surprising, is congruent with previous research which shows lower SES families own more electronic media equipment than higher SES families [246,311]. This suggests that the socioeconomic differences in electronic media equipment access are not driven by financial factors. In the case of this cluster, parents living in poorer neighbourhoods have more safety concerns [463], less time to supervise children's active play [464] and lack access to structured PA and play areas [298], making screen-based entertainment a more convenient alternative to PA. Similarly, parents with a lower educational level, another indicator of low SES, scored lower on the low accessibility and availability of electronic media equipment cluster. This cluster was also negatively associated with home-based sitting. Three of the four factors forming this cluster have been associated with increased screen-time [41,235], a particularly prevalent sedentary behaviour. Therefore, the combination of the factors may be having an important synergistic effect on children's sitting at home.

One of the keys strengths of this study is the clustering approach, which, to our knowledge, has only been used in two previous studies investigating parenting practices [288,289]. Indeed, the present study provides an insight into how physical and social factors within the home cluster, thereby enabling more effective interventions through targeting multiple factors simultaneously. Further strengths include, but are not limited to, the use of the validated audit to comprehensively assess the home physical environment [299], the investigation of home-specific environmental factors and home-based behaviours, as well as the objective measures of behaviours. Nonetheless, the study is not without limitations. First, information on the physical and social environment was only obtained from one parent. The other parent may have been more influential, with some studies indicating that the father is the most likely role model for boys' PA, whereas mothers are for girls [272,465]. However, the number of parents was adjusted for in each analysis. Additionally, PCA is not a confirmatory, but an exploratory method, and therefore does not produce definitive clusters. Indeed, the clusters yielded from the analyses are strongly influenced by researcher-led decisions, particularly which factors are included in analyses [466]. The factors were chosen based on theoretical rationales and whether they have been related to children's PA and sedentary time in previous studies. The cross-sectional nature, and therefore the inability to infer causal relationships, coupled with the reliance on self-report data for identifying social factors and periods when the child was at home, were also limitations.

9.6. Conclusion

In conclusion, the findings provide evidence of clustering or co-occurrence of some physical and social activity related factors within the home. The clusters were shown to be associated with several parental, child and family characteristics, with socioeconomic factors particularly influential. Specifically, healthy and unhealthy clusters were more likely to be found in high and low SES groups, respectively. The healthy and unhealthy clusters were positively associated with favourable (PA and sitting breaks) and negative (sedentary time) behaviours, respectively. This indicates that the effects on PA and sedentary behaviour may increase synergistically when several factors occur simultaneously. Nonetheless, whilst further research is required to determine why clusters of physical and social factors occur in certain SES groups, interventions which target clusters of social and physical factors within the home, especially among low SES families, are warranted.

Thesis map

Study	Aims	Key findings
1. Relationship between Sedentary Time, Physical Activity and Multiple Lifestyle Factors in Children	To explore associations between multiple lifestyle factors and being sufficiently active ($\geq$60 min·day^{-1}) or engaging in excessive screen-time ($\geq$2 h·day^{-1}) in children.	Sufficient MVPA and excessive screen-time were associated with healthy and unhealthy factors, respectively, with relationships sometimes differing by sex. Specifically, fruit and vegetable consumption and CRF were positively associated with sufficient MVPA, irrespective of sex. Excessive screen-time was positively associated with sugary snack consumption in boys and girls, and diet soft drink intake in boys ($p < 0.05$). In addition, excessive screen-time was negatively associated with MVPA before school for both boys and girls, as well as with sleep duration and fruit and vegetable consumption for girls ($p < 0.05$).
2. Validity and reliability of the HomeSPACE-II instrument to assess the influence of the home physical environment on children's physical activity and sedentary behaviour	To test the criterion validity and reliability of the HomeSPACE-II instrument.	The study revealed that most items, outside of accessibility and size measures, had strong reliability and validity. Therefore, the HomeSPACE-II is a valid and reliable instrument for measuring physical factors that influence children's physical activity and sedentary behaviour within the home.
3. Associations between the Home Physical Environment and Children's Home-Based Physical Activity and Sitting	To investigate the relationship between characteristics of the physical home environment and children's home-based sitting, PA, standing and sitting breaks.	An open plan living area (OPLA), musical instrument accessibility and availability, and perceived house size were negatively and positively associated, whereas media equipment accessibility and availability was positively and negatively associated with sitting and standing, respectively. Additionally, an OPLA was positively associated with total and moderate-to-vigorous PA. Furthermore, sitting breaks were positively associated with objective garden size and negatively associated with digital TV. The physical home environment has an important influence on

		children's sitting, standing and PA at home.
4. Are parental and child activity preferences and priorities, as well parental rules at home associated with children's home-based behaviour and the home physical environment	To investigate the influence of parental priorities, preferences and rules regarding activity at home on: (i) children's home-based overall sitting time, breaks in sitting, and PA, and; (ii) the home physical environment.	The findings suggest that parental activity preferences, priorities and rules are not only directly associated with children's sitting and PA, particularly during weekdays, but also indirectly via the physical environment within the home. Parental activity preference had the greatest influence on the physical home space and child activity preference was the strongest correlate of children's behaviour at home.
5. Clustering of home physical and social environmental factors	To investigate clustering of social and physical factors within the home, and how these clusters are related to home-based sitting, sitting breaks, MPVA and total physical activity (TPA). Associations of parental, family and child characteristics with the clusters were also examined.	The findings show that physical and social activity related home environmental factors cluster. The clusters were shown to be associated with several parental, child and family characteristics, with socioeconomic factors appearing to be particularly influential. The clusters were also associated with home-based PA and sitting in the hypothesised directions.

10. Thesis synthesis

10.1. Summary

The overarching aim of this thesis was to investigate the relationship between the home environment and children's sedentary behaviour and PA at home. This thesis was meticulously thought out, with each study addressing a gap/rationale. The aim has been met with 5 studies, each providing novel and valuable insight for researchers. The evidence from study 1 that PA and sedentary behaviour are strongly related with important health related factors among children in Swansea who largely do not meet PA and sedentary guidelines, highlighted the need for correlate research in this population. The development of a robust comprehensive measure of the physical environment in relation to children's PA and sedentary behaviour at home, will enhance the evidence base on correlates of PA and sedentary behaviour in children through its use. Given the environment is recognised to be an important sphere of influence on behaviour [37], and that children spend significant time at home [38,39] accumulating a high proportion of their PA and sedentary time [40], the identification of correlates within this environment will provide particularly valuable insight for interventions.

Chapter 1 described the evidence demonstrating the high prevalence of inactivity and sedentary behaviour in children. Such high rates are of concern, given the discussed physiological and psychological benefits and detriments of PA [6] and sedentary behaviour [5] in children, respectively. Of the sedentary behaviours children engage in, screen-time is the most strongly associated with health and is the most prevalent [5]. Ubiquitous lifestyle factors important to children's health such as sleep, diet and CRF have been associated with children's PA [6,89,323] and screen-time [83,85,88]. However, research investigating associations between lifestyle factors and PA is lacking, specifically amongst British children. Further, previous studies have only assessed relationships between lifestyle factors and MVPA or screen-time in isolation. The investigation of both relationships simultaneously in the same sample would allow an improved understanding of the associated lifestyle factors, as well as providing valuable insight for future interventions. To address such gaps in the literature, the first study of this thesis explored associations between multiple lifestyle factors and being sufficiently active ($\geq$60 min·day^{-1}) or engaging in excessive screen-time ($\geq$2 h·day^{-1}) in children.
Study 1 provides much needed insight on associations between lifestyle factors and PA in British children, as well allowing a better understanding of associations between lifestyle factors, PA and screen-time, by assessing relationships simultaneously. This chapter found that sufficient MVPA and excessive screen-time were associated with healthy and unhealthy factors, respectively, with relationships sometimes differing by sex. Such findings support the importance of increasing children's PA and reducing their sedentary time, given the associations between the measured lifestyle factors and obesity in children [5,320]. Additionally, the children in the study on average were not sufficiently active for 3 days a week and engaged in excessive screen-time for 4 days a week, suggesting that more insight into the correlates of these behaviours was needed.

Identifying the correlates of PA and sedentary time is key to the development of successful interventions [35]. The home is thought to be a significant sphere of influence on children's PA and sedentary time [41].Therefore the following chapters focused on improving understanding of these behaviours in the home, to inform effective evidence-based interventions. Within the home, social and physical environmental factors and individual characteristics have been shown to influence children's sedentary time and PA [43]. According to ecological models, the environment has a particularly important influence [37]. Whilst a large body of evidence exists on the social environment of the home, research investigating the physical environment, beyond PA and electronic media equipment, is lacking [41]. Therefore, particular attention was paid to the physical environment of the home in the following studies, whilst still recognising the important influence of the social environment.

Valid and reliable comprehensive measures of the environment are essential to improving understanding of how the home environment influences children's PA and sedentary time. Whilst the HomeSPACE-I instrument is a comprehensive measurement tool with proven validity and reliability, it was tested for use in Western Australia in mostly one-storey homes which differ in layout and design to two-storey homes which are commonplace in the UK. Further, it only measures an item's availability, and not its accessibility. Therefore, study 2 developed HomeSPACE-II, an instrument for use in two-storey homes, with a measure of accessibility, to comprehensively measure the physical environment in relation to children's home-based PA and sedentary time. It was revealed that most items, including availability, average accessibility and the combined accessibility and availability summary scores, but excluding some specific accessibility ratings and size measures, had strong reliability and validity. This suggests it can be independently used by parents to measure aspects of the physical environment of homes that may influence children's PA and sedentary time. Therefore, it was used as a measure of the home physical environment in study 3 and thereafter.

Although there is an emerging evidence base on the influence of the home physical environment on children's PA and sedentary time, it is largely limited to PA and media equipment and findings are inconsistent [41]. Research has also been hampered by the reliance of self-report surveys to measure the environment and the lack of studies measuring home-based behaviour [41]. The indoor physical environment has received limited attention compared with the outdoor environment [41]. However, this environment is particularly relevant in the UK, given its temperamental climate [389] forcing children indoors [38]. Thus, study 3 sought to assess associations between objectively measured home physical environment, with a particular focus on the indoor environment, on children's home-based PA, standing, sitting breaks and sitting time.

Study 3 showed that some aspects of the home physical environment have an important relationship with children's sitting, standing and PA at home, even after adjusting for socio- demographic and social factors. The home physical environment was found to be most strongly associated with TPA, sitting and standing, therefore future home-based interventions should concentrate on targeting these behaviours. Of note, some relationships were strongly attenuated or strengthened with the addition of social environmental and individual characteristics to the models. Given these confounding effects, and the previously demonstrated influence of the social environment, interventions seeking to create home environments conducive to PA, need to consider the social environment in their design. Whilst a large body of evidence exists on the influence of the home social environment on children's PA and sedentary time, few studies have investigated associations between home-specific factors and home-based behaviours. Further, it was not known which social and individual factors influence how parents create their home physical environments, such research would provide invaluable information to interventions seeking to create home environments more conducive to PA and give insight into the pathways by which parents influence their children's PA and sedentary time. Therefore, study 4 investigated the influence of home-specific social and individual factors on: (i) children's home-based sitting time, breaks in sitting, and PA, and; (ii) the home physical environment.

In the study, parental and child preferences and priorities, as well as parental rules for leisure activity at home, were associated with children's sitting and PA at home, particularly during weekdays. They were also associated with factors related to leisure activity in the physical environment, providing evidence that they may also be indirectly associated with children's PA and sitting via the physical environment. This finding adds to the evidence that social factors are directly associated with children's behaviour. It is worth noting that parental factors had the strongest associations with the physical environment of the home. Indeed, qualitative research has shown that parents possess the control to structure their physical home space to align with their preferences and beliefs. Therefore, physical and social factors may cluster accordingly. Identifying which factors cluster would lead to more successful and economical interventions, through employing strategies which target more than one factor simultaneously. However, previous research investigating clustering of social and physical environmental factors was limited, but studies which investigate clustering of factors specific to the home were particularly lacking. Indeed, clusters of these factors could have an important synergistic effect on behaviour given that physical and social factors were shown to have strong associations with children's behaviour at home in study 3 and 4, respectively. Fittingly, the last study, study 5, investigated clustering of physical and social leisure activity related factors within the home, and their relationships with home-based sitting and PA outcomes in children. Since an understanding of how clusters arise is imperative to any interventions applying a cluster approach, associations of parental, family and child characteristics with clusters were also explored.

As hypothesised, study 5 found evidence of physical and social factors co-occurring within the home, which is in line with the few studies that have examined clustering of parenting practices [288,289]. In addition, clusters were related to children's home-based behaviours in the expected direction: healthy clusters (i.e., low accessibility and availability of electronic media equipment) and the unhealthy cluster of high smartphones availability and access to digital TV were positively associated with positive behaviours (i.e., PA and sitting breaks) and negative behaviours (i.e., sedentary time), respectively. Taken together, the findings suggest that when social and physical factors occur simultaneously within the home, they may have an important synergistic effect on children's behaviour at home. Interventions which focus on clusters of social and physical factors at home particularly among low SES groups seem warranted, albeit more nuanced research is needed to determine why some clusters are more likely to occur in certain SES groups.

In conclusion, given study 1 demonstrated the importance of meeting PA and sedentary behaviour recommendations in terms of health related lifestyle behaviours, and studies 3, 4 and 5 showed that the home environment has a significant relationship with children's PA, sedentary time and sedentary breaks, interventions targeting increases in PA and sedentary breaks as well as reductions in sedentary time in this environment are needed. Given the multitude of health benefits associated with sufficient PA [6] and the emerging, albeit preliminary, evidence that excessive sedentary behaviour, particularly of a prolonged nature is adversely associated with health outcomes [447], such interventions would have important implications for improving children's health. Additionally, increases in PA and reductions in sedentary time during childhood may also lead to improved health in adulthood, through delaying the onset of serious chronic diseases such as cardiovascular disease and some types of cancer [32], since behaviour habits have been shown to track from childhood to adulthood [31].

10.2. Strengths and limitations

The most important strength of this study is the novelty of the 5 studies. Study 1 provides much needed insight on the relationship between PA and diet in British children as well as an improved understanding of how PA and sedentary behaviour are related to lifestyle factors through the assessment of relationships simultaneously. The inclusion of the latest technology in the assessment of screen-time also advanced past work that focused exclusively on television viewing [85,334,335]. Additionally, the sample was socio-demographically representative of the population and many confounding factors were controlled for. The development of HomeSPACE-II, a comprehensive measure of the physical environment in relation to children's PA and sedentary behaviour at home, in study 2 was a particularly important step in this thesis, given its use in study 3 and thereafter. Although, the instrument was largely based on HomeSPACE-I [290], it builds on it by being tested for use in two storey homes and because it includes a wider range of PA equipment, and a measure of accessibility, as well as availability. Since HomeSPACE-II was also the first instrument of its kind to be rigorously tested for its reliability and validity outside of Australia and the USA, it may be the most appropriate measure of the home physical environment in countries which resemble the UK in terms of geographical and home characteristics. Study 3 was the first to examine relationships between several home physical environment factors and children's PA and sedentary behaviour and one of the first to measure home-based behaviour. The inclusion of both perceived and objective measures (i.e., GIS and the audit, which is more objective than surveys) as well as the high response rate were also strengths. Study 4 was the first study to examine associations between home-specific social factors and children's behaviour and the first quantitative study to provide such an in depth understanding of what individual and social factors may influence the creation of the home physical environment. Study 5 enables a unique understanding of how home-specific social and physical factors cluster as well as how they relate to children's home-based behaviour and background characteristics. The key strength of this study is the clustering method utilised, which had only been used twice previously to examine clustering of parenting practices [288,289]. The insight provided by this method will enable more effective interventions, through informing an approach that targets several factors simultaneously. Lastly, the use of objective measures to assess children's behaviour and the physical environment at home as well as the large number of variables controlled for in study 3 and thereafter, would have enhanced precision in determining meaningful relationships.

Despite the numerous strengths, several limitations should be acknowledged. The measure used to assess diet, MVPA, screen-time and sleep duration in study 1 may have introduced some measurement error. First, it was a self-report instrument, thus increasing the probability of making a type II error [169]. Second, the time-specific questions may not have been sensitive enough to provide reliable estimates of habitual behaviour. The over representation of high SES parents in study 2, may limit the generalisability of the Home-SPACE-II to other less affluent groups. Further, the subjective nature of some measures made validating them against a researcher a challenge. The reliance on self-report to determine when the children were at home for study 3 and thereafter was also a limitation, however there was no feasible alternative for measuring this objectively. Whilst the objective measures of house and garden were key strengths of studies 3-5, they may not reflect true size for the specific homes, given they only pertain to each postcode unit. The lack of data on social factors from both parents in studies 4 and 5 was also a limitation. Indeed, it is possible that the other parent was more influential in their child's behaviour, with some studies reporting gender differences in parental influence [272,465]. However, an attempt was made to partly overcome this limitation by controlling for the number of parents in each analysis. Principal component analysis, used to examine clustering of physical and social factors in study 5, is exploratory, and therefore not a confirmatory method capable of yielding definitive clusters. This means that decisions made by the researcher, such as which factors to include in the analysis, have a significant bearing on the clusters produced [466]. However, deciding which factors to include was an iterative process, based on theoretical rationale and previous findings.

10.3. Future directions

Study 1 is a good starting point for demonstrating the importance of meeting PA and sedentary behaviour recommendations in terms of health-related lifestyle factors. However, future studies should seek to confirm the findings by measuring diet, screen-time, MVPA and sleep duration over 7 days, which will provide more reliable estimates of habitual behaviour. Such studies should also use the most valid and reliable measures available to enhance measurement accuracy, specifically diary/logs for the assessment of diet and screen-time and accelerometers for the measurement of sleep duration and MVPA.

The high rates of inactivity and excessive screen-time observed in children also indicate a pressing need for more interventions which promote children's PA and reduce their sedentary behaviour. Given that multiple lifestyle factors, differing by sex, were associated with sufficient levels of MVPA and excessive screen-time in study 1, one approach could be to target change in multiple lifestyle behaviours in single sex interventions with sex-specific strategies. Single sex family-based interventions have been shown to be more effective than mixed-sex studies among girls [467,468]. In support of targeting multiple lifestyle factors, a recent review found targeting change in multiple health behaviours to be effective at increasing PA in school-based interventions [469]. In contrast, family-level interventions of the same design were shown to have little influence on PA [469]. The ease of delivery [470] and the additional approaches employed in school-based interventions such as school policy changes and whole-school implementation of intervention principles may explain their greater success. Indeed, further research is warranted on how to make such interventions work at the family-level.

The findings from this thesis demonstrate that the environment plays an important role in children's PA and sedentary behaviour at home. Specifically, the findings of study 3 and thereafter will provide the foundation for research helping to create home environments more supportive to PA and less conducive to sedentary behaviour. Whilst, most gaps in the literature were addressed in this thesis, several still remain. For example, greater insight into the context of PA and sedentary behaviour at home such as the type of behaviour being performed, where the behaviour is being performed and with whom [202] is urgently needed. Such contextual information would allow more specificity in the identification of PA and sedentary behaviour correlates, necessary for informing successful behaviour change interventions. According to social ecological models, there is an important link between location and behaviour [36,37], Therefore the objective measurement of where PA and sedentary behaviour occur at home is imperative. Such measurement would also allow researchers to determine time at home objectively. Bluetooth proximity monitoring using ActiGraph monitors holds most promise for inferring the location of children’s PA and sedentary behaviour at home. However, whilst BLE proximity monitoring has been shown to accurately measure location in adults within an office setting [209], its accuracy in the home environment among children is unknown. Wearable cameras can also measure location as well as the type of behaviour being performed and the social context [206], however the associated ethical and analytical issues complicate the use of such devices [218]. Similarly, their utility within the home environment among children is also unknown. Therefore, future research should seek to assess the feasibility of using wearable cameras and BLE proximity monitoring to assess the context of children’s behaviour in the home environment.

Given children spent a significant proportion of their time at home sitting (67 %) and the paucity of previous studies [41], home environment interventions are recommended. Based on the results from Study 3, changing the physical environment at home holds promise, particularly for increasing TPA and standing and reducing sitting. The results suggest strategies such as keeping electronic media in locations which enable parental supervision, making changes to furniture layouts to free up space, increasing time outdoors at home and introducing electronic media breaks could be effective. The layout of homes, although not examined in detail in this thesis, specifically the distance required to reach key destinations (i.e., kitchen, toilet etc..), may also affect children’s step counts and sitting time. Spatial software could be used to calculate spatial layouts using floor plans [209], and subsequently distances between different destinations. Based on this information, physical environments could be reconfigured to prompt incidental PA and discourage sitting. Additionally, if Bluetooth proximity monitoring was utilised to measure where behaviours occur, locations in which prolonged sitting is most likely to occur could be targeted. For example, if children spend a lot of time sitting in the lounge or their bedrooms, changes could be made in these locations to enhance movement. Given study 4 demonstrated that parents have a significant relationship with the physical environment at home, to give such interventions the best chance of success, negotiation with parents as well as the entire family on the design of the intervention is important to ensure buy in from all family members, but in particular the parents. Indeed, it is important that researchers gauge from families which strategies would be acceptable and practical before designing a tailored intervention. The results from study 4 also indicate that interventions need to provide education to parents on how to best support their child’s PA and restrict their sitting at home. Specifically, parents could be educated on the harmful effects of excessive screen-time and the importance of PA for all ages, strategies for limiting screen-time and increasing PA at home as well as how to create healthier home environments. Further, parents should be encouraged to model healthy behaviours including limiting screentime and participating in PA themseselves, promote particpation in PA as a family, and enforce limits on screen-time as well as help children find active alternatives. Since parental and child activity preferences were shown to be significant influences on the physical environment and children's home-based behaviour, respectively, changing activity preferences or finding equally enjoyable active alternatives to sedentary activities at home will also be an important challenge for future research. Although we acknowledge it will not be easy, one approach for increasing children's preference for PA is to target improvements in their fundamental movement skills (FMS), as mastery of FMS may lead to increased enjoyment of PA [446]. This in combination with limits on screen-based sedentary behaviours enforced by parents, will provide children with opportunities to experience active alternatives to sedentary activities, which they may enjoy equally as much, if not more. Parental activity preferences may be harder to change, as they are more ingrained. However, through provision of education of the importance of PA and detriments of sedentary behaviour, parents may perceive PA as more important, which may prompt them to create home environment more supportive of PA.

10.4. Final comments and reflections

This thesis has provided much needed insight into correlates of children's PA and sedentary behaviour that previously had received limited attention. In particular, the findings will allow a much-improved understanding of the relationship between the home environment and children's PA and sedentary behaviour at home. Study 1 investigated relationships between important health related lifestyle factors and sufficient levels of MVPA or excessive screen-time. The strong associations observed between the obesity related lifestyle factors and PA and sedentary behaviour reinforced the importance of promoting PA and discouraging sedentary behaviour in children. Additionally, the low rates of children meeting MVPA and sedentary behaviour guidelines also indicated that an improved understanding of the correlates of such behaviours was urgently needed to inform interventions. Given the recognised influence of the environment on children's PA and the significant time children spend at home, studies 2 and thereafter aimed to improve insight into the correlates of PA and sedentary behaviour in the home environment. There was a need for a comprehensive measure of the home physical environment in relation to children's PA and sedentary behaviour validated for use in two-story homes, therefore study 2 sought to develop HomeSPACE-II, an instrument which addressed the limitations of previous measures. Using HomeSPACE-II to measure the physical environment, study 3 examined associations between the home physical environment and children's home-based PA, standing, sitting breaks and sitting time. Certain aspects of the physical environment were shown to be significantly related, however some relationships were strongly confounded by social and individuals' factors. Due to the interaction observed between social and physical factors specific to the home and the established influence of the social environment, study 4 investigated how home-specific social and individual factors influence: (i) children's home-based sitting time, breaks in sitting, and PA, and: (ii) the home physical environment. Study 4 showed that parents control the formation of the physical home space to suit their preferences and attitudes, providing an indication that physical and social factors cluster accordingly. Identifying which physical and social activity related factors cluster at home will allow approaches which target more than one factor simultaneously, resulting in more effective and economical interventions. Previous research also suggested that clusters of such factors could have an important synergistic effect on children's behaviours. Thus, study 5 explored clustering of physical and social activity related factors at home, and how they relate to home-based PA and sedentary behaviour. Due to the necessity of understanding why clusters arise for interventions, associations of parental, child and family characteristics with clusters were also examined. The findings of this thesis support the importance of interventions which aim to increase PA and reduce sedentary behaviour in the home environment. The results from the individual studies can be utilised to inform the design and development of such interventions, as well as future research.

11. References

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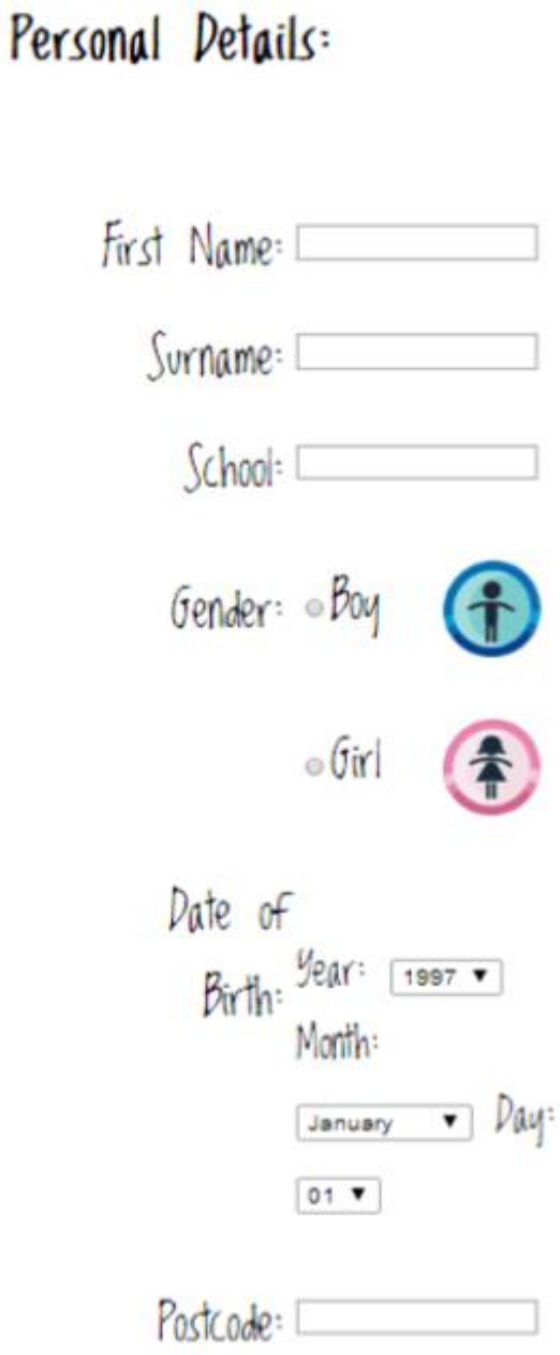
12. Appendices

Appendix I: Child health and activity tool: online questionnaire



Personal Details:

First Name:

Surname:

School:

Gender: Boy

Girl

Date of Birth: Year: 1997

Month: January

Day: 01

Postcode:

Do you consider yourself to have a disability?

○ Yes ○ No

☐ Wheelchair user ☐ Physical disability ☐ Visual impairment

☐ Hearing impairment ☐ Learning difficulty ☐ Other

0%

Forward →

CHAT

Child Health and Activity Tool

Firstly, think carefully about what you did <u>YESTERDAY</u> and then answer the following questions....

3%

← Back Forward →

1. What time did you get up <u>YESTERDAY</u>?

○ 05.00
○ 05.30
○ 06.00
○ 06.30
○ 07.00
○ 07.30
○ 08.00
○ 08.30
○ 09.00
○ Other Time:

2. What did you eat for breakfast <u>YESTERDAY</u>?

 Nothing

 Toast

 Cereal

 Cooked Breakfast

 Snacks

 Yoghurt

 Fruit

 Other

3. What did you have to drink for breakfast?

- ☐Nothing
- ☐Water
- ☐Milk
- ☐Fruit juice e.g. Orange juice, apple juice etc
- ☐Squash
- ☐Energy drink e.g. Lucozade Sport, Powerade, Red Bull
- ☐Fizzy Drink e.g. Coke, Sprite
- ☐Diet fizzy drink e.g. Diet Coke, Diet Fanta
- ☐Other:

4. a) <u>BEFORE LESSONS STARTED YESTERDAY</u>, how long did you spend doing sports or exercise? ↓

6. What did you do for <u>most</u> of your <u>MORNING</u> break <u>YESTERDAY</u>? Please only tick one option.

This includes sitting down talking to friends, watching TV, reading, doing homework and using the computer

Sat around inside or outside

This includes doing any activities or playing sports where your heart beats fast, you breathed faster and you felt warmer

Ran around

Stood around

This includes doing any activities or playing sports where your heart beats fast, you breathed faster and you felt warmer

Ran around

Stood around

Walked around

7. a) What did you have to eat for lunch?

School Dinner

Packed Lunch

Nothing

b) What did you have to drink for lunch?

Water

Fruit Juice

Fizzy Drink

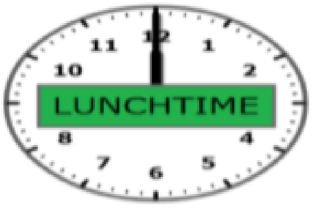
Diet Fizzy Drink

Squash

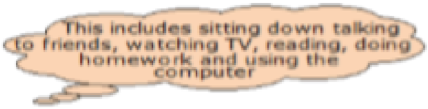
Energy Drink

Milk

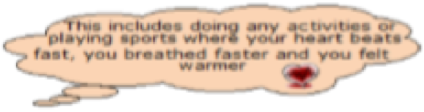
Nothing



8. Apart from eating your food, what did you do for <u>MOST</u> of your lunchtime <u>YESTERDAY</u>? Please only tick one option.



 Sat around inside or outside

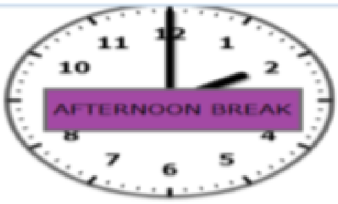


 Ran around

 Stood around

 Walked around

---



9. What did you do for most of your afternoon break <u>YESTERDAY</u>?

 Didn't have an afternoon break

This includes sitting down talking to friends, watching TV, reading, doing homework and using the computer

Sat around inside or outside

This includes doing any activities or playing sports where your heart beats fast, you breathed faster and you felt warmer

Ran around

Stood around

Walked around

10. ***How did you get home YESTERDAY?***

On the bus

On bike

In the car/taxi

Walked

Ran/jogged

Scooter

Skateboarded/Rollerbladed

Did you travel with an adult?

- Yes
- No

11. a) <u>AFTER SCHOOL YESTERDAY</u>, how long did you spend doing sports or exercise? ↓

No time at all	10 minutes	20 minutes	30 minutes	40 minutes	50 minutes	1 hour
Between 1 and 2 hours	Between 2 and 3 hours	More than 3 hours				

b) <u>AFTER SCHOOL YESTERDAY</u>, how long did you spend sitting down watching TV/playing computer games/using IPAD or internet? ↓

No time at all	10 minutes	20 minutes	30 minutes	40 minutes	50 minutes	1 hour
Between 1 and 2 hours	Between 2 and 3 hours	More than 3 hours				

c) <u>AFTER SCHOOL YESTERDAY</u>, how long did you spend doing homework/reading? ↓

No time at all	10 minutes	20 minutes	30 minutes	40 minutes	50 minutes	1 hour
Between 1 and 2 hours	Between 2 and 3 hours	More than 3 hours				

12. How many portions of fruit and vegetables did you eat yesterday?

○0 ○1 ○2 ○3 ○4 ○5 ○6 ○7

13. How many times did you brush your teeth yesterday?

0  1

 2  More Than 2

14. What time did you go to sleep? 

○7pm	○7.30pm
○8pm	○8.30pm
○9pm	○9.30pm
○10pm	○10.30pm
○11pm	○11.30pm
○12am	○Other Time:

Well done you are half way through! 

50%

15. Now think about what you did in the last *WEEK*......(INCLUDING THE WEEKEND)

This includes doing any activities or playing sports where your heart beats fast, you breathed faster and you felt warmer

a) How many days of the week did you do sports or exercise for at least an hour in total?

- 0
- 1
- 2
- 3
- 4
- 5
- 6
- 7 Days

b) How many days of the week did you watch TV/play on consoles/use IPAD/use the internet etc for 2 or more hours a day?

- 0
- 1
- 2
- 3
- 4
- 5
- 6
- 7 Days

c) How many days of the week did you feel tired?

- 0
- 1
- 2
- 3
- 4
- 5
- 6
- 7 Days

d) How many days of the week did you feel like you could concentrate/focus well in class?

- 0
- 1
- 2
- 3
- 4
- 5 Days

e) How many days of the week did you drink at least one fizzy drink e.g. coke, fanta, sprite?

- 0
- 1
- 2
- 3
- 4
- 5
- 6
- 7 Days

f) How many days of the week did you drink at least one <u>DIET</u> fizzy drink e.g. Diet coke, diet fanta?

- 0
- 1
- 2
- 3
- 4
- 5
- 6
- 7 Days

g) How many days of the week did you eat at least one sugary snack e.g. sweets/chocolate/cake?

- 0
- 1
- 2
- 3
- 4
- 5
- 6
- 7 Days

h) How many days of the week did you eat take away foods e.g. McDonalds, KFC, chinese?

- 0 - 1 - 2 - 3
- 4 - 5 - 6 - 7 Days

i) How many days of the week did you eat fish?

- 0 - 1 - 2 - 3
- 4 - 5 - 6 - 7 Days

16. What type of bread do you eat?

 I don't eat bread

 White

 Brown/wholemeal

 50:50

17. What type of milk do you drink?

 I don't drink milk

 Whole milk

 Semi-skimmed milk

 Skimmed milk

18. What sport clubs or physical activities do you take part in at least once a week?

<u>IN SCHOOL:</u> (this does <u>not</u> include PE)

Nothing	Athletics
Badminton	Basketball
Cricket	Dance
Football	Golf
Gymnastics	Hockey
Netball	Rounders
Rugby	Swimming
Tennis	Other

<u>OUT OF SCHOOL:</u>

Nothing	Athletics
Badminton	Basketball
Cricket	Cycling
Dance	Football
Golf	Gymnastics
Hockey	Martial Arts
Netball	Rock Climbing
Rounders	Rugby
Skateboard	Swimming
Tennis	Trampolining
Water Sports	Other

19. Are you a member of cubs, brownies, guides or scouts?

 Yes  No

20. WHO do you <u>usually</u> take part in physical activity or sport with?

IN SCHOOL:

 On your own

 With Friends

 With Parents/Guardians

 With Brother/Sister

 Other:

OUT OF SCHOOL:

 On your own

 With Friends

 With Parents/Guardians

 With Brother/Sister

 Other:

21. How many times a week do your parents/guardians do exercise or sport (This includes going for a run or going to the gym)?

Parent/Guardian 1: Female Male

- Not at all
- 1-2
- 3-4
- 5 or more

Parent/Guardian 2: Female Male
(Optional)

- Not at all
- 1-2
- 3-4
- 5 or more

22. Where can you play at home/in the surrounding area that you can <u>walk to</u>?

 Nowhere

 Backyard

 Garden

 Grassy area/playing field

 Playground

 Park

 On the street

 Leisure/sport centre

 School

23. Which of these physical activities or sports would you like to do more of?

 Athletics

 Netball

 Rugby

 Cricket

 Tennis

 Dance

 Swimming

 None of these

 Other

24. What physical activities or sports would you like to take part in that you have <u>not</u> tried before?

25. Can you ride a bike?

 Yes

 No

26. a) Can you swim?

 Yes

 No

26. b) Can you swim 25 metres?

 Yes

 No

27 How do you feel about:

a) Your health: 

b) Your fitness: 

c) Your school: 

d) Your family: 

e) Your friends: 

28. Now tell us whether you agree or disagree with the following

a) I am doing well at school:

Strongly disagree	Disagree	Don't agree or disagree	Agree	Strongly agree
✗	✗		✓	✓

b) I have lots of choice over things which are important to me

Strongly disagree	Disagree	Don't agree or disagree	Agree	Strongly agree
✗	✗		✓	✓

c) There are lots of things I am good at

Strongly disagree	Disagree	Don't agree or disagree	Agree	Strongly agree
✗	✗		✓	✓

29. What do you think could be done in your local area to improve the health of children?

CHAT

Child Health and Activity Tool

Well done, you've completed the questionnaire.

Thank you!

Start again

100%

Appendix II: Standard operating procedure for child health and activity tool

Standard Operating Procedure

For

Child Health and Activity Tool (CHAT)

www.childactivity.co.uk

1.0 INTRODUCTION

This section introduces the standard operating procedure (SOP) to administer the Child's Health and Activity Tool (CHAT). CHAT has been designed as an online health and lifestyle questionnaire for primary school children. The data collected from CHAT will be used alongside fitness test data to determine the health and fitness parameters of children. CHAT is compatible with iPads and laptops and is available in English and Welsh.
This SOP will explain in detail how a researcher should administer CHAT to a class of children. The SOP includes instruction for:

1.1 Information prior to administering CHAT.
1.2 Administering CHAT.
1.3 Accessing the data after administering CHAT.

1.1 PRIOR TO ADMINISTERING CHAT

1) **Date and time**
2) **IT Facilities**
3) **Postcodes**

1) Arrange date and time for questionnaire to take place

- Contact the school 2-3 weeks in advance of administering CHAT and gauge interest in taking part (phone call and standard recruitment email).
- Send out head teacher, parent and participant information sheets and consent forms to schools.
- CHAT can't be administered on a Monday or after a Bank Holiday due to questions asking what the children did yesterday (also avoid administering on weeks focused on health and exercise, such as walk or cycle to school week etc.).
- Find out how many classes will be completing CHAT.
- Find out the number of pupils in each class.
- Allow minimum of 45 minutes for a class to complete CHAT in one sitting. This allows for introduction and explanation, the children to complete CHAT, and thanks at the end.
- Remember to ask about break and lunchtime schedules.
- Ask the teacher beforehand if there is anything the children do once they finish CHAT as some children will finish sooner than others. These other activities may be educational online games or other work that they have been doing.

2) IT Facilities

- Ensure there are enough computers/iPads for all children in class to complete CHAT at the same time. Otherwise class will need to be split.
- Ask about the IT facilities that the school has. Does the school have Wi-Fi and use iPads or laptops or does it have an IT suite where the computers all have a local connection.

- If the children will be using iPads or laptops, ensure they will all have been charged beforehand and check wireless network connection and what usernames and passwords are required.
- If the IT facilities (IT suite, laptops, iPads) need to be booked make sure this is done in advance.
- Clarify that Google Chrome is the best internet browser to administer CHAT.

3) **<u>Postcodes:</u>**

- Ask the teacher to bring several copies of sheets with the children's postcodes.
- If unwilling to bring sheets then ask to bring student info folder from main office.
- Have all children who don't know their post code raise their hand at the start of CHAT and then wait for their teacher to come over and tell them.

1.2 <u>ADMINISTERING CHAT</u>

4) **Introduction**
5) **If CHAT stops working**
6) **Start page**
7) **CHAT Questions 1-29**

4) **<u>Introduction:</u>**

- Before administering CHAT explain what it is about.
  "It asks questions on how much exercise you did, what you ate, what time you went to sleep and how you feel about certain things. The first part follows a timeline of what you did yesterday from when you woke up to when you went to sleep. You can follow the clock at the top for idea of time. So, think carefully about what you did yesterday before answering. Some questions look similar but if you read it closely it's asking about different section of day (the clock on top helps with this). There are no right or wrong answers but it is important you answer all questions honestly. Read the question slowly to make sure you understand it properly and do not rush – it's not a race. If you don't understand a question, see if there is a speech bubble which normally explains a bit further. If you have read the speech bubble and still don't understand, put up your hand and wait for the teacher to explain. If ill or on holiday, think of the last normal school day when you were in school".
- Log on to <u>www.childactivity.co.uk</u>.
- Bilingual: Option to complete in welsh by clicking "cymraeg" in top right corner.

5) **<u>Problem</u>**

If CHAT freezes or will not let you go forward, try and click the refresh button by the web address. If this does not work or the pupil closes the CHAT window, they will have to start from the beginning. If they had got further than 3 or 4 questions, have a researcher take note of the child's previous progress, help them fill in the first page correctly and then click any answer for the questions that they had already completed. Once they reach where

CHAT had previously frozen, the child can carry on with completing CHAT. The data will then have to be edited manually by a researcher after CHAT is completed.

6) **Start Page**

If they don't know if they have a disability ask them to go through each of the disability options to see if any apply to them, if they don't have any then tell them to click no.

7) **CHAT Questions 1-29**

Question 1) What time did you wake up?

- Choose closest time or click other for more specific (choose time they woke up **not** got up).

Question 2) What did you eat for breakfast?

- Healthy and unhealthy cereal (if unsure click other at bottom and put the name of the cereal).
- Sometimes the other box will appear higher on the page.

Question 3) What did you drink for breakfast?

- Children can click more than one option.

Question 4) Before school how long did you spend..

a) ***Doing sport or exercise?***
- Make sure children read the speech bubble (Brisk walking would count but not slow/normal walking).

b) ***Sitting down watching TV/playing video games/using iPad/internet?***
- Ask them to use length of TV programmes as guide and to make sure they add up each sedentary activity.

c) ***Doing homework or reading?***
- Reading after school has started does not count.

Questions 5) How did you get to school?

- If the children say they did more than one option, ask them which they spent the most of their journey doing.
- If they travelled with an adult, ask if they travelled most of the way with them? If so, then YES but if not then NO.

Question 6) What did you do for most of your morning break?

- Make sure the children read the speech bubbles above "sit around" and "ran around" for examples.

Question 7) What did you have to..

a) ***Eat for lunch?***

b) ***Drink for lunch***

Question 8) What did you do for most of lunchtime apart from eating food?

- Make sure children read the part of the question explaining that the period of time eating lunch does not count.
- Make sure the children read the speech bubbles above "sit around" and "ran around" for examples.

Question 9) What did you do for most of your afternoon break?

- Make sure the children read the speech bubbles above "sit around" and "ran around" for examples.

Questions 10) How did you travel home from school?

- If the children say they did more than one option, ask them which they spent the most of their journey doing.
- If they travelled with an adult, ask if they travelled most of the way with them. ? If so, then YES but if not then NO.

Question 11) After school how long did you spend..

a) Doing sport or exercise?

- Make sure children read the speech bubble (Brisk walking would count but not slow/normal walking).

b) Sitting down watching TV/playing video games/using iPad/internet?

- Ask them to use length of TV programmes as guide and to make sure they add up each sedentary activity.

c) Doing homework or reading?

Question 12) How many portions of fruit and vegetables did you eat yesterday?

- Remember potatoes don't count.
- Follow the link below to see what amount of fruit and vegetables counts as a portion: *http://www.nhs.uk/Livewell/5ADAY/Documents/Downloads/5ADAY_portion_guide.pdf.*

Question 13) How many times did you brush your teeth yesterday?

- Remember to ask whether children brush their teeth at school as well.

Question 14) What time did you go to sleep?

- Choose closest time or click other for more specific (choose time they went to sleep **not** went to bed).

Question 15) How many days a week..

a) Did you do sport or exercise for 1 hour or more?

- Make sure children read the speech bubble

- Includes weekdays and weekends

b) ***Did you watch TV/play on consoles/use iPad/use the internet for 2 hours or more?***

- Make sure children realise it is 2 hours or more in total, not for each activity.

c) ***Did you feel tired?***

- Make sure children understand it means all day, not just drowsy in the morning or at night.

d) ***Did you feel like you could concentrate/focus in class?***

- If children don't understand concentrate/focus use alternatives. For example: "pay attention to what the teacher is saying during class."

e) ***Did you drink one fizzy drink?***

- Remember to remind the children this is how many days a week not how many fizzy drinks.
- It only includes full sugar drinks, for example: Coca Cola not Coca Cola Diet or Coca Cola Zero.

f) ***Did you drink one diet fizzy drink?***

- Remember to remind the children this is how many days a week **not** how many diet fizzy drinks.
- Includes zero sugar drinks such as Coca Cola Zero/Fanta Zero as well as diet fizzy drinks.

g) ***Did you eat one sugary snack?***

- Remember to remind the children this is how many days a week **not** how many sugary snacks.
- This includes cakes, sweets and chocolate.

h) ***Did you eat a takeaway?***

- This includes all fast food takeaways.

i) ***Did you eat fish?***

- This includes all types of fish, including fresh, battered and tinned.

Question 16) What type of bread do you eat?

- If children have more than one type of bread, ask them to choose which one they have the most.

Question 17) What type of milk do you have?

- If children have more than one type of milk, ask them to choose which one they have the most.
- If they have rice/soy milk, select "I don't drink milk."

Question 18) What sports/activities do you take part in..

a) In school?

- Children should only select sports/activities that are **not** part of the curriculum.

- They should only select sports/activities that are extra-curricular (such as school teams) or sports/activities that they do at breaktime/lunchtimes.
- The sports/activities should be something they take part in on a regular basis (such as once a week).

b) Outside of school?

- The sports/activities should be something they take part in on a regular basis (such as once a week).

Question 19) Are you a member of brownies/cubs/guides/scouts?

- If the children are not members at present, then click "No."

Question 20) Who do you usually take part in physical activity or sport with..

a) In school?

- If children say they don't take part in any physical activity or sport, then get them to select "other" and type "don't do any" in.
- If children say they take part in physical activity or sport with more than one than one group or person, ask them to select the option they take part in physical activity or sport with most.

b) Outside of school?

- If children say they don't take part in any physical activity or sport, then get them to select "other" and type "don't do any" in.
- If children say they take part in physical activity or sport with more than one than one group or person, ask them to select the option they take part in physical activity or sport with most.

Question 21) How many time a week do your parents/guardians do exercise or sport?

- Select gender of first parent/guardian, then how many times a week they do exercise or sport.
- Second parent is optional.

Question 22) Where can you play at home or in surrounding area within walking distance?

- Children can select as many options as they like.
- School only counts as an option if the school's grounds are open outside of school hours.
- Backyard just relates to non grassy space.
- Garden is a grassy space.

Question 23) Which of these physical activities or sports would you like to do more of?

- Children can select more than one option.

Question 24) What sports or physical activities would you like to take part in that you have not tried before?

- If children are having difficulty thinking of an answer, ask them "have you ever seen something on TV which you would like to try or on the Olympics or your friend/family has taken part in."

Question 25) Can you ride a bike?

- Stabilisers don't count

Question 26)

*a) **Can you swim?***

- This doesn't specify distance, but whether they can swim unaided without touching the sides.

*b) **Can you swim 25 metres?***

- If children ask what this means, ask them if they have a 25m badge? If not ask them if they can swim a length on their own, unaided, without armbands not touching sides (not of the national pool though-this would be half the length of that).

Question 27) How do you feel about..

*a) **Your health?***

- Health is overall condition of their body, including diet, fitness, free from illness etc.

*b) **Your fitness?***

- This question relates to how children feel about their bodies when they are performing sports and exercise. For example, do they get out of breath easily etc?

*c) **Your school?***

- How do children feel about how their school overall? This includes teachers, other children and their school performance.

*d) **Your family?***

- How do children feel about their family? This includes parents and siblings.

*e) **Your friends?***

- How do children feel about their friends in school and outside of the school.

Question 28) Do you agree or disagree with..

a) "I am doing well at school"

- This is asking about how children feel they are doing performing academically at school.

b) "I have lots of choice over things that are important to me"

- Ask the children what is important to them personally such as diet, sports, playing with friends, bedtime, what they watch on TV etc and whether they have much choice over it.

c) "There are lots of things I am good at"

- Give examples if needed. For example: school, musical instrument, sports etc.

Question 29) What do you think could be done to improve the health of children in your local area?

- If children are unsure, make suggestion, such as parks, cycle lanes, youth clubs, local sports clubs etc.

1.3 ACCESSING THE DATA AFTER ADMINISTERING CHAT

8) Accessing The Data After Administering CHAT

Steps:

- Log onto: *http://www.childactivity.co.uk/login.php*
- Username: AVAILABLE UPON REQUEST
- Password: AVAILABLE UPON REQUEST
- Click “Submit”
- Click “Download”
- Open up the Excel document.
- Copy and Paste school’s data into new Excel document.

Appendix III: Paper-based home-physical environment audit tool

Swansea University
Prifysgol Abertawe

The HomeSPACE Study

ID No______

HomeSPACE Home Audit

We are interested in learning more about your home and how it might influence children's physical activity and sitting at home.

This checklist will ask you about the size, space and design of your home, and the types of equipment you have at home. If you have any questions about the checklist or the study, please contact the Lead Researcher:

Michael Sheldrick
Email: [redacted]
College of Engineering; Swansea University
Bay Campus; Fabian Way; Swansea; SA1 8EN

Thank you for helping us with this study!

SECTION 1: HOME AUDIT

Instructions

Please walk through each room in your house, garden and garage.
For each room/area please answer the first two questions: "Whose room is this?" and "How big is this room?" by circling the best answer.
Then use the numbered list to indicate which items are in the room by writing the corresponding numbers in the row of boxes (see example below). The numbered list is on the next page and repeated for your convenience on page 8. There is physical activity, media, musical and furniture items on the list. Please write only one item per box.

Also, we would like you to use the following list to indicate how accessible each item is, by writing the appropriate letter in the bottom row of boxes

- **A)** Put away and difficult to get to ....(e.g., A games console kept on top of a cupboard
- **B)** Put away and easy to get to ....(e.g., A tablet Computer behind a cabinet door)
- **C)** In plain view and difficult to get to ....(e.g., A Table Tennis table stored in the garage)
- **D)** In plain view and easy to get to ....(e.g., A skateboard on the floor in doorway)

When rating an item's accessibility, you should take into account its condition. For example, a punctured football in plain view should be given a C rating, as it's in plain view but difficult to get to. While a tennis racquet in usable condition should be given a rating of D, as it's in plain view and easy to get to.

Important Notes

1. Please take the time to walk through your home rather than sitting in one place to complete this checklist. Walking through each room will help your memory.
2. If there is more than one of the same item in a room (e.g. two bikes in the garage), write the code number in the top left of the box and the amount of the item in the bottom right of the box (see example below).
3. If there are not enough boxes for all of the items in the room, use one of the "Other" rows and write in the name of the room.
4. Count all items regardless of condition
5. If the room does not apply to your home, write "NA" in the first box for that room.
6. If there is nothing from the list in the room, write "0" in the "Item #" row.
7. If your home has other rooms not mentioned please use one of the "Other" rows and write in the name of the room.

Example: medium sized family lounge room with a piano, two couches, a TV and DVD player.

Room: Lounge Room

children / adults / everyone

small / medium / large

Item #	20	33/2	23	24						
Access #	D	D	D	B						

Equipment Item Number List	
Sports Equipment 1 Balls (e.g. football, rugby, basketball) 2 Bats / racquets (e.g. cricket, softball, tennis) 3 Frisbee 4 Skipping rope 5 Hula hoop **Transportation Equipment** 6 Bicycle 7 Scooter / skateboard / ripstick / skates **Fitness Equipment** 8 Stationary (aerobic) exercise equipment (e.g. treadmill, exercise bike, punch bag) 9 Weights / toning equipment (e.g. weights bench, sit up machine) **Outdoor Play Equipment** 10 Basketball Ring 11 Fixed Play Structure (e.g. swings, slide, climbing, sandpit) 12 Cubby/Tree house 13 Trampoline 14 Pool (in ground or above) 15 Football goal net 16 Swing ball **Indoor Play Equipment** 17 Pool/snooker Table 18 Table Tennis Table 19 Table football	**Musical Instruments** 20 Piano / Keyboard 21 Drums 22 Other Instrument (e.g. guitar, trumpet, violin, flute) **Media Equipment - Fixed** 23 Television 24 VCR / DVD / Blu-ray Player 25 Pay TV (e.g. Sky) 26 TV on Demand (e.g. Apple TV) 27 Desktop Computer 28 Video game system (attached to TV) (e.g. X-Box, Wii, Playstation) **Media Equipment - Portable** 29 Handheld Video Game Player (e.g. Nintendo DS, Sony PSP) 30 Laptop Computer 31 Tablet Computer (e.g., iPad, Samsung galaxy) 32 Ipod Touch / Galaxy Player (or similar) **Furniture** 33 Couch (2+ seater) 34 Lounge Chair (single seater) 35 Coffee Table 36 Dining / Kitchen Chair 37 Dining / Kitchen Table 38 Office Chair 39 Desk

ROOMS IN THE HOUSE

Room: Entry / Foyer / Hall
small / medium / large;
children / adults / everyone

Item #									
Accessibility									

Room: Bedroom of Child in study
small / medium / large; ___________
children / adults / everyone

Room: Open Plan Living Area
small / medium / large; ___________
children / adults / everyone

Item #									
Accessibility									

Room: Bedroom 2
small / medium / large; ___________
children / adults / everyone

Room: Kitchen
small / medium / large; ___________
children / adults / everyone

Item #									
Accessibility									

Room: Bedroom 3
small / medium / large; ___________
children / adults / everyone

Room: Lounge Room (separate)
small / medium / large; ___________
children / adults / everyone

Item #									
Accessibility									

Room: Bedroom 4
small / medium / large; ___________
children / adults / everyone

Room: Dining Room (separate)
small / medium / large; ___________
children / adults / everyone

Item #									
Accessibility									

Room: Games/Activities Room
small / medium / large; ___________
children / adults / everyone

Room: Study/Office
small / medium / large; ___________
children / adults / everyone

Item #									
Accessibility									

Room: Bathrooms
small / medium / large; ___________
children / adults / everyone

Accessibility rating of items:

A=The item is put away and difficult to get to **B**=The item is put away and easy to get to
C=The item is in plain view and difficult to get **D**= The item is in plain view and easy to get to

Room: Other ________________ (specify)

small / medium / large; __________

children / adults / everyone

Room: Other ________________(specify)

small / medium / large; __________

children / adults / everyone

Item #																		
Accessibility																		

Accessibility rating of items:

A= The item is put away and difficult to get to

B= The item is put away and easy to get to

C= The item is in plain view and difficult to get to

D= The item is in plain view and easy to get to

7

Equipment Item Number List	
Sports Equipment	**Musical Instruments**
1 Balls (e.g. football, rugby, basketball)	20 Piano / Keyboard
2 Bats / racquets (e.g. cricket, softball, tennis)	21 Drums
3 Frisbee	22 Other Instrument (e.g. guitar, trumpet, violin, flute)
4 Skipping rope	
5 Hula hoop	**Media Equipment - Fixed**
Transportation Equipment	23 Television
6 Bicycle	24 VCR / DVD / Blu-ray Player
7 Scooter / skateboard / ripstick / skates	25 Pay TV (e.g. Sky)
	26 TV on Demand (e.g. Apple TV)
Fitness Equipment	27 Desktop Computer
8 Stationary (aerobic) exercise equipment (e.g. treadmill, exercise bike, punch bag)	28 Video game system (attached to TV) (e.g. X-Box, Wii, Playstation)
9 Weights / toning equipment (e.g. weights bench, sit up machine)	
	Media Equipment - Portable
Outdoor Play Equipment	29 Handheld Video Game Player (e.g. Nintendo DS, Sony PSP)
10 Basketball Ring	30 Laptop Computer
11 Fixed Play Structure (e.g. swings, slide, climbing, sandpit)	31 Tablet Computer (e.g., iPad, Samsung galaxy)
12 Cubby/Tree house	32 Ipod Touch / Galaxy Player (or similar)
13 Trampoline	
14 Pool (in ground or above)	**Furniture**
15 Football goal net	33 Couch (2+ seater)
16 Swing ball	34 Lounge Chair (single seater)
	35 Coffee Table
Indoor Play Equipment	36 Dining / Kitchen Chair
17 Pool/snooker Table	37 Dining / Kitchen Table
18 Table Tennis Table	38 Office Chair
19 Table football	39 Desk

OUTSIDE AREA

Area: Back Garden *
small / medium / large; ___________
children / adults / everyone

Item #									
Accessibility									

Area: Outdoor Eating Area
small / medium / large; ___________
children / adults / everyone

Area: Front garden (including Porch) *
small / medium / large; ___________
children / adults / everyone

Item #									
Accessibility									

Area: Garage
small / medium / large; ___________
children / adults / everyone

Area: Front Verge *
small / medium / large; ___________
children / adults / everyone

Item #									
Accessibility									

Area: Garden Shed
small / medium / large; ___________
children / adults / everyone

Area: Other______________________ (specify)
small / medium / large; ___________
children / adults / everyone

Item #									
Accessibility									

Area: Other________________ (specify)
small / medium / large; ___________
children / adults / everyone

Accessibility rating of items:

A= The item is put away and difficult to get to
B= The item is put away and easy to get to
C= The item is in plain view and difficult to get to
D= The item is in plain view and easy to get to

Additional Features of Front garden, Back garden and Verge (if applicable)*

Does the home have any of the following outdoor features? Please circle Yes or No for each item in the back garden, front garden and verge.

Outdoor Features	**Back garden**	**Front garden**	**Verge**
Tree - able to be climbed	Yes / No	Yes / No	Yes / No
Wall - able to throw/kick a ball against	Yes / No	Yes / No	Yes / No
Garden area	Yes / No	Yes / No	Yes / No
Grassed area	Yes / No	Yes / No	Yes / No
Undercover area	Yes / No	Yes / No	Yes / No
Shaded area	Yes / No	Yes / No	Yes / No
Driveway	Yes / No	Yes / No	Yes / No
Paved area	Yes / No	Yes / No	Yes / No
Footpath	-	-	Yes / No
Windows from the home overlook this area	Yes / No	Yes / No	Yes / No

SECTION 2: ADDITIONAL QUESTIONS

Instructions

You are now finished Section 1 - The Home Audit.

Section 2 asks you to complete some additional questions about your home, and your family. This will not take too long to complete.

Please remember that there are no right or wrong answers. We are just interested in what you think.

SECTION 2A: HOME FEATURES

1. Which best describes the home? *(Please tick one box only)*

   Separate House ☐
   Semi-detached / Townhouse / Terrace House / Villa ☐
   Flat/Unit/Apartment ☐
   Other, (please specify) ________________________ ☐

2. How many storeys does the home have? *(Please tick one box only)*

   One ☐ Two ☐ More than Two ☐

3a Does the home have internal stairs? (e.g. between storeys or levels)
(please tick one box only)

   Yes ☐ No ☐

3b Does the home have external stairs (e.g. to get to the front or back door)?
(please tick one box only)

   Yes ☐ No ☐

4 Is there a front fence/gate that encloses the front garden? *(Please tick one box only)*

   Yes ☐ No ☐ Partially ☐

5. Are any of the following spaces directly beside/behind the home?
(Please tick yes or no for each)

	Yes	No
Public open space (e.g. park)	☐	☐
Back/side laneway	☐	☐
Vacant block	☐	☐
Pedestrian cut through	☐	☐

6. What would you say your house is? *(Please tick one box only)*

Small ☐
Medium ☐
Large ☐

7. What would you say your garden is? *(Please tick one box only)*

Small ☐
Medium ☐
Large ☐
No Garden ☐

SECTION 2B: EQUIPMENT

Please circle one answer for each of the following questions.

1. How many books do you currently have in your home?

0	1-50	51-100	101-150	151-200	>200

2. How many magazines do you have in your home?

0	1-50	51-100	101-150	151-200	>200

3. How many DVDs do you currently have in your home?

0	1-25	26-50	51-75	76-100	>100

4. How many TV channels do you currently have available in your home?

0	1-25	26-50	51-75	76-100	>100

5. How many electronic games (including computer games) do you currently have in your home?

0	1-10	11-20	21-30	31-40	>40

6. How many of these electronic games in your home are **active** video games?

0	1-5	6-10	11-15	16-20	>20

7. How many smart phones do you currently have in your home?

0	1-2	3-4	5-6	7-8	>8

8. What best describes your type of internet service? (please tick one box only)

   No internet access ☐

   Dial up modern ☐

   Wireless Broadband ☐

9. Do you own a dog? *(please tick one box only)*

   Yes ☐

   No ☐

10. Do you own any other pets? (please specify)

SECTION 3: YOU AND YOUR FAMILY

1. What is your age in years?

   ____

2. What is your gender? *(please tick one box only)*

   Male ☐ Female ☐

3. In which country were you born?

   ____

4. What is the main language spoken in your home?

   ____

5. Which best describes your ethnicity?
   - White ☐
   - Mixed Race ☐
   - Asian or Asian British ☐
   - Black or Black British ☐
   - Chinese ☐
   - Other ☐

6. How many people (including yourself) live in your household?

   ____

7. How many children under 18 years of age live in your household?

   ____

8. What are the ages and gender of the children living in your household?
   (please write the age and circle the gender)

   1. ______ M / F 2. ______ M / F 3. ______ M / F

   4. _______ M / F 5. ______ M / F 6. ______ M / F

9. Which best describes your highest level of education completed? *(please tick one)*

   Some Secondary High School ☐

   Completed Secondary High School (Year 11) ☐

   Trade Qualifications / Apprenticeship ☐

   Diploma / Certificate ☐

   University Bachelor Degree or Higher ☐

10. What is your approximate annual household income before tax? *(please tick one box only)*

- Under £10,000 ☐
- £10,000 – £20,000 ☐
- £20,000 - £30,000 ☐
- £30,000 - £50,000 ☐
- £50,000 - £70,000 ☐
- £70,000 - £100,000 ☐
- £100,000 and above ☐

11. Which best describes your family situation? *(please tick one box only)*

- Single Parent Household ☐
- Two Parent Household ☐
- Other ☐

12. Do you rent or own your home? *(Please tick one box only)* ☐ Rent ☐ Own / Paying Off

13. How long have you been at your current address?

____

14. Please write today's date

__________day__________month__________year

15. What suburb/area do you live in? ___________ What is your postcode? __________

THANK YOU!

Appendix IV: Description of HomeSPACE-II Instrument Items and Summary Scores

Audit Categories - Room/Area Level	*Individual Items*	*Summary Scores*			
		Sum of	*Density*	*Average Accessibility Rating*	*Accessibility and Availability Score*
Physical Activity (PA) Equipment	Number, accessibility and location of 19 types	- Sports Equipment - Transport Equipment - Exercise Equipment - Outdoor Play Equipment - Indoor Play Equipment - PA Equipment Indoors - PA Equipment Outdoors - PA Equipment Home	- PA Equipment Indoors - PA Equipment Outdoors - PA Equipment Home	- PA Equipment Indoors - PA Equipment Outdoors - PA Equipment Home	- PA Equipment
Musical Instruments	Number, accessibility and location of 3 types	- Musical Instruments Home	- Musical Instruments Home	- Musical Instruments Home	- Musical Instruments Home
Media Equipment	Number, accessibility and location of 10 types	- Fixed Media Equipment - Portable Media Equipment - Bedroom Media Equipment - Media Equipment Home	- Media Equipment Home	- Media Equipment Home	- Media Equipment Home
Seated Furniture	Number, accessibility and location of 7 types.	- Seated Furniture Bedroom - Seated Furniture Indoors - Seated Furniture Outdoors - Seated Furniture Home	- Seated Furniture Indoors - Seated Furniture Outdoors - Seated Furniture Home	- Seated Furniture Indoors - Seated Furniture Outdoors - Seated Furniture Home	- Seated Furniture Home
Rooms/Areas in Home	Number and perceived size of up to 14 indoor rooms and 8 outdoor areas Perceived size of overall house and garden	- Livings Rooms - Bedrooms - Indoor Rooms - Outdoor Areas - Total Rooms/Areas			

Outdoor Features	Presence of 10 types of outdoor features in 3 outdoor areas	- Back Garden Features - Front Garden Features - Verge Features - Total Outdoor Features	
Audit Categories – Overall	***Individual Items***		***Item Categories***
Home Features	Type of home		Detached house; semi-detached/townhouse/terrace house/villa; flat/unit/apartment; other (4)
	Number of storeys		one; two; more than two (3)
	Presence of: internal stairs; external stairs		yes; no (2)
	Presence of front fence that encloses garden		yes; no; partially (3)
	Location next to 4 types of public space (public open space; back/side laneway; vacant block; pedestrian cut-through)		yes; no (2)
Questionnaire Items	***Individual Items***		***Item Categories***
Home Equipment	Number of books		0; 1-50; 51-100;101-150;151-200; >200 (6)
	Number of magazines		0; 1-50; 51-100;101-150;151-200; >200 (6)
	Number of DVDs		0;1-25; 26-50; 51-75; 76-100; >100 (6)
	Number of TV channels		0;1-25; 26-50; 51-75; 76-100; >100 (6)
	Number of electronic games		0; 1-10; 11-20; 21-30; 31-40; >40 (6)
	Number of active video games		0; 1-5; 6-10; 11-15; 16-20; >20 (6)
	Number of smartphones		0; 1-2;3-4;5-6; 7-8; >8 (6)
	Type of internet service		No internet access; dial-up modem; wireless broadband (3)
Pet Ownership	Ownership of dog; other pets		yes; no (2)

Appendix V: Online instrument feasibility questions

Audit tool feasibility questions

Type of question	Examples
Design	• What do you think of the overall design of the audit tool, e.g., graphics and colour? • What are your first thoughts when you look at the audit, e.g., do you think it's text heavy, does it look like it might take a while to do? • What is your opinion on the outdoor area images, perhaps animated images would look better? • Do you think spaces in between the questions would give the perception that the instrument is less demanding on time and therefore less look daunting?
Format	• Do you like the layout of the additional questions section, e.g., the zig zag design?
Clarity	• Does everything make sense in the instructions? • Is it clear what is being asked with the who the room is for and how big the room is questions? • Do you know what a verge, or would a definition be useful? • Is it clear with the outdoor features item, that we want you to check a feature if it is present for the front garden, back garden and verge separately, rather than to check features that are present in all 3 areas? • Is the font size big enough to read throughout? • Is the language used simple enough for most people to understand?
Additional thoughts	• Are there any physical factors missing from the audit that in your opinion may influence a child's sitting and physical activity at home? • Do you have any comments to finish? • How do you think we could improve the audit? • In general, did the online version of the tool easier to complete than the paper version, if so why?

Questionnaire feasibility questions

Type of question	Examples
Design	• What do you think of the overall design of the questionnaire, e.g., graphics and colour?

	• What are your first thoughts when you look at the questionnaire, e.g., do you think it's text heavy, does it look like it might take a while to do?
Format	• What do you think of the format of the questions e.g., do they look tidy?
Clarity	• For each question, is it clear what is being asked? • Do you think the language used is appropriate, and fairly straight forward to understand? • Are the activity examples relatable, e.g., are they applicable to your family? • Is the font size big enough to read throughout?
Additional thoughts	• Do you have any comments to finish? • How do you think we could improve the audit? • In general, do you think you would find this electronic version of the questionnaire easier to complete than a paper version, if so why?

Appendix VI: Online audit tool

HomeSPACE audit tool

We are interested in learning more about your home and how it might influence children's physical activity and sitting at home.
This checklist will ask you about the size, space and design of your home, and the types of equipment you have at home. If you have any questions about the checklist or the study please contact the Lead Researcher:

Michael Sheldrick
Email: [redacted]
College of Engineering; Swansea University
Bay Campus; Fabian Way; Swansea; SA1 8EN

Thank you for helping us with this study!

Swansea University
Prifysgol Abertawe

The HomeSPACE Study

SECTION 1: HOME AUDIT

Instructions

Please walk through each room in your house, garden and garage. We recommend you complete this audit tool on a tablet, but if you don't own one it can also be completed via a laptop or smart phone.
For each room/area please answer the first two questions: "Room size?" and "Who is the room for?" by selecting the best answer. Then select the items which are in the room using the drop-down menu. Please find below the list of items included in the audit tool, there are physical activity, media, music and furniture items on the list and they are grouped by the following categories; 1-5: sports equipment; 6-7: Transportation equipment; 8-9: Fitness equipment; 10-17: Outdoor play equipment; 18-20: Indoor play equipment; 21-23: Musical instruments; 24-30: Fixed-media equipment; 31-34: Portable-media equipment; 35-41: Seated furniture.

Sports equipment
1) Balls (e.g. tennis, football, rugby, basketball)
2) Bats/racquets (e.g. cricket, baseball, tennis)
3) Frisbee
4) Skipping rope
5) Hula hoop

Transportation equipment
6) Bicycle
7) Scooter / skateboard / ripstick / skates

Fitness equipment
8) Stationary (aerobic) exercise equipment (e.g. treadmill, exercise bike, punch bag)
9) Weights / toning equipment (e.g. weights bench, sit up machine)

Outdoor play equipment
10) Basketball Ring
11) Fixed Play Structure (e.g. swings, slide, climbing, sandpit)
12) Cubby/Tree house
13) Trampoline
14) Pool (in ground or above)
15) Football goal net
16) Swing ball
17) Badminton/Volleyball net

Indoor play equipment
18) Pool/snooker Table
19) Table Tennis Table
20) Table football

Musical instruments
21) Piano / Keyboard
22) Drums
23) Other Instrument (e.g. guitar, trumpet, violin, flute)

Fixed-media equipment
24) Television
25) VCR / DVD / Blu-ray Player
26) Pay TV (e.g. Sky)
27) TV on Demand (e.g. Apple TV, Amazon Fire TV, Now TV)
28) Desktop Computer
29) Video game system (attached to TV, e.g. X-Box, Wii, Playstation)
30) **Active** video game system (e.g. Wii fit, X-Box kinect, Playstation move)

Portable-media equipment
31) Handheld Video Game Player (e.g. Nintendo DS, Sony PSP)
32) Laptop Computer
33) Tablet Computer (e.g. iPad, Samsung galaxy)
34) Ipod Touch / Galaxy Player (or similar)
Seated furniture
35) Couch/Bench (2+ seater)
36) Lounge Chair (single seater [Indoor and Outdoor])
37) Coffee Table (Indoor and Outdoor)
38) Dining / Kitchen Chair (Indoor and Outdoor)
39) Dining / Kitchen Table (Indoor and Outdoor)
40) Office Chair
41) Desk

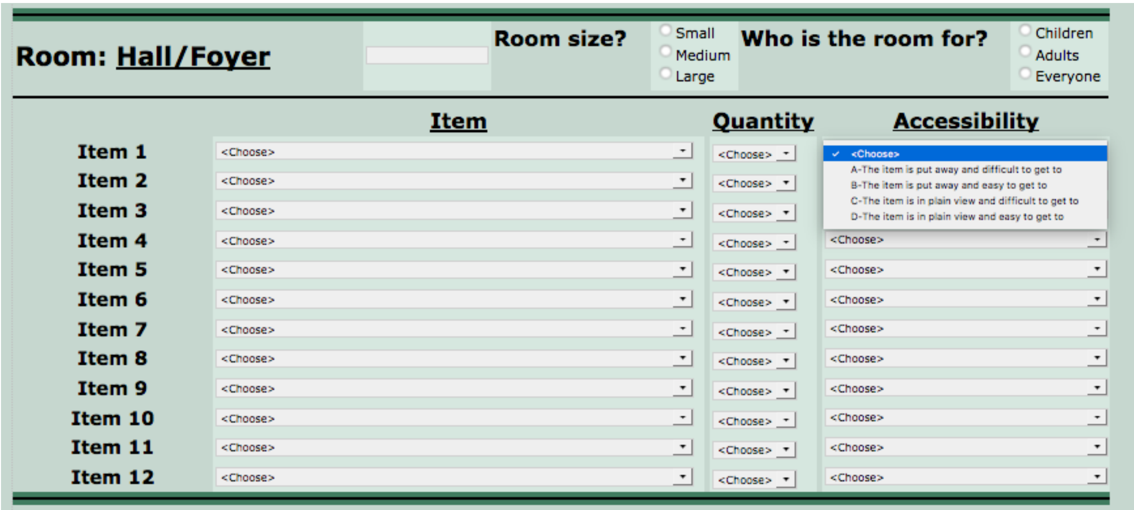
Also we would like you to use the following list to indicate how accessible each item is by selecting the relevant ratings using the drop down menu:
A) Put away and difficult to get to (e.g. A games console kept on top of a cupboard)
B) Put away and easy to get to (e.g. A tablet Computer behind a cabinet door)
C) In plain view and difficult to get to (e.g. A Table Tennis table stored in the garage)
D) In plain view and easy to get to (e.g. A TV on a TV stand in the lounge)
When rating the accessibilty of an item, you should take into account its condition. For example, if a football is punctured and in plain view, you would give it a rating of C, as it's in plain view but difficult to get to. Similarly, if a tennis racquet is in good condition and in plain view, you would give it a rating of D, as it's in plain view and easy to get to.
Also, if there is more than one of the same item in one room, but the items have different levels of accessibility, you should input each item with a unique level of accessbility separately.

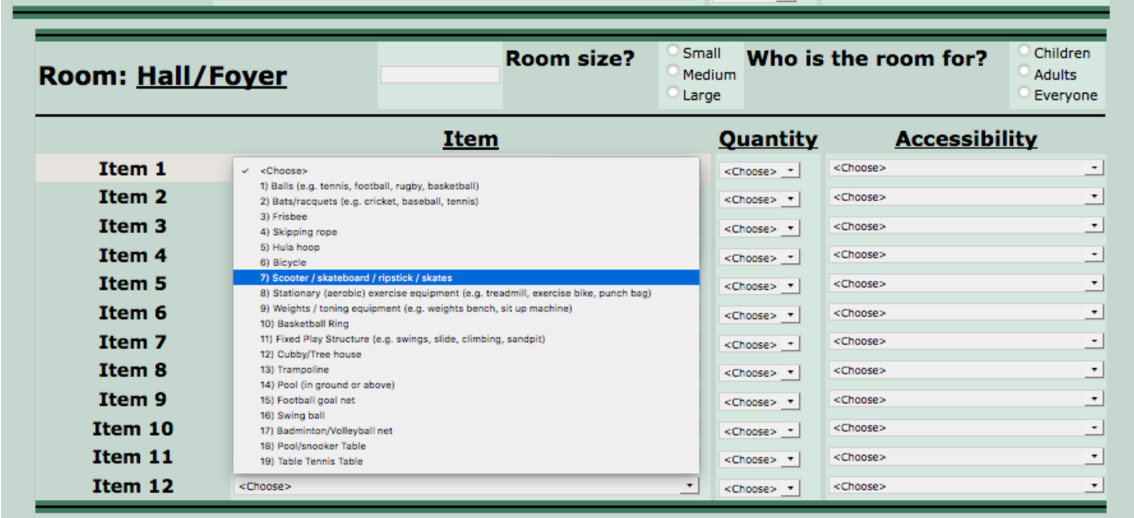
Important Notes

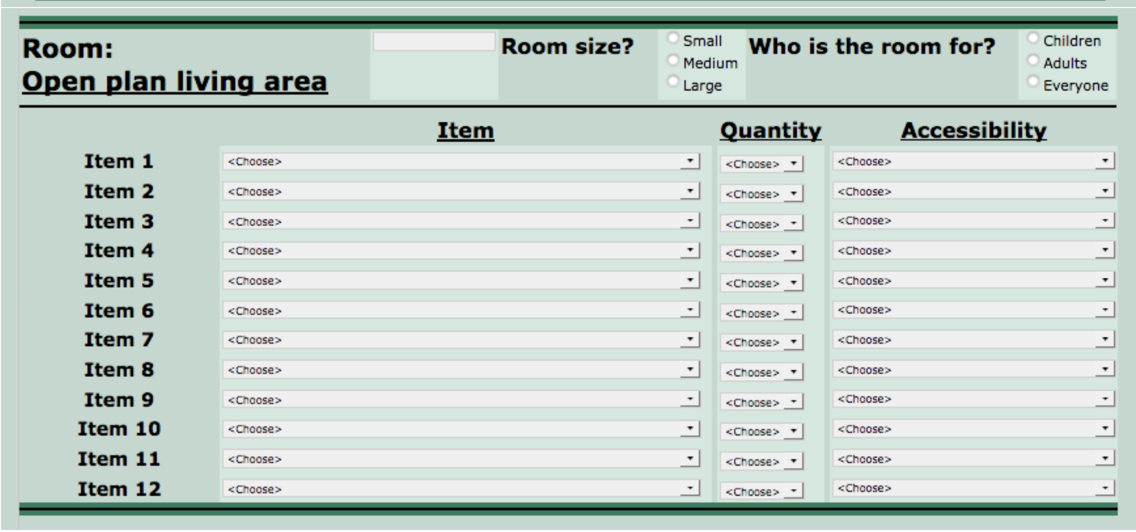
1. Please take the time to walk through your home rather than sitting in one place to complete this checklist. Walking through each room will help your memory.
2. If there are more than 12 different items with unique accessibility ratings in a room, use one of the "Other (specify)" sections or a section for a room that isn't in the home and type in the name of the room in the space to the right. If there are more than 40 of the same item with the same level of accessibility within a room, just input any additional number of that item seperately.
3. For the bedrooms, we are interested in knowing which room belongs to who. So in the space to the right of each bedroom, we would be grateful if you could type in who the room belongs to. Do not refer to each person by their names, just put their relation to the main child in the study. For example, for your room, you would type in parents.
4. Count all items, regardless of condition.
5. If the room does not apply to your home just type "N/A" in the space to the right.
6. If there is nothing from the list in the room, once you have selected the room size and indicated who the room's for, you can skip the room.
7. If your home has other rooms not mentioned, please use one of the "Other (specify)" rows and write in the name of the room in the space to the right. Toilets and bathrooms are excluded deliberately, because they're unlikely to have any items on the list of items within them. If your home has more than 2 rooms not mentioned, for any additional rooms please use a section for a room that you don't have in your home. However, you must remember to type the name of that room in the space to the right.

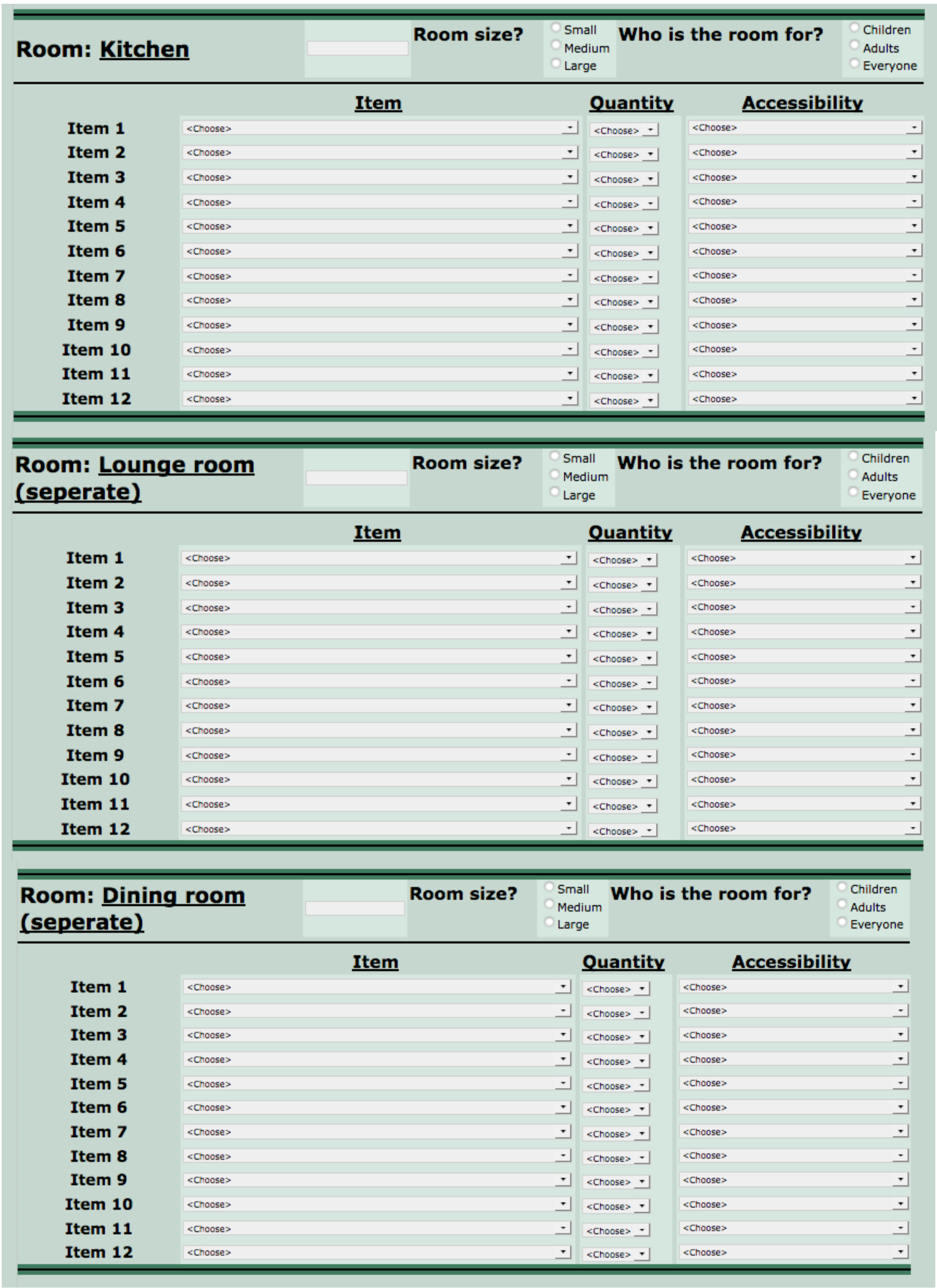
Room: Hall/Foyer — **Room size?** Small / Medium / Large — **Who is the room for?** Children / Adults / Everyone

	Item	Quantity	Accessibility
Item 1	<Choose>	✓ <Choose> 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19	<Choose>
Item 2	<Choose>		<Choose>
Item 3	<Choose>		<Choose>
Item 4	<Choose>		<Choose>
Item 5	<Choose>		<Choose>
Item 6	<Choose>		<Choose>
Item 7	<Choose>		<Choose>
Item 8	<Choose>		<Choose>
Item 9	<Choose>		<Choose>
Item 10	<Choose>		<Choose>
Item 11	<Choose>		<Choose>
Item 12	<Choose>	<Choose>	<Choose>


Room: Hall/Foyer
Room size?
Small
Medium
Large
Who is the room for?
Children
Adults
Everyone
Item
Quantity
Accessibility
Item 1
Item 2
Item 3
Item 4
Item 5
Item 6
Item 7
Item 8
Item 9
Item 10
Item 11
Item 12
<Choose>
A-The item is put away and difficult to get to
B-The item is put away and easy to get to
C-The item is in plain view and difficult to get to
D-The item is in plain view and easy to get to


Room: Hall/Foyer
Room size?
Small
Medium
Large
Who is the room for?
Children
Adults
Everyone
Item
Quantity
Accessibility
Item 1
Item 2
Item 3
Item 4
Item 5
Item 6
Item 7
Item 8
Item 9
Item 10
Item 11
Item 12
<Choose>
1) Balls (e.g. tennis, football, rugby, basketball)
2) Bats/racquets (e.g. cricket, baseball, tennis)
3) Frisbee
4) Skipping rope
5) Hula hoop
6) Bicycle
7) Scooter / skateboard / ripstick / skates
8) Stationary (aerobic) exercise equipment (e.g. treadmill, exercise bike, punch bag)
9) Weights / toning equipment (e.g. weights bench, sit up machine)
10) Basketball Ring
11) Fixed Play Structure (e.g. swings, slide, climbing, sandpit)
12) Cubby/Tree house
13) Trampoline
14) Pool (in ground or above)
15) Football goal net
16) Swing ball
17) Badminton/Volleyball net
18) Pool/snooker Table
19) Table Tennis Table


Room:
Open plan living area
Room size?
Small
Medium
Large
Who is the room for?
Children
Adults
Everyone
Item
Quantity
Accessibility
Item 1
Item 2
Item 3
Item 4
Item 5
Item 6
Item 7
Item 8
Item 9
Item 10
Item 11
Item 12
<Choose>



Room: Kitchen		Room size?	Small Medium Large	Who is the room for?	Children Adults Everyone

	Item	Quantity	Accessibility
Item 1	<Choose>	<Choose>	<Choose>
Item 2	<Choose>	<Choose>	<Choose>
Item 3	<Choose>	<Choose>	<Choose>
Item 4	<Choose>	<Choose>	<Choose>
Item 5	<Choose>	<Choose>	<Choose>
Item 6	<Choose>	<Choose>	<Choose>
Item 7	<Choose>	<Choose>	<Choose>
Item 8	<Choose>	<Choose>	<Choose>
Item 9	<Choose>	<Choose>	<Choose>
Item 10	<Choose>	<Choose>	<Choose>
Item 11	<Choose>	<Choose>	<Choose>
Item 12	<Choose>	<Choose>	<Choose>

Room: Lounge room (seperate)		Room size?	Small Medium Large	Who is the room for?	Children Adults Everyone

	Item	Quantity	Accessibility
Item 1	<Choose>	<Choose>	<Choose>
Item 2	<Choose>	<Choose>	<Choose>
Item 3	<Choose>	<Choose>	<Choose>
Item 4	<Choose>	<Choose>	<Choose>
Item 5	<Choose>	<Choose>	<Choose>
Item 6	<Choose>	<Choose>	<Choose>
Item 7	<Choose>	<Choose>	<Choose>
Item 8	<Choose>	<Choose>	<Choose>
Item 9	<Choose>	<Choose>	<Choose>
Item 10	<Choose>	<Choose>	<Choose>
Item 11	<Choose>	<Choose>	<Choose>
Item 12	<Choose>	<Choose>	<Choose>

Room: Dining room (seperate)		Room size?	Small Medium Large	Who is the room for?	Children Adults Everyone

	Item	Quantity	Accessibility
Item 1	<Choose>	<Choose>	<Choose>
Item 2	<Choose>	<Choose>	<Choose>
Item 3	<Choose>	<Choose>	<Choose>
Item 4	<Choose>	<Choose>	<Choose>
Item 5	<Choose>	<Choose>	<Choose>
Item 6	<Choose>	<Choose>	<Choose>
Item 7	<Choose>	<Choose>	<Choose>
Item 8	<Choose>	<Choose>	<Choose>
Item 9	<Choose>	<Choose>	<Choose>
Item 10	<Choose>	<Choose>	<Choose>
Item 11	<Choose>	<Choose>	<Choose>
Item 12	<Choose>	<Choose>	<Choose>

Room: Study/Office

Room size? Small / Medium / Large

Who is the room for? Children / Adults / Everyone

	Item	Quantity	Accessibility
Item 1	<Choose>	<Choose>	<Choose>
Item 2	<Choose>	<Choose>	<Choose>
Item 3	<Choose>	<Choose>	<Choose>
Item 4	<Choose>	<Choose>	<Choose>
Item 5	<Choose>	<Choose>	<Choose>
Item 6	<Choose>	<Choose>	<Choose>
Item 7	<Choose>	<Choose>	<Choose>
Item 8	<Choose>	<Choose>	<Choose>
Item 9	<Choose>	<Choose>	<Choose>
Item 10	<Choose>	<Choose>	<Choose>
Item 11	<Choose>	<Choose>	<Choose>
Item 12	<Choose>	<Choose>	<Choose>

Room: Bedroom of child in study

Room size? Small / Medium / Large

Who is the room for? Children / Adults / Everyone

	Item	Quantity	Accessibility
Item 1	<Choose>	<Choose>	<Choose>
Item 2	<Choose>	<Choose>	<Choose>
Item 3	<Choose>	<Choose>	<Choose>
Item 4	<Choose>	<Choose>	<Choose>
Item 5	<Choose>	<Choose>	<Choose>
Item 6	<Choose>	<Choose>	<Choose>
Item 7	<Choose>	<Choose>	<Choose>
Item 8	<Choose>	<Choose>	<Choose>
Item 9	<Choose>	<Choose>	<Choose>
Item 10	<Choose>	<Choose>	<Choose>
Item 11	<Choose>	<Choose>	<Choose>
Item 12	<Choose>	<Choose>	<Choose>

Room: Bedroom 2

Room size? Small / Medium / Large

Who is the room for? Children / Adults / Everyone

	Item	Quantity	Accessibility
Item 1	<Choose>	<Choose>	<Choose>
Item 2	<Choose>	<Choose>	<Choose>
Item 3	<Choose>	<Choose>	<Choose>
Item 4	<Choose>	<Choose>	<Choose>
Item 5	<Choose>	<Choose>	<Choose>
Item 6	<Choose>	<Choose>	<Choose>
Item 7	<Choose>	<Choose>	<Choose>
Item 8	<Choose>	<Choose>	<Choose>
Item 9	<Choose>	<Choose>	<Choose>
Item 10	<Choose>	<Choose>	<Choose>
Item 11	<Choose>	<Choose>	<Choose>
Item 12	<Choose>	<Choose>	<Choose>

Room: Bedroom 3

Room size? Small / Medium / Large

Who is the room for? Children / Adults / Everyone

	Item	Quantity	Accessibility
Item 1	<Choose>	<Choose>	<Choose>
Item 2	<Choose>	<Choose>	<Choose>
Item 3	<Choose>	<Choose>	<Choose>
Item 4	<Choose>	<Choose>	<Choose>
Item 5	<Choose>	<Choose>	<Choose>
Item 6	<Choose>	<Choose>	<Choose>
Item 7	<Choose>	<Choose>	<Choose>
Item 8	<Choose>	<Choose>	<Choose>
Item 9	<Choose>	<Choose>	<Choose>
Item 10	<Choose>	<Choose>	<Choose>
Item 11	<Choose>	<Choose>	<Choose>
Item 12	<Choose>	<Choose>	<Choose>

Room: Bedroom 4

Room size? Small / Medium / Large

Who is the room for? Children / Adults / Everyone

	Item	Quantity	Accessibility
Item 1	<Choose>	<Choose>	<Choose>
Item 2	<Choose>	<Choose>	<Choose>
Item 3	<Choose>	<Choose>	<Choose>
Item 4	<Choose>	<Choose>	<Choose>
Item 5	<Choose>	<Choose>	<Choose>
Item 6	<Choose>	<Choose>	<Choose>
Item 7	<Choose>	<Choose>	<Choose>
Item 8	<Choose>	<Choose>	<Choose>
Item 9	<Choose>	<Choose>	<Choose>
Item 10	<Choose>	<Choose>	<Choose>
Item 11	<Choose>	<Choose>	<Choose>
Item 12	<Choose>	<Choose>	<Choose>

Room: Games/Activities room

Room size? Small / Medium / Large

Who is the room for? Children / Adults / Everyone

	Item	Quantity	Accessibility
Item 1	<Choose>	<Choose>	<Choose>
Item 2	<Choose>	<Choose>	<Choose>
Item 3	<Choose>	<Choose>	<Choose>
Item 4	<Choose>	<Choose>	<Choose>
Item 5	<Choose>	<Choose>	<Choose>
Item 6	<Choose>	<Choose>	<Choose>
Item 7	<Choose>	<Choose>	<Choose>
Item 8	<Choose>	<Choose>	<Choose>
Item 9	<Choose>	<Choose>	<Choose>
Item 10	<Choose>	<Choose>	<Choose>
Item 11	<Choose>	<Choose>	<Choose>
Item 12	<Choose>	<Choose>	<Choose>

Room: Other (specify) | **Room size?** Small / Medium / Large | **Who is the room for?** Children / Adults / Everyone

	Item	Quantity	Accessibility
Item 1	<Choose>	<Choose>	<Choose>
Item 2	<Choose>	<Choose>	<Choose>
Item 3	<Choose>	<Choose>	<Choose>
Item 4	<Choose>	<Choose>	<Choose>
Item 5	<Choose>	<Choose>	<Choose>
Item 6	<Choose>	<Choose>	<Choose>
Item 7	<Choose>	<Choose>	<Choose>
Item 8	<Choose>	<Choose>	<Choose>
Item 9	<Choose>	<Choose>	<Choose>
Item 10	<Choose>	<Choose>	<Choose>
Item 11	<Choose>	<Choose>	<Choose>
Item 12	<Choose>	<Choose>	<Choose>

Room: Other (specify) | **Room size?** Small / Medium / Large | **Who is the room for?** Children / Adults / Everyone

	Item	Quantity	Accessibility
Item 1	<Choose>	<Choose>	<Choose>
Item 2	<Choose>	<Choose>	<Choose>
Item 3	<Choose>	<Choose>	<Choose>
Item 4	<Choose>	<Choose>	<Choose>
Item 5	<Choose>	<Choose>	<Choose>
Item 6	<Choose>	<Choose>	<Choose>
Item 7	<Choose>	<Choose>	<Choose>
Item 8	<Choose>	<Choose>	<Choose>
Item 9	<Choose>	<Choose>	<Choose>
Item 10	<Choose>	<Choose>	<Choose>
Item 11	<Choose>	<Choose>	<Choose>
Item 12	<Choose>	<Choose>	<Choose>

Outdoor area

Area: Back garden

Area size? Small / Medium / Large

Who is the area for? Children / Adults / Everyone

	Item	Quantity	Accessibility
Item 1	<Choose>	<Choose>	<Choose>
Item 2	<Choose>	<Choose>	<Choose>
Item 3	<Choose>	<Choose>	<Choose>
Item 4	<Choose>	<Choose>	<Choose>
Item 5	<Choose>	<Choose>	<Choose>
Item 6	<Choose>	<Choose>	<Choose>
Item 7	<Choose>	<Choose>	<Choose>
Item 8	<Choose>	<Choose>	<Choose>
Item 9	<Choose>	<Choose>	<Choose>
Item 10	<Choose>	<Choose>	<Choose>
Item 11	<Choose>	<Choose>	<Choose>
Item 12	<Choose>	<Choose>	<Choose>

Area: Front garden (including Porch)

Area size? Small / Medium / Large

Who is the area for? Children / Adults / Everyone

	Item	Quantity	Accessibility
Item 1	<Choose>	<Choose>	<Choose>
Item 2	<Choose>	<Choose>	<Choose>
Item 3	<Choose>	<Choose>	<Choose>
Item 4	<Choose>	<Choose>	<Choose>
Item 5	<Choose>	<Choose>	<Choose>
Item 6	<Choose>	<Choose>	<Choose>
Item 7	<Choose>	<Choose>	<Choose>
Item 8	<Choose>	<Choose>	<Choose>
Item 9	<Choose>	<Choose>	<Choose>
Item 10	<Choose>	<Choose>	<Choose>
Item 11	<Choose>	<Choose>	<Choose>
Item 12	<Choose>	<Choose>	<Choose>

Area: Front verge

Area size? Small / Medium / Large

Who is the area for? Children / Adults / Everyone

	Item	Quantity	Accessibility
Item 1	<Choose>	<Choose>	<Choose>
Item 2	<Choose>	<Choose>	<Choose>
Item 3	<Choose>	<Choose>	<Choose>
Item 4	<Choose>	<Choose>	<Choose>
Item 5	<Choose>	<Choose>	<Choose>
Item 6	<Choose>	<Choose>	<Choose>
Item 7	<Choose>	<Choose>	<Choose>
Item 8	<Choose>	<Choose>	<Choose>
Item 9	<Choose>	<Choose>	<Choose>
Item 10	<Choose>	<Choose>	<Choose>
Item 11	<Choose>	<Choose>	<Choose>
Item 12	<Choose>	<Choose>	<Choose>

Area: Outdoor eating area

Area size? Small / Medium / Large

Who is the area for? Children / Adults / Everyone

	Item	Quantity	Accessibility
Item 1	<Choose>	<Choose>	<Choose>
Item 2	<Choose>	<Choose>	<Choose>
Item 3	<Choose>	<Choose>	<Choose>
Item 4	<Choose>	<Choose>	<Choose>
Item 5	<Choose>	<Choose>	<Choose>
Item 6	<Choose>	<Choose>	<Choose>
Item 7	<Choose>	<Choose>	<Choose>
Item 8	<Choose>	<Choose>	<Choose>
Item 9	<Choose>	<Choose>	<Choose>
Item 10	<Choose>	<Choose>	<Choose>
Item 11	<Choose>	<Choose>	<Choose>
Item 12	<Choose>	<Choose>	<Choose>

Area: Garage

Area size? Small / Medium / Large

Who is the area for? Children / Adults / Everyone

	Item	Quantity	Accessibility
Item 1	<Choose>	<Choose>	<Choose>
Item 2	<Choose>	<Choose>	<Choose>
Item 3	<Choose>	<Choose>	<Choose>
Item 4	<Choose>	<Choose>	<Choose>
Item 5	<Choose>	<Choose>	<Choose>
Item 6	<Choose>	<Choose>	<Choose>
Item 7	<Choose>	<Choose>	<Choose>
Item 8	<Choose>	<Choose>	<Choose>
Item 9	<Choose>	<Choose>	<Choose>
Item 10	<Choose>	<Choose>	<Choose>
Item 11	<Choose>	<Choose>	<Choose>
Item 12	<Choose>	<Choose>	<Choose>

Area: Garden shed

Area size? Small / Medium / Large

Who is the area for? Children / Adults / Everyone

	Item	Quantity	Accessibility
Item 1	<Choose>	<Choose>	<Choose>
Item 2	<Choose>	<Choose>	<Choose>
Item 3	<Choose>	<Choose>	<Choose>
Item 4	<Choose>	<Choose>	<Choose>
Item 5	<Choose>	<Choose>	<Choose>
Item 6	<Choose>	<Choose>	<Choose>
Item 7	<Choose>	<Choose>	<Choose>
Item 8	<Choose>	<Choose>	<Choose>
Item 9	<Choose>	<Choose>	<Choose>
Item 10	<Choose>	<Choose>	<Choose>
Item 11	<Choose>	<Choose>	<Choose>
Item 12	<Choose>	<Choose>	<Choose>

Area: Other (specify) | **Area size?** ○ Small ○ Medium ○ Large | **Who is the area for?** ○ Children ○ Adults ○ Everyone

	Item	Quantity	Accessibility
Item 1	<Choose>	<Choose>	<Choose>
Item 2	<Choose>	<Choose>	<Choose>
Item 3	<Choose>	<Choose>	<Choose>
Item 4	<Choose>	<Choose>	<Choose>
Item 5	<Choose>	<Choose>	<Choose>
Item 6	<Choose>	<Choose>	<Choose>
Item 7	<Choose>	<Choose>	<Choose>
Item 8	<Choose>	<Choose>	<Choose>
Item 9	<Choose>	<Choose>	<Choose>
Item 10	<Choose>	<Choose>	<Choose>
Item 11	<Choose>	<Choose>	<Choose>
Item 12	<Choose>	<Choose>	<Choose>

Area: Other (specify) | **Area size?** ○ Small ○ Medium ○ Large | **Who is the Area for?** ○ Children ○ Adults ○ Everyone

	Item	Quantity	Accessibility
Item 1	<Choose>	<Choose>	<Choose>
Item 2	<Choose>	<Choose>	<Choose>
Item 3	<Choose>	<Choose>	<Choose>
Item 4	<Choose>	<Choose>	<Choose>
Item 5	<Choose>	<Choose>	<Choose>
Item 6	<Choose>	<Choose>	<Choose>
Item 7	<Choose>	<Choose>	<Choose>
Item 8	<Choose>	<Choose>	<Choose>
Item 9	<Choose>	<Choose>	<Choose>
Item 10	<Choose>	<Choose>	<Choose>
Item 11	<Choose>	<Choose>	<Choose>
Item 12	<Choose>	<Choose>	<Choose>

Additional Features of back garden, front garden and Verge (if applicable)*

Does the home have any of the following outdoor features? For the back garden, front garden and verge (e.g. a narrow strip of grass bordering a pavement in front of a house), please select a feature if it is present.

Back Garden	Front Garden	Verge
☐ Tree - able to be climbed	☐ Tree - able to be climbed	☐ Tree - able to be climbed
☐ Wall - able to throw/kick a ball against	☐ Wall - able to throw/kick a ball against	☐ Wall - able to throw/kick a ball against
☐ Garden area	☐ Garden area	☐ Garden area
☐ Grassed area	☐ Grassed area	☐ Grassed area
☐ Undercover area	☐ Undercover area	☐ Undercover area
☐ Shaded area	☐ Shaded area	☐ Shaded area
☐ Driveway	☐ Driveway	☐ Driveway
☐ Paved area	☐ Paved area	☐ Paved area
☐ Footpath	☐ Footpath	☐ Footpath
☐ Windows from the home overlook this area	☐ Windows from the home overlook this area	☐ Windows from the home overlook this area

SECTION 2: ADDITIONAL QUESTIONS

Instructions

You're now finished with Section 1 - The Home Audit.

Section 2 asks you to complete some additional questions about your home. This will not take you too long to complete.

1. Which best describes the home? *

- Detached
- Semi-detached
- Terrace house
- Bungalow
- Flat / Unit / Apartment

2. How many floors does the home have? *

- One
- Two
- More than two

3a Does the home have internal stairs? (e.g. between floors) *

- Yes
- No

3b Does the home have external stairs? (e.g. to get to the front or back door) *

- Yes
- No

4. Is there a front gate/fence that encloses the front garden? *

- Yes
- No
- Partially

5. Are any of the following spaces directly beside/behind the home? *

- Public open space (e.g. park)
- Back/side laneway
- Vacant block
- Pedestrian cut through
- None

6. What would you say your house is? *

- Small
- Medium
- Large

7. What would you say your garden is? *

- Small
- Medium
- Large
- No garden

SECTION 2B: EQUIPMENT

Please select one answer for each of the following questions.

1. How many books do you currently have in your home? *

- 0
- 1-50
- 51-100
- 101-150
- 151-200
- >200

2. How many magazines do you currently have in your home? *

- 0
- 1-50
- 51-100
- 101-150
- 151-200
- >200

3. How many DVDs do you have in your home? *

- 0
- 1-25
- 26-50
- 51-75
- 76-100
- >100

4. How many electronic games (including computer games, but excluding gaming apps) do you currently have in your home? *

- 0
- 1-25
- 26-50
- 51-75
- 76-100
- >100

6. What would you say your house is? *

- Small
- Medium
- Large

7. What would you say your garden is? *

- Small
- Medium
- Large
- No garden

SECTION 2B: EQUIPMENT

Please select one answer for each of the following questions.

1. How many books do you currently have in your home? *

- 0
- 1-50
- 51-100
- 101-150
- 151-200
- >200

2. How many magazines do you currently have in your home? *

- 0
- 1-50
- 51-100
- 101-150
- 151-200
- >200

3. How many DVDs do you have in your home? *

- 0
- 1-25
- 26-50
- 51-75
- 76-100
- >100

4. How many electronic games (including computer games, but excluding gaming apps) do you currently have in your home? *

- 0
- 1-25
- 26-50
- 51-75
- 76-100
- >100

5. How many of these electronic games are active video games? (any game that gets you up and moving e.g. Wii sports, Just dance, Shape up etc...) *

- 0
- 1-5
- 6-10
- 11-15
- 16-20
- >20

6. How many smart phones do you currently have in your home? *

- 0
- 1-2
- 3-4
- 5-6
- 7-8
- >8

7. How many fitness trackers do you currently have in your home? (e.g. fitbit, Garmin, apple watches etc..) *

- 0
- 1-2
- 3-4
- 5-6
- 7-8
- >8

8. What best describes your type of internet service? *

- No internet access
- Dial up modern
- Wireless broadband

9. What best describes your type of TV service? *

- Freeview
- Digital TV (e.g. SKY, Virgin Media, TalkTalk, BT etc..)
- Other

10. Do you subscribe to or have access to a movie/TV streaming service? (e.g. Netflix, Now TV, Amazon Video, Kodi etc...) *

- Yes
- No

11. Do you own a dog? *

- Yes
- No

12. Do you own any other pets? (specify)

SECTION 3: YOU AND YOUR FAMILY

Please answer the following questions.

1. What is your age in years? *

2. What is your gender? *

- Male
- Female

3. In which country were you born? *

4. What is the main language spoken in your home? *

5. Which best describes your ethnicity?

- White
- Mixed Race
- Asian or Asian British
- Black or Black British
- Chinese
- Other

6. How many people (including yourself) live in your household? *

7. How many children under 18 years of age live in your household? *

8. What are the ages and gender of the children living in your household? (for each child please write their age and select either female or male)

1. Male / Female
2. Male / Female
3. Male / Female
4. Male / Female
5. Male / Female
6. Male / Female
7. Male / Female

9. Which best describes your highest level of education completed?

- Some Secondary High School
- Completed Secondary High School (Year 11)
- Trade Qualifications / Apprenticeship
- Diploma / Certificate
- University Bachelor Degree or Higher

10. What is your approximate **annual household** income before tax?

- Under £10,000
- £10,000 - £20,000
- £20,000 - £30,000
- £30,000 - £50,000
- £50,000 - £70,000
- £70,000 - £100,000
- £100,000 and above

11. Which best describes your family situation? *

- Single Parent Household
- Two Parent Household
- Other

12. Do you rent or own your home? *

- Rent
- Own/Paying off

13. How long have you been at your current address? *

14. Please write today's date *

15. What suburb/area do you live in? *

16. What is your postcode? *

17. Participant number? *

THANKS FOR TAKING THE TIME TO COMPLETE OUR AUDIT TOOL!

Appendix VII: Questionnaire investigating social environmental factors

HomeSPACE Questionnaire

We are interested in learning more about your home and how it might influence children's physical activity and sitting at home.

This series of questions will ask you about you and your family's perceptions, preferences, and priorities for housing and activities at home.

If you have any questions about the questionnaire or the study please contact the Lead Researcher:

Michael Sheldrick

Email: 708824@swansea.ac.uk

College of Engineering; Swansea University

Bay Campus; Fabian Way; Swansea; SA1 8EN

Thank you for helping us with this study!

Swansea University
Prifysgol Abertawe

The HomeSPACE Study

We would like the same parent/guardian who completed the home audit to also complete this questionnaire. Please type your age and select your gender below.

Your age *		Your gender *	Male Female

SECTION 1A: PERCEPTIONS

This series of questions will refer to your child. For these questions please think of your child who is aged between 9 and 13 years and who is taking part in the study. If you have more than 1 child in this group participating, please think of the child who has the next birthday.
Please type the Child's age and their participant number and select their gender below. The researcher should have given you your child's participant number. However, if you don't remember it, you can find it on the front of your child's participant booklet.

1. Participant number *		Child's age *		Child's gender *	Boy Girl

How strongly do you agree or disagree with the following statements about your home?
(Please select the answer that best applies)

2. Space

There is enough space for my child to:	**(1)** strongly disagree	**(2)** disagree	**(3)** agree	**(4)** strongly agree	**(5)** N/A
.... play in the front garden *					
.... play in the back garden *					
.... play on the verge outside the house *					
.... play inside the house *					
.... play an active game inside the house *					
.... move around freely inside the house *					

3. Safety

	(1) strongly disagree	(2) disagree	(3) agree	(4) strongly agree	(5) N/A
It is easy to see clearly into the back garden from inside the house *	○	○	○	○	○
It is easy to see clearly into the front garden from inside the house *	○	○	○	○	○
It is easy to see clearly onto the verge from inside the house *	○	○	○	○	○
The back garden is a safe place for my child to play *	○	○	○	○	○
The front garden is a safe place for my child to play *	○	○	○	○	○
The verge is a safe place for my child to play *	○	○	○	○	○

4. Connection and flow

	(1) strongly disagree	(2) disagree	(3) agree	(4) strongly agree	(5) N/A
The front garden and back garden connect so my child can move freely between the two areas *	○	○	○	○	○
The front garden and verge connect so my child can move freely between the two areas *	○	○	○	○	○
It is easy for my child to get from inside the house to the back garden *	○	○	○	○	○
It is easy for my child to get from inside the house to the front garden *	○	○	○	○	○

SECTION 1B: ACTIVITY PREFERENCES

5. This question is about the activities that **your child** prefers to do **when at home.** 'Home' includes both inside your house, and outside in your garden, driveway or verge area. For each item please select the answer that best characterises **your child.**

Given the choice, when at home, my child prefers either the activities on the left or on the right:

	(1) Almost Always	**(2)** Mostly	**(3)** About Equal	**(4)** Mostly	**(5)** Almost Always	
Quiet activities, such as reading or drawing *	○	○	○	○	○	Energetic activites, such as kicking a ball, playing in the pool or bouncing on a trampoline
Watching TV or movies ▪	○	○	○	○	○	Active types of play, such as playing catch, riding a scooter or dancing
Playing electronic games or using the computer for fun ▪	○	○	○	○	○	Active types of play, such as playing catch, riding a scooter or dancing
Sitting around ▪	○	○	○	○	○	Running around
Playing indoors ▪	○	○	○	○	○	Playing outdoors
To be alone ▪	○	○	○	○	○	To be with other family members

6. This question is about the activities that **you** prefer to do **when at home.** 'Home' includes both inside your house, and outside in your garden, driveway or verge area. For each item please select the answer that best characterises **you.**

Given the choice, when at home, I prefer either the activities on the left or on the right:

	(1) Almost Always	**(2)** Mostly	**(3)** About Equal	**(4)** Mostly	**(5)** Almost Always	
Quiet pursuits like reading or craft *	○	○	○	○	○	Active pursuits like exercise or gardening
Watching TV or movies ▪	○	○	○	○	○	Doing something physically active
Using the computer or playing electronic games for entertainment ▪	○	○	○	○	○	Doing something physically active
To be indoors ▪	○	○	○	○	○	To be outdoors
Watching TV or movies with my child ▪	○	○	○	○	○	Doing physical activity, such as kicking a ball or playing outside, with my child
Playing electronic games or using the computer for fun with my child ▪	○	○	○	○	○	Doing physical activity, such as kicking a ball or playing outside, with my child
Doing outdoor activities with my children ▪	○	○	○	○	○	Doing indoor activities with my children

SECTION 1C: ACTIVITY PRIORITIES

7. This questions asks you to rate how **important or unimportant** you believe it is for **your child** to do certain activities **when at home.** 'Home' includes both inside your house, and outside in your garden, driveway or verge. For each item please select the answer that best applies.

When at home, how important is it to you that your child:	**(1)** Very un-important	**(2)** Un-important	**(3)** Moderately important	**(4)** Important	**(5)** Very important
Does homework *	○	○	○	○	○
Play or practice sports, such as kicking a football or shooting a basketball •	○	○	○	○	○
Watch TV or movies •	○	○	○	○	○
Do some active types of play, such as running around, climbing a tree or riding a scooter •	○	○	○	○	○
Spend time reading •	○	○	○	○	○
Be physically active •	○	○	○	○	○
Play electronic games or use the computer for fun •	○	○	○	○	○
Spend time outside •	○	○	○	○	○

SECTION 1D: HOME PRIORITIES

8. The following 2 questions will ask you to rate how important it is to have certain **features and equipment in your family home.** 'Home' includes both inside your house, and outside in your garden, driveway or verge. For each item please select the answer that best applies.

How important is it for your family home to have:	**(1)** Very un-important	**(2)** Un-important	**(3)** Moderately important	**(4)** Important	**(5)** Very important
a dedicated home theatre room/area *	○	○	○	○	○
a dedicated music, craft or reading room/area •	○	○	○	○	○
a dedicated 'activity' or 'games' room/area for children •	○	○	○	○	○
at least two separate living areas so adults and children have their own space •	○	○	○	○	○
space for children to play outside •	○	○	○	○	○
space for children to play inside •	○	○	○	○	○
children's bedrooms that have space to play •	○	○	○	○	○
a swimming pool •	○	○	○	○	○

How important is it for your family home to have:	**(1)** Very un-important	**(2)** Un-important	**(3)** Moderately important	**(4)** Important	**(5)** Very important
a home theatre system for watching TV and movies *					
at least two TV's so family members can watch their own programme *					
a TV specifcally for your child's use *					
a computer specifically for your child's use *					
a TV in your child's bedroom *					
a computer in your child's bedroom *					
an electronic games console *					
a computer in a place that you can see when being used by your child *					
a range of books in your house *					
musical instruments in the house *					
outdoor play equipment (e.g. swings, tree house, basketball ring) *					
exercise equipment (e.g. exercise bike, weights) *					
sports equipment (e.g. bats, balls, bike) *					

SECTION 2: FAMILY ENVIRONMENTAL FACTORS RELATED TO PHYSICAL ACTIVITY

9. This section consists of questions asking for your perception on family environmental factors which may influence your child's physical activity.

Value. Referring to your perceptions of your families shared valuation of the importance of being physically active.

In our family...	**(1)** strongly disagree	**(2)** disagree	**(3)** agree	**(4)** strongly agree
... we make a point of being physically active during daily life. *				
... it is normal to be physically active on a regular basis. *				
... it goes without saying that we exercise and are physically active on a regular basis. *				
... it is normal to be physically active in our leisure time. *				

Cohesion. Refers to participating in physical activities together as a family and the interaction during these activities.

In our family...	**(1)** strongly disagree	**(2)** disagree	**(3)** agree	**(4)** strongly agree
... we like being together during physical activities (e.g. bike rides, Tennis etc..). *				
... we enjoy exercising together. *				
... we have fun doing physical activities together (e.g. bike rides, tennis etc...). *				
... we find it very pleasent to be physically active together. *				
... we like spending time together in sports activities. *				

Information. Refers to your families search, sharing and use of information related to sport and exercise.

In our family...	**(1)** strongly disagree	**(2)** disagree	**(3)** agree	**(4)** strongly agree
... we watch TV-programmes on physical activity and exercise. *	○	○	○	○
... we explicitly look for the latest information on physical activity and exercise to stay up to date. *	○	○	○	○
... we read newspaper or magazine articles on fitness, physical activity, and exercise. *	○	○	○	○
... we collect information (e.g. on the internet) on physical activity and exercise. *	○	○	○	○

SECTION 3: RULES

10. Do you apply any of the following outdoor safety rules with your child (please select yes or no for each)

Stay close/within sight of house/parent *	○ Yes ○ No	Do not go into street *	○ Yes ○ No	Do not ride bike on street *	○ Yes ○ No

11. Do you apply any of the following rules about electronic media with your child (Please select yes or no for each)

No TV/Tablet/Computer/Games console (I.e. electronic media) before homework *	○ Yes ○ No	Maximum number of hours per day of TV/Tablet/Computer /Games console (I.e. electronic media) *	○ Yes ○ No	No use of TV/Tablet /Computer/Games console (I.e. electronic media) at the dinner table *	○ Yes ○ No

12. Do you apply any of the following rules about indoor home-based physical activity with your child (Please select yes or no for each)

No running in the house *	○ Yes ○ No	No ball games in the house *	○ Yes ○ No

SECTION 4:YOUR ACTIVITY AT HOME

13. This last question will ask you to report **YOUR** time spent in different activities when at **home** on both weekdays and weekend days. **'Home'** includes both inside your house, and outside in your garden, driveway or verge.

On a typical **WEEKDAY when at home,** how much time do **YOU** spend doing the following activities? **'Home'** includes both inside your house, and outside in your garden, driveway or verge.

	None	15 min. or less	30 min.	1 hr	2 hrs	3 hrs	4 hrs	5 hrs	6 hrs or more
1. Watching television (including movies) *	○	○	○	○	○	○	○	○	○
2. Using a mobile phone/tablet/handheld games console for leisure activities (e.g. games, information, chatting) *	○	○	○	○	○	○	○	○	○
3. Using a computer or games console while sitting down for entertainment (e.g. Xbox, playstation, PC, Laptop) *	○	○	○	○	○	○	○	○	○
4. Playing **active** video games using a games console (i.e. **video games that get you up and about and moving**, e.g. just dance, wii sports) *	○	○	○	○	○	○	○	○	○
5. Doing paperwork or productive computer work (e.g. office work, emails, paying bills, etc.) *	○	○	○	○	○	○	○	○	○
6. Sitting reading a book or magazine *	○	○	○	○	○	○	○	○	○
7. Playing a musical instrument *	○	○	○	○	○	○	○	○	○
8. Doing artwork or crafts *	○	○	○	○	○	○	○	○	○
9. Doing exercise or being physically active at **home** (including both inside the **house,** and outside in your **garden, driveway or verge)** *	○	○	○	○	○	○	○	○	○
10. Doing housework or gardening *	○	○	○	○	○	○	○	○	○

On a typical **WEEKEND DAY when at home,** how much time do **YOU** spend doing the following activities? **'Home'** includes both inside your house, and outside in your garden, driveway or verge.

	None	15 min. or less	30 min.	1 hr	2 hrs	3 hrs	4 hrs	5 hrs	6 hrs or more
1. Watching television (including movies) *									
2. Using a mobile phone/tablet/handheld games console for leisure activities (e.g. games, information, chatting) *									
3. Using a computer or games console while sitting down for entertainment (e.g. Xbox, playstation, PC, Laptop)) *									
4. Playing **active** video games using a games console (i.e. **video games that get you up and about and moving**, e.g. just dance, wii sports) *									
5. Doing paperwork or productive computer work (e.g. office work, emails, paying bills, etc.) *									
6. Sitting reading a book or magazine *									
7. Playing a musical instrument *									
8. Doing artwork or crafts *									
9. Doing exercise or being physically active at **home** (including both inside your **house**, and outside in your **garden, driveway or verge)** *									
10. Doing housework or gardening *									

THANKS FOR TAKING THE TIME TO COMPLETE THESE QUESTIONS!

Appendix VIII: Description of independent variables for study 3

Description of Independent variables		
Audit variables	***Calculation***	***Items***
Physical activity (PA) equipment accessibility and availability summary score	Each PA item was multiplied by its accessibility rating (A=1, B=2, C=3, D=4). The PA equipment values for the home were then summed.	**Sports equipment** 1. Balls (e.g., football, rugby, basketball) 2. Bats/Racquets (e.g., cricket, softball, tennis) 3. Frisbee 4. Skipping rope 5. Hula hoop **Transportation equipment** 6. Bicycle 7. Scooter/skateboard/ripstick/skates **Fitness equipment** 8. Stationary (aerobic) exercise equipment (e.g., treadmill, exercise bike, punch bag) 9. Weights/toning equipment **Outdoor play equipment** 10. Basketball ring 11. Fixed play structure (e.g., swings, slide, climbing, sandpit) 12. Cubby/Tree house 13. Trampoline 14. Pool (in ground or above) 15. Football goal net 16. Swing ball 17. Badminton/Volleyball net **Indoor play equipment** 18. Pool/snooker table 19. Table tennis table 20. Table football
Musical instrument accessibility and availability summary score	Each musical instrument item was multiplied by its accessibility rating (A=1, B=2, C=3, D=4). The musical instrument values for the home were then summed.	21. Piano/ keyboard 22. Drums 23. Other instruments (e.g., guitar, trumpet, violin, flute)
Overall media equipment accessibility and	Each media equipment item in the home was multiplied by its accessibility	**Fixed** 24. Television 25. VCR/DVD/Blue-ray player 26. Pay TV (e.g., Sky)

availability summary score	rating (A=1, B=2, C=3, D=4). The media equipment values for the home were then summed.	27. TV on demand (e.g., Apple TV) 28. Desktop computer 29. Video game system (attached to TV) (e.g., Xbox, Wii, PlayStation)
Bedroom media equipment accessibility and availability summary score	Each media equipment item in the primary child's bedroom was multiplied by its accessibility rating (A=1, B=2, C=3, D=4). The media equipment values in the child's bedroom were then summed.	30. **ACTIVE** video game system (e.g., Wii Fit, Xbox Kinect, PlayStation Move) **Portable** 31. Handheld video game player (e.g., Nintendo DS, Sony PSP) 32. Laptop computer 33. Tablet computer (e.g., iPad, Samsung Galaxy) 34. Ipod Touch/ Galaxy Player (or similar)
Seated furniture accessibility and availability summary score	Each seated furniture item was multiplied by its accessibility rating (A=1, B=2, C=3, D=4). The seated furniture item values for the home were then summed.	35. Sofa (2+ seater) 36. Lounge chair (single seater) 37. Coffee table 38. Dining/kitchen chair 39. Dining/kitchen table 40. Office chair 41. Desk
Number of living areas with a TV	Total number of living areas in the home with a TV	**Living areas** Open plan living area Lounge Office Other room
Presence of a TV in the child's bedroom	Whether there was a TV located in the primary child's bedroom	Yes/no
Presence of an open plan living area in the home	Whether there was an open plan living area present	Yes/no
Audit questions	***Individual items***	***Item categories***
Home features	Type of home	Detached house; Semi-detached; Terrace house; Bungalow; Flat/unit/apartment (5)
	Number of floors	One; Two; More than two (3)
	House size	Small; Medium; Large (3)
	Garden size	Small; Medium; Large; No garden (4)
Electronic media	Type of TV service	Freeview; Digital TV (e.g., SKY, Virgin Media, TalkTalk, BT etc…); Other (3)
	Subscription to a movie/TV streaming service? (e.g., Netflix,	Yes; No (2)

	Now TV, Amazon Video, Kodi etc…)	
	Number of smartphones	0; 1-2;3-4;5-6;7-8;>8 (6)
Space to play	There is enough space to play…: ... in the front garden … in the back garden ... inside the house	Strongly disagree; disagree; agree; strongly agree; (N/A) (5)

PA: Physical activity

Appendix IX: Description of independent variables for study 4

Description of variables		
Audit variables	***Calculation***	***Items***
Physical activity (PA) equipment accessibility and availability summary score	Each PA item was multiplied by its accessibility rating (A=1, B=2, C=3, D=4). The PA equipment values for the home were then summed.	**Sports equipment** 42. Balls (e.g., football, rugby, basketball) 43. Bats/Racquets (e.g., cricket, softball, tennis) 44. Frisbee 45. Skipping rope 46. Hula hoop **Transportation equipment** 47. Bicycle 48. Scooter/skateboard/ripstick/skates **Fitness equipment** 49. Stationary (aerobic) exercise equipment (e.g., treadmill, exercise bike, punch bag) 50. Weights/toning equipment **Outdoor play equipment** 51. Basketball ring 52. Fixed play structure (e.g., swings, slide, climbing, sandpit) 53. Cubby/Tree house 54. Trampoline 55. Pool (in ground or above) 56. Football goal net 57. Swing ball 58. Badminton/Volleyball net **Indoor play equipment** 59. Pool/snooker table 60. Table tennis table 61. Table football
Musical instrument accessibility and availability summary score	Each musical instrument item was multiplied by its accessibility rating (A=1, B=2, C=3, D=4). The musical instrument values for the home were then summed.	62. Piano/ keyboard 63. Drums 64. Other instruments (e.g., guitar, trumpet, violin, flute)

Overall media equipment accessibility and availability summary score	Each media equipment item in the home was multiplied by its accessibility rating (A=1, B=2, C=3, D=4). The media equipment values for the home were then summed.	**Fixed** 65. Television 66. VCR/DVD/Blue-ray player 67. Pay TV (e.g., Sky) 68. TV on demand (e.g., Apple TV) 69. Desktop computer 70. Video game system (attached to TV) (e.g., Xbox, Wii, PlayStation)
Bedroom media equipment accessibility and availability summary score	Each media equipment item in the primary child's bedroom was multiplied by its accessibility rating (A=1, B=2, C=3, D=4). The media equipment values in the child's bedroom were then summed.	71. **ACTIVE** video game system (e.g., Wii Fit, Xbox Kinect, PlayStation Move) **Portable** 72. Handheld video game player (e.g., Nintendo DS, Sony PSP) 73. Laptop computer 74. Tablet computer (e.g., iPad, Samsung Galaxy) 75. Ipod Touch/ Galaxy Player (or similar)
Fixed media equipment accessibility and availability summary score	Each fixed media equipment item in the home was multiplied by its accessibility rating (A=1, B=2, C=3, D=4). The fixed media equipment values for the home were then summed.	24. Television 25. VCR/DVD/Blue-ray player 26. Pay TV (e.g., Sky) 27. TV on demand (e.g., Apple TV) 28. Desktop computer 29. Video game system (attached to TV) (e.g., Xbox, Wii, PlayStation) 30. **ACTIVE** video game system (e.g., Wii Fit, Xbox Kinect, PlayStation Move)
Portable media equipment accessibility and availability summary score	Each portable media equipment item in the home was multiplied by its accessibility rating (A=1, B=2, C=3, D=4). The portable media equipment values for the home were then summed.	31. Handheld video game player (e.g., Nintendo DS, Sony PSP) 32. Laptop computer 33. Tablet computer (e.g., iPad, Samsung Galaxy) 34. Ipod Touch/ Galaxy Player (or similar)
Presence of a TV in the child's bedroom	Whether there was a TV located in the	Yes/no

	primary child's bedroom	
Presence of an open plan living area in the home	Whether there was an open plan living area present	Yes/no
Audit questions	***Individual items***	***Item categories***
Electronic media	Type of TV service	Freeview; Digital TV (e.g., SKY, Virgin Media, TalkTalk, BT etc…); Other (3)
	Number of smartphones	0; 1-2;3-4;5-6;7-8;>8 (6)
Space to play	There is enough space to play…: … in the back garden ... inside the house	Strongly disagree; disagree; agree; strongly agree; (N/A) (5)
Social and individual factors	***Individual items***	***Item categories /summary scores***
Parental leisure activity priorities	How important is it that your child when at home …: … participates in active play … plays electronic games/computer for fun … watch TV/movies … spend time outside	Very unimportant; unimportant; neither important nor unimportant; important; very important (5)
Activity preferences	5 choice items for child activity preferences at home 7 choice items for parental activity preferences at home	Child activity preferences at home scale Parent activity preferences at home scale
Rule limiting screen-time	Does the parent enforce a maximum hrs/day of screen-time rule with their child	Yes/no

Appendix X – Univariate regression associations for Study 4

Table 25. Univariate associations between social and individual factors and children's home–based sitting time and breaks

Variable	Home-based sitting						Home-based sitting breaks					
	Overall		***Weekday***		***Weekend***		***Overall***		***Weekday***		***Weekend***	
	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI
Parental activity preferences	-0.11	-2.05, 0.27	-0.12	-2.33, 0.16	-0.09	-2.27, 0.59	0.19*	0.13, 0.85	0.21*	0.20, 0.95	0.11	-0.11, 0.79
Child activity preferences	-0.23*	-2.62, -0.63	-0.27*	-3.14, -1.03	-0.01	-1.93, 0.42	0.10	-0.10, 0.54	0.15*	0.01, 0.69	-0.03	-0.45, 0.30
Max h/day of screen-time	-0.06	-2.60, 1.04	-0.04	-2.56, 1.37	-0.07	-3.07, 1.20	0.11	-0.12, 1.03	0.05	-0.38, 0.84	0.16*	0.04, 1.40
Importance of active play [1]	-0.08	-1.63, 0.47	-0.09	-1.83, 0.44	-0.05	-1.59, 0.83	0.18*	0.10, 0.76	0.15*	0.02, 0.72	0.20*	0.12, 0.88
Importance of time outside [1]	-0.06	-1.59, 0.70	-0.05	-1.67, 0.83	-0.05	-1.77, 0.94	0.18*	0.10, 0.82	0.18*	0.10, 0.86	0.11	-0.11, 0.75
Importance of watching TV/movies [1]	-0.09	-1.96, 0.46	-0.08	-1.99, 0.62	-0.14	-2.65, 0.14	-0.08	-0.60, 0.17	-0.09	-0.67, 0.14	0.00	-0.44, 0.46
Importance of using E-games/computer [1]	0.10	-0.35, 1.87	0.12	-0.19, 2.23	0.04	-0.93, 1.65	-0.08	-0.54, 0.16	-0.04	-0.50, 0.26	-0.10	-0.68, 0.15

Table 26. Univariate associations between social and individual factors and children's home–based PA

Variable	Home-based LPA						Home-based MVPA					
	Overall		***Weekday***		***Weekend***		***Overall***		***Weekday***		***Weekend***	
	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI
Parental activity preferences	0.10	-0.18, 0.93	0.10	-0.17, 1.01	0.04	-0.50, 0.85	0.08	-0.18, 0.69	0.10	-0.12, 0.79	0.03	-0.45, 0.63
Child activity preferences	0.01	-0.46, 0.53	0.09	-0.20, 0.84	-0.10	-0.96, 0.20	0.15*	0.04, 0.81	0.20*	0.18, 0.97	0.04	-0.35, 0.58
Max h/day of screen-time	0.07	-0.45, 1.34	0.00	-0.95, 0.95	0.13	-0.14, 1.96	0.14*	0.01,1.40	0.13	-0.08, 1.38	0.15*	0.01, 1.70
Importance of active play [1]	0.14	-0.02, 1.01	0.17*	0.11, 1.18	0.11	-0.15, 1.06	0.09	-0.13, 0.67	0.10	-0.12, 0.73	0.05	-0.32, 0.66
Importance of time outside [1]	0.07	-0.28, 0.85	0.10	-0.19, 1.01	0.04	-0.50, 0.84	0.01	-0.41, 0.48	0.03	-0.37, 0.56	-0.04	-0.67, 0.41
Importance of watching TV/movies [1]	-0.05	-0.79, 0.41	-0.05	-0.84, 0.43	-0.01	-0.77,0.64	-0.01	-0.50, 0.44	-0.02	-0.56, 0.42	-0.01	-0.59, 0.55
Importance of using E-games/ computer [1]	-0.13	-1.04, 0.04	-0.12	-1.06, 0.11	-0.08	-0.98, 0.29	-0.14*	-0.84, 0.00	-0.11	-0.81, 0.09	-0.15*	-1.01, 0.00

* p =<0.05. [1] Parent perceived importance of activities for their child.

Table 27. Univariate associations between social and individual factors and the media equipment accessibility and availability summary scores

Variable	Overall media equipment [1]		Portable media equipment [1]		Fixed media equipment [1]		Bedroom media equipment [1]	
	β	95% CI	β	95% CI	β	95% CI	β	95% CI
Parental activity preferences	-0.19*	-7.85, -1.20	-0.08	-2.60, 0.66	-0.18	-5.99, -0.86	-0.16*	-2.53, -0.18
Child activity preferences	-0.03	-3.64, 2.42	-0.08	-2.26, 0.68	0.00	-2.29, 2.38	-0.04	-1.32, 0.79
Max h/day of screen-time	-0.12	-10.12, 0.74	-0.14*	-5.33, -0.11	-0.05	-5.57, 2.80	-0.10	-3.23, 0.57
Importance of active play [2]	0.01	-2.97, 3.39	-0.09	-2.57, 0.50	0.04	-1.72, 3.16	0.04	-0.82, 1.40
Importance of time outside [2]	-0.03	-4.24, 2.73	-0.10	-2.85, 0.52	0.00	-2.68, 2.69	0.02	-1.06, 1.38
Importance of watching TV/ movies [2]	-0.05	-5.14, 2.45	-0.03	-2.18, 1.49	-0.07	-4.31, 1.51	-0.03	-1.57, 1.09
Importance of using E-games/computer [2]	0.11	-0.65, 5.97	0.02	-1.34, 1.89	0.11	-0.57, 4.52	0.06	-0.68, 1.64

Table 28. Univariate associations between social and individual factors and the additional physical environment factors

Variable	PA equipment [1]		Musical instruments [1]		Smartphones		TV in child's bedroom		Digital TV	
	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI
Parental activity preferences	0.10	-3.34, 20.01	-0.04	-1.76, 1.04	-0.06	-0.16, 0.07	-0.13	-0.18, 0.01	-0.12	-0.13, 0.01
Child activity preferences	0.24*	7.94, 28.56	-0.13	-2.36, 0.08	0.06	-0.06, 0.15	-0.01	-0.09, 0.08	0.02	-0.06, 0.07
Max h/day of screen-time	0.12	-2.83, 35.19	-0.00	-2.25, 2.18	-0.16*	-0.38, -0.02	-0.09	-0.25, 0.05	-0.09	-0.19, 0.04
Importance of active play [2]	0.22*	6.57, 28.31	0.02	-1.13, 1.45	-0.11	-0.19, 0.02	-0.01	-0.10, 0.08	-0.09	-0.11, 0.02
Importance of time outside [2]	0.12	-1.39, 22.87	0.06	-0.85, 1.98	-0.13	-0.22, 0.01	-0.02	-0.11, 0.09	-0.12	-0.14, 0.01
Importance of watching TV/movies [2]	-0.15*	-27.10, -0.78	-0.12	-2.82, 0.24	-0.04	-0.16, 0.09	-0.04	-0.14, 0.07	0.06	-0.05, 0.12
Importance of using E-games/ computer [2]	-0.02	-12.99, 10.31	-0.15*	-2.82, -0.16	0.06	-0.07, 0.15	0.00	-0.09, 0.09	0.07	-0.04, 0.10

* p =<0.05. [1] Accessibility and availability equipment summary score. [2] Parent perceived importance of activities for their child.

Table 29. Univariate associations between social and individual factors and architecture/home design physical environmental factors

Variable	**House size**		**Garden size**		**Space to play inside house**		**Space to play in back garden**		**Open plan living area**	
	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI
Parental activity preferences	0.04	-7.32, 12.50	0.05	-19.87, 43.04	-0.08	-0.20, 0.05	-0.06	-0.19, 0.08	0.10	-0.02, 0.16
Child activity preferences	-0.00	-8.74, 8.42	0.07	-14.50, 40.64	0.03	-0.09, 0.14	0.02	-0.10, 0.14	0.05	-0.06, 0.11
Max h/day of screen-time	0.10	-4.18, 26.18	0.06	-28.73, 70.61	0.01	-0.19,0.22	-0.04	-0.28, 0.16	0.05	-0.10, 0.20
Importance of active play [2]	-0.03	-10.89, 6.93	0.06	-17.30, 40.45	0.12	-0.01, 0.22	0.17*	0.03, 0.28	0.07	-0.04, 0.13
Importance of time outside [2]	-0.04	-12.21, 7.31	0.17*	5.66, 67.99	0.06	-0.07, 0.19	0.17*	0.03, 0.30	0.05	-0.06, 0.13
Importance of watching TV/movies [2]	-0.07	-15.92, 5.65	-0.07	-52.47, 17.49	0.03	-0.10, 0.17	0.01	-0.13, 0.16	-0.00	-0.11, 0.10
Importance of using E-games/computer [2]	-0.08	-14.89, 3.92	-0.03	-36.90, 24.47	0.11	-0.03, 0.22	-0.00	-0.13, 0.13	-0.01	-010, 0.09

* p =<0.05. [1] Objectively measured house and garden size. [2] Parent perceived importance of activities for their child.

Appendix XI: Ethical approval applications

HomeSPACE-II instrument validity and reliability study application for ethical approval

Swansea University
Prifysgol Abertawe

Applied Sports Technology Exercise and Medicine Research Centre (A-STEM)
Sport and Health Portfolio, College of Engineering

APPLICATION FOR ETHICAL COMMITTEE APPROVAL OF A RESEARCH PROJECT

In accordance with A-STEM and College of Engineering Safety Policy, all research undertaken by staff or students linked with A-STEM must be approved by the A-STEM Ethical Committee.

RESEARCH MAY ONLY COMMENCE ONCE ETHICAL APPROVAL HAS BEEN OBTAINED

The researcher(s) should complete the form in consultation with the project supervisor. After completing and signing the form students should ask their supervisor to sign it. The form should be submitted electronically to Prof Mike McNamee ([redacted]) and Dr Melitta McNarry ([redacted]).

Applicants will be informed of the Committee's decision via email to the project leader/supervisor.

1. TITLE OF PROJECT
HomeSPACE study

2. DATE OF PROJECT COMMENCEMENT AND PROPOSED DURATION OF THE STUDY
1st October 2015-30th September 2016

3. NAMES AND STATUS OF RESEARCH TEAM

State the names of all members of the research group including the supervisor(s). State the current status of the student(s) in the group i.e. Undergraduate, Postgraduate, Staff or Other (please specify).

Michael Sheldrick: Postgraduate Sport and Exercise science masters by research student (DBS checked, certificate number: 001468440434)
Luke Martin: Postgraduate Sport and Exercise science masters by research student (DBS), copy of DBS will follow.
Supervisor: Professor Gareth Stratton (DBS checked).
2nd supervisor: Dr Kelly Mackintosh (DBS checked).

4. RATIONALE AND REFERENCES

With reference to appropriate sources of information (using the Harvard system), describe in no more than 200 words the background to the proposed project.

In recent years house sizes in countries such as Australia and the USA have increased while private outdoor space has decreased (Australian Bureau of Statistics, 2011), indeed, the majority of a child's active leisure time at home is spent outdoors and their time spent indoors is most likely spent sedentary (Biddle et al., 2009). Additionally, the use of electronic media and labour saving devices within the home is on the increase, both of which facilitate sedentary behaviours (Owen et al., 2010). Together with these changes in home space children's opportunity to play freely in their local neighbourhoods is now limited, due to concerns about safety and a lack of places to play (Living streets, 2009).
As a result children spend much of their time at home, (Karsten, 2005) consequently the above changes in home space may negatively affect their health through encouraging sedentariness, associated with overweight and obesity, reduced fitness and a variety of other physiological and psychological problems (Tremblay et al., 2010). Currently, few children meet public health recommendations of at least 60 minutes of moderate to vigorous PA per day and spend a high proportion of their discretionary time sedentary (e.g. watching television (TV) or playing video games) (Tremblay et al., 2011). The results of this study will have the potential to impact UK home design and planning policy in the future in order to decrease sedentary behaviour and facilitate children's activity.

Australian Bureau of Statistics. Larger Dwellings, Smaller Households. Canberra: Commonwealth of Australia; 2007.

Biddle, S. J., Marshall, S. J., Gorely, T., & Cameron, N. (2009). Temporal and environmental patterns of sedentary and active behaviors during adolescents' leisure time. *International journal of behavioral medicine, 16*(3), 278-286.

Living Streets (2009) No Ball Games Here (or Shopping or Talking to their Neighbours): How UK streets have become no-go areas for our communities. London: Living Streets.

Owen, N., Healy, G. N., Matthews, C. E., & Dunstan, D. W. (2010). Too much sitting: the population-health science of sedentary behavior. *Exercise and sport sciences reviews*, *38*(3), 105.

Maitland, C., Stratton, G., Foster, S., Braham, R., & Rosenberg, M. (2014). The Dynamic Family Home: a qualitative exploration of physical environmental influences on children's sedentary behaviour and physical activity within the home space. *International Journal of Behavioral Nutrition and Physical Activity*,*11*(1), 157.

Karsten, L. (2005). It all used to be better? Different generations on continuity and change in urban children's daily use of space. *Children's Geographies*, *3*(3), 275-290.

Tremblay, M. S., Colley, R. C., Saunders, T. J., Healy, G. N., & Owen, N. (2010). Physiological and health implications of a sedentary lifestyle. *Applied Physiology, Nutrition, and Metabolism*, *35*(6), 725-740.

Tremblay, M. S., LeBlanc, A. G., Kho, M. E., Saunders, T. J., Larouche, R., Colley, R. C., Goldfield, G. and Gorber, S. (2011) 'Systematic review of sedentary behaviour and health indicators in school-aged children and youth', *International Journal of Behavioral Nutrition and Physical Activity*, 8(1),98.

5. OBJECTIVES

State the objectives of the project, i.e. one or more precise statements of what the project is designed to achieve.

-To investigate the influence of the physical environment of the home space on the sedentary and non-sedentary behaviour of children aged 10-12 years.
-To test and develop a valid and reliable home audit tool to measure parameters of the home physical environment that may influence children's sedentary and non-sedentary behaviour at home.

- To discover the sedentary and physical activity habits of typical school children aged 10-12 years in Wales.

6.1 STUDY DESIGN

- outline the chosen study design (e.g. cross-section, longitudinal, intervention, RCT, questionnaire etc)

We will use a research approach, which will involve one parent/guardian from a family and a researcher simultaneously walking through a home, independently completing a home audit tool (validity) already validated for use in Australian homes. Once the researcher and the parent have completed the Home audit the children of the family will be asked to answer an online health and lifestyle questionnaire called the Child Health and Activity Tool (CHAT) in the presence of their parent, the leader researcher and another member of the study team who will be supervising the visit. Lastly, the same parent/guardian will be asked to complete the home audit independently one week later and return via post (reliability).

6.2 STUDY DESIGN

- state the number and characteristics of study participants

- state the inclusion criteria for participants

- state the exclusion criteria for participants and identify any requirements for health screening

- state whether the study will involve vulnerable populations (i.e. young, elderly, clinical etc.)

- state the requirements/commitments expected of the participants (e.g. time, exertion level etc)

Eligible participants include families from South Wales with at least one parent/guardian of any age and gender and at least one child aged 10 to 12 years of any gender. 15 families will be recruited to this study. The sample will include families that are demographically represented using the Welsh Index of Multiple Deprivation (WIMD).

6.3 PARTICIPANT RECRUITMENT

How and from where will participants be recruited?

Participants will be recruited to the HomeSPACE study via advertising through a variety of channels as required. Channels will include schools, the Swan-Linx physical activity programme, university intranet and sport and recreational clubs. Firstly to access participants I will need to request approval from the head teachers of the schools to make a visit either via the Swan-Linx programme or exclusively to recruit for homeSPACE and the head coaches of the sports clubs to both explain the study and to give out packs in envelopes to the children. Upon approval, the children will be given envelopes containing participant information sheets for their parents/guardians enquiring about their potential contribution to the study. Interested parents will be directed to call or email the researcher for further details of the study or to agree upon a time for the home visit. Additionally the lead researcher will offer to meet parents/guardians at the school or sport sessions to explain the study if required. If the parent/guardian is happy to proceed a pack (including participant consent and assent forms) will be given in person or sent via email. If necessary snowball recruitment methods will be used in order to achieve the recruitment target. In this case, existing study participants will be asked to inform other potential participants of the study details who can contact the study team via email for further information and to sign up. The participants for the pilot study will be existing contacts of myself and will be contacted directly via email enquiring about their potential contribution to the study. I will also offer to meet up with the families or speak on the phone to answer any further queries they may have. Copies of the audit tool and PI sheets will be given and consent/assent forms completed. Given these families will be existing contacts of myself they may feel obliged to contribute however I will stress that participation should be entirely voluntary and that I will not be hurt if they wish not to participate. A family weekend pass for Swansea's leisure complex (LC2), a water park and activity centre, will be offered to the parent/guardian providing they complete the second audit one week later and return via post to show appreciation for the time committed to participate in the study and to perhaps provide an incentive to initially contribute. The weekend pass is subject to availability.

6.4 DATA COLLECTION METHODS

- describe all of the data collection/experimental procedures to be undertaken

- state any dietary supplementation that will be given to participants and provide full details in Section 6.5

- state the inclusion of participant information and consent forms (in appendices)

- refer to the use of the ACA/ACSM health screening questionnaire where appropriate (usually for maximal effort exercise)

Following receipt of institutional ethics board approval participants will be recruited to the HomeSPACE study via advertising through a variety of channels as required. Channels will include schools, the Swan-Linx physical activity programme, the university internet and sport and recreational clubs or if necessary through snowball recruitment methods. The participants will be invited to make a suitable time for the lead researcher and another member of the study team to come to their home. Another member of the study team will accompany the researcher during the home visit to supervise proceedings, ensuring the safety of the researcher and that of the family and help children complete the CHAT. The audit tool will be developed and pilot tested first with a convenience sample of three families recruited through existing contacts of the researcher to complete and comment on the audit to ensure instruction clarity of the questions and format. Firstly, one parent/guardian will be asked to complete a written home environmental audit, already validated for use in Australian homes (Maitland et al., 2014). Questions will be adapted to the British context where appropriate. For example for income the dollars signs, the currency in Australia will be changed to pound sterling. Upon entering the house, as part of the home audit the researcher will first ask the participants to provide some written demographic background information (e.g. age; gender; postcode; education; number, age and sex of children). Secondly, the parent/guardian and the researcher will walk through the house simultaneously but independently completing the home audit tool with as little communication as possible. If the participant does speak, the researcher will ask them not to speak. The audit tool is a checklist which will include questions about house and garden size, space and design, and physical activity and media equipment. In addition, there will be some questions about preferences for housing and leisure activities at home, and family. The participant will be informed of the procedures regarding the home visit in the participant information sheet prior to agreeing to contribute. Participants will be advised that it is completely up to them as where to where they go in the home and they are free to avoid any rooms or questions if they please. The researcher will respect the decisions of the participant and will wait to be invited or will ask the parent/guardian before entering each room. The audit tool will take approximately 30 minutes to complete. However this will depend on the size of the home and the number of items present. The draft audit tool is attached to this ethics application. Following this procedure will allow us to test the validity of the home audit tool. Once the researcher and the parent have completed the Home audit the children will be asked to answer an online health and lifestyle questionnaire called the Child Health and Activity Tool (CHAT) on a laptop provided by the study team unless they would prefer to use one of their own. The children will complete the CHAT in the presence of their parent and both members of the study team who will be happy to answer any questions if necessary. The CHAT requires children to record detailed information on the temporal sequence of their activities including their diet habits. The CHAT will give an idea of how much time the child spends in specific behaviours that potentially occur in the home, such as watching TV, video games, homework, active play and leisure time PA.

Lastly at the end of the first visit, the researcher will leave a blank audit tool with the participant to complete independently one week later following the same procedure as before. A stamped-addressed envelope will be provided for mailing the completed inventory back to the researcher. Reminder messages via email will be made to families one day prior to the day when the second tool is meant to be completed. This procedure will allow the reliability of the home audit tool to be quantified. This procedure has been successfully used previously to validate and reliability test an inventory to assess home electronic media and physical activity equipment (Sirard et al., 2008).

6.5 DATA ANALYSIS TECHNIQUES

- describe the techniques that will be used to analyse the data

The computer programme SPSS statistics will be used for all data analyses. Firstly, the data from all 3 copies of the audit tool will be analysed for descriptive statistics. Test-retest reliability of the variables from the audit tool (i.e., number of items, who uses the room (e.g. children, parents and everyone), outdoor features and the size of the room (small, medium, large) will be assessed by intraclass correlation coefficient (ICC, 95% confidence intervals). The categorical variables (i.e., additional equipment) will be assessed by spearman rank order correlation. Mean differences in variables between the 1st audit and 2nd audit completed by the parent/guardian will be identified with a chi-squared test. Validity will be evaluated by examining between data from the participant and the researcher using Pearson product moment correlation coefficients for the above variables. Mean differences in variables between the participant and the researcher will be identified with two-tailed independent t-tests. The CHAT data set will be submitted through Google which I can retrieve and download into Microsoft excel for analysis. The CHAT data will then be analysed for descriptive statistics to identify the sedentary and activity behaviours.

6.6 STORAGE AND DISPOSAL OF DATA AND SAMPLES

- describe the procedures to be undertaken for the storage and disposal of data and samples

- identify the people who will have the responsibility for the storage and disposal of data and samples

- Identify the people who will have access to the data and samples

- state the period for which the data will be retained on study completion (normally 5 years, or end of award)

All the data collected will be kept private and confidential. Any hard copies of the home audit and consent/assent forms will be kept in a secure office. The CHAT data and any additional personal information will be stored on a password protected computer for up to 7 years until they are eventually destroyed by the supervisor of the project. The data received will only be available for viewing by the researcher and other responsible individuals of the research team from Swansea University providing consent is provided by the family. The data we collect may be used to influence future UK home design and planning policy to facilitate children's activity.

6.7 HOW DO YOU PROPOSE TO ENSURE PARTICIPANT CONFIDENTIALITY AND ANONYMITY?

Initial anonymity in this study is hard to achieve due to the nature of the research approach as naturally the family will be referring to each other by their names during the home visit. However upon completing data collection the researcher will remove identifiers to protect confidential information. The clean data set will not contain information that identifies the participants, such as a name or address, such information may be stored somewhere else, in separate, protected files.

Identities will be easily masked for example, the family names will be replaced with numbers or pseudonyms and the full addresses replaced with postcodes. For the CHAT specifically, a coding scheme will be devised in which each child will have their own personal identification number. Therefore, when they complete the CHAT they will use the ID number and not their own names. If any unaccepted behaviours or physical environments are observed within the house confidentiality may not always be possible. At this point, a legal issue arises. The law may not necessarily always allow privacy (Allen et al., 2011). In such a circumstance, national regulation states the researcher may be under legal and professional obligation to breach confidentiality and disclose information to the appropriate authorities. It may be apparent that emergency action should be taken to safeguard and promote the welfare of a child, in the form of calling the police which will most likely lead to a strategy discussion between the police, local authority children' social services and other agencies as appropriate. In some cases, it may be necessary to ensure either that the child remains in a safe place or that the child is removed to a safe place, either on a voluntary basis or by obtaining an Emergency Protection Order.

6.8 PLEASE PROVIDE DETAILS OF ANY DIETARY SUPPLEMENTATION (DELETE IF NOT APPLICABLE)

N/A

7. LOCATION OF THE PREMISES WHERE THE RESEARCH WILL BE CONDUCTED.

- list the location(s) where the data collection and analysis will be carried out

- identify the person who will be present to supervise the research at that location

- If a first aider is relevant, please specify the first aider

Parents/guardians that agree to participate in the study will be invited to decide upon a suitable time for the researcher and another member of the study team to make the home visit to complete the audit and CHAT.

8. POTENTIAL PARTICIPANT RISKS AND DISCOMFORTS

- identify any potential physical risk or discomfort that participants might experience as a result of participation in the study.

- identify any potential psychological risk or discomfort that participants might experience as a result of participation in the study.

- Identify the referral process/care pathway if any untoward events occur

The only burden we predict as a result of participating in this study is the time taken to participate in the tour and complete the CHAT.

9.1 HOW WILL INFORMED CONSENT BE SOUGHT?

Will any organisations be used to access the sample population?

Will parental/coach/teacher consent be required? If so, please specify which and how this will be obtained and recorded?

Participants will be recruited to the HomeSPACE study via advertising through a variety of channels as required. Channels will include schools, the Swan-Linx physical activity programme, and the university intranet and sport and recreation clubs in South Wales. Firstly, in order to access participants I will need to request approval from the head teachers of the schools and the head coaches of the clubs to explain the study and to give out packs in envelopes to the children to hand over to their parents enquiring about their potential contribution to the study. Additionally the lead researcher will offer to meet parents/guardians at the schools or club sessions to explain the study if required. If the parent/guardian is happy to proceed a pack (including participant consent and assent forms) will be given in person or sent via email. Indeed, the parent/guardian will be required to provide their active written consent as well as consent for their child before commencing the home tour and will be provided with the option to withdraw at that point. Additionally, the children will provide their own assent to participate. In addition to receiving the participant information sheet, consent form and assent form prior to the home visit, parents/guardians will be reminded by the researcher on arrival about the study and what to expect as a participant. Although it is not necessary to obtain written informed consent from all family members the parents should seek their verbal permission to allow the researcher to enter their home.

9.2 INFORMATION SHEETS AND CONSENT/ASSENT FORMS

- Have you included a Participant Information Sheet for the participants of the study? YES
- Have you included a Parental/Guardian Information Sheet for the parents/guardians of the study? YES
- Have you included a Participant Consent (or Assent) Form for the participants of the study? YES
- Have you included a Parental/guardian Consent Form for the participants of the study? YES

10. IF YOUR PROPOSED RESEARCH IS WITH VULNERABLE POPULATIONS (E.G. CHILDREN, PEOPLE WITH A DISABILITY), HAS AN UP-TO-DATE DISCLOSURE AND BARRING SERVICE (DBS) CEHCK (PREVIOUSLY CRB) IF UK, OR EQUIVALENT NON-UK, CLEARANCE BEEN REQUESTED AND/OR OBTAINED FOR ALL RESEARCHERS? EVIDENCE OF THIS WILL BE REQUIRED.

DBS checked, certificate number:001468440434

11. STUDENT DECLARATION

Please read the following declarations carefully and provide details below of any ways in which your project deviates from these. Having done this, each student listed in section 2 is required to sign where indicated.

- ***"I have ensured that there will be no active deception of participants.***
- ***I have ensured that no data will be personally identifiable.***
- ***I have ensured that no participant should suffer any undue physical or psychological discomfort (unless specified and justified in methodology).***
- ***I certify that there will be no administration of potentially harmful drugs, medicines or foodstuffs.***
- ***I will obtain written permission from an appropriate authority before recruiting members of any outside institution as participants.***
- ***I certify that the participants will not experience any potentially unpleasant stimulation or deprivation.***
- ***I certify that any ethical considerations raised by this proposal have been discussed in detail with my supervisor.***
- ***I certify that the above statements are true with the following exception(s):"***

Student/Researcher signature: (include a signature for each student in research team)

Date:

12. SUPERVISOR'S APPROVAL

Supervisor's signature:

Date:

Swansea University
Prifysgol Abertawe

Applied Sports Technology Exercise and Medicine Research Centre (A-STEM)

Sport and Health Portfolio, College of Engineering

CHILD INFORMATION SHEET
(04/10/2015)

Project Title:

HomeSPACE study

Contact Details:

Michael Sheldrick-Email:[redacted]

Professor Gareth Stratton- Email:[redacted]
Office Telephone: [redacted]

Luke Martin-Email:[redacted]

Invitation Paragraph

We would like to learn more about your home and how it may affect the amount of time you spend sitting and in physical activity. You are invited to take part in the HomeSPACE study led by Swansea University.

What is the purpose of the study?

Our aim is look at how the physical home space affects the amount of time you spend sitting and in physical activity.

3. Why have I been chosen?

You and your family have been invited to take part in the HomeSPACE study, because you are between the ages of 10 to 12 years. If you feel like you would like to stop at any time just let us know no one will be upset or cross.

4. What will happen to me if I take part?

After one of your parents and the researcher having taken a tour of your house you will be asked to complete an online questionnaire called the Child Health and Activity Tool (CHAT) on a laptop provided by us unless you would like to use your own. The CHAT will ask you to record detailed information on the type of activities and sports you get up to, which will help us better understand the time you spend sitting and in activity. The CHAT will take you about 15 minutes to complete.

5. What are the possible disadvantages of taking part?

The only downside in taking part in this study is the time it takes

6. What are the possible benefits of taking part?

Some children spend a lot of time at home and spend most of it watching TV or playing video games and not much time doing physical activity. Too much time spent sitting particularly doing these things can lead to overweight and obesity, reduced fitness and other problems, but physical activity is good for you and can be fun at the same time. Taking part in this study will help us to understand how the physical home space may affect the amount of time you spend sitting, in physical activity and your health.

7. Will my taking part in the study be kept confidential?

Your name and the information you give us will be kept a secret – only the people who are doing the research will be able to see this information.

8. What if I have any questions?

If you have any questions with the project ask your parents to get in contact with me or another member of the research team (see contact details above) and I'll be happy to answer any of them.

If you are currently dealing with any issues which are causing you distress (e.g. abuse, neglect etc.), please don't hesitate to call Childline at: **0800 1111**, a free 24 hour counseling service for children which may be able to help.

PARENT INFORMATION SHEET
(04/10/2015)

Project Title:

HomeSPACE study

Contact Details:

Michael Sheldrick -Email:[redacted]

Professor Gareth Stratton -Email:[redacted]
Office Telephone: [redacted]

Luke Martin-Email[redacted]

1. Invitation Paragraph

We would like to learn more about your home and how it may affect the amount of time your child spends sitting and in physical activity. Your family is invited to take part in the HomeSPACE study led by Swansea University. The study has already been done in Australian homes but now needs to be tried out in the UK.

2. What is the purpose of the study?

Our aim is look at how the physical home space affects children's (aged 10-12 years) activity and time spent sitting. Another aim of this study is to test and develop a home audit tool that has already been used in Australian homes to measure factors of the physical home space that may influence children's time spent sitting and in physical activity. The information we collect will be used in a student's project and will help impact future home and planning design to reduce time spent sitting and to help promote healthy active living in families.

3. Why have I been chosen?

You and your family have been invited to take part in the HomeSPACE study, because at least one of your children is aged 10 to 12 years and goes to primary school. During the study if either you or anyone else in your family does not feel comfortable with anything you can stop at anytime without fear of penalty.

4. What will happen to me if I take part?

You will be asked to give a good time for the main researcher and another colleague to come to your home. To start with they will ask you to answer some questions about you and your family (for example gender; age; postcode; education; number, age and gender of children). They will then ask you to complete the audit tool by walking around your house and garden and answering the items on the tool. The researcher will follow you and complete the same audit tool at the same time. It is up to you as to where you go in your home and you can avoid any places or questions from the tool. The audit tool is a checklist which will include questions about house and garden size, space and design, and physical activity and media equipment. There will also be some questions about you and your family's preferences for housing and activities at home. The audit tool will take about 30 minutes to complete. After you and the researcher have completed the audit tool your children will be asked to complete an online questionnaire called the Child Health and Activity Tool (CHAT). The CHAT will ask your children to record detailed information on the type of activities and sports they get up to, which will help us better understand their time spent sitting and in activity. If you would like a copy of either the audit or CHAT, just get in touch with any of the researchers via the contact details above and they will happily send you a copy.
At the end of the home visit you will be left a second copy of the checklist which you will be asked to complete one week later and to return in a stamp addressed envelope provided. The time taken in this study will be about 55 minutes in total. This includes 30 minutes to complete the first checklist with the researcher during the home visit, and 25 minutes to complete the second checklist. You will be offered a free family weekend pass for Swansea's leisure complex (LC2), a water park and activity centre, after returning the second checklist, to thank you for your time in taking part in this study (subject to availability).

5. What are the possible disadvantages of taking part?

The only downside in taking part in this study is the time it takes

6. What are the possible benefits of taking part?

Since children spend a lot of time at home its space can have a large impact on the time they spend sitting and in physical activity. At the moment the amount of time children spend sitting using electronic devices (e.g. watching television (TV) or playing video game) at home is on the rise. Also, children's opportunity to play freely in their local areas has decreased, due to worries about safety and a lack of open spaces to play. As a result, not many children these days meet public health recommendations of at least 60 minutes of moderate to vigorous physical activity per day. Too much time spent on the above devices can lead to overweight and obesity, reduced fitness and a variety of other problems where as regular moderate to vigorous physical activity can prevent the above as well as being important for healthy muscle and bones. Taking part in this study may be able to increase your awareness of how your home environment may affect the amount of time your child spends sitting and in physical activity and their health. Lastly, the results from this study may be able to impact future UK home and planning design to increase children's activity.

7. Will my taking part in the study be kept confidential?

All the data collected will be kept private and confidential. Any hard copies of the home audit and CHAT will be kept in a secure office and computer files with any personal information will be stored on a password protected computer. The data collected will only be available to look at by responsible individuals of the research team from Swansea University. The data we collect may be used to impact future UK home design and planning rules to increase children's activity. If any unacceptable behaviours such as physical or verbal abuse or unsafe physical environments are observed within the house confidentiality will have to be breached. At this point we would invoke disclosure procedures.

8. What if I have any questions?

If you have any further questions with the project please contact me or another member of the research team (see contact details above).

Study letter – English version

Applied Sports Technology Exercise and Medicine Research Centre (A-STEM)
Sport and Health Portfolio, College of Engineering

Dear Parent or Guardian

In order to learn more about your home and how it may affect the amount of time your child spends sitting and in physical activity, your family is invited to take part in a Swan-Linx associated study called HomeSPACE study. This study has only been done in Australian homes, and now we hope to be the first to try this out in the UK. **The information collected will help impact future home and planning design to reduce time spent sitting and to help promote healthy active living in families.** Taking part in this study may also increase your awareness of how your home environment may affect the amount of time your child spends sitting and in physical activity, and how these are related to their health.

To take part you will be asked to give a good time for the main researcher and another colleague to come to your home. You will then be asked to complete an audit tool by walking around your house and garden and answering the items on the tool. The researcher will follow you and complete the same audit tool at the same time. It is up to you as to where you go in your home and you can avoid any places or questions from the tool. The audit tool is a checklist which will include questions about house and garden size, space and design, and physical activity and media equipment. There will also be some questions about you and your family's preferences for housing and activities at home. **The audit tool will only take about 30 minutes to complete.** After you and the researcher have completed the audit tool **your children will be asked to complete an online questionnaire called the Child Health and Activity Tool (CHAT).** The CHAT will ask your children to record detailed information on the type of activities and sports they get up to, which will help us better understand their time spent sitting and in activity.

Your child would have already met both members of the research team at the fitness fun day that they participated in with the rest of their class mates as part of another programme led by Swansea University called Swan-Linx.

A Family Pass (up to 4 people) for Swansea's leisure complex (LC2), water park and activity centre, will be offered to every family who takes part in this study, as a thank you for the time committed to the study.

If you would like to take part, please fill out the information below and hand the letter back to your child for them to bring in to school

Name: ....

Contact details: Telephone: .... **Email:** ....

Alternatively if you are interested in taking part or would like any further information you can contact the lead researcher Michael via email at: [redacted]

The HomeSPACE Study

Study letter – Welsh version

Applied Sports Technology Exercise and Medicine Research Centre (A-STEM)
Sport and Health Portfolio, College of Engineering

Annwyl Rhiant/Gwarchodwr(aig),

I ddysgu mwy am eich cartref a sut gall hyn effeithio'r amser mae eich plentyn/plant yn gwario mewn actifedd a chyfnod eisteddog, mae eich teulu wedi cael eich gwahodd i cymryd rhan yn yr astudiaeth Homespace. Mae'r astudiaeth wedi cael ei redeg yn Awstralia yn barod ac rydym yn gobeithio taw ni bydd y sefydliad cyntaf i ceisio hyn yn y DU. **Bydd y gwybodaeth sydd yn cael eu gasglu yn helpu creu effaith ar cynllun tai yn y dyfodol er mwyn lleihau'r nifer o oriau sydd yn cael eu wario yn eistedd ac hybu nifer yr oriau o actifedd yn y cartref.** Trwy cymryd rhan yn yr astudiaeth yma, bydd eich ymwybyddiaeth o sut mae eich plentyn/plant yn ymddwyn yn eich cartref, a sut mae'r hyn maent yn gwneud yn effeithio'u iechyd.

I cymryd rhan, bydd angen i chi nodi amser sydd yn addas i chi, er mwyn i'r prif ymchwiliydd ac un o'i gyd-weithwyr i ymweld â'ch cartref. Yn gyntaf, bydd angen i chi ateb questiynnau amdanoch chi a'ch teulu (e.e. rhyw, oedran, addysg, a.y.y.b.), cyn llenwi mewn archwiliad, sydd yn cynnwys rhestr wirio ac holiadur ar cyflwr eich cartref (a'r gardd). Bydd y prif ymchwilydd yn cwblhau union yr un archwiliad a chi yr un pryd. Does dim angen ateb pob elfen o'r archwiliad, a rydych chi'n dal yr opsiwn o osgoi unrhyw ystafell/ardal o'ch cartref trwy gydol yr archwiliad. **Bydd yr archwiliad yn cymryd tua 30-munud i gyflawni, gyda'r cwestiynnau yn amrywio o maint eich gardd i nifer y cyfleusterau chwaraeon/cerddodol.** Ar ôl i chi a'r prif ymchwilydd cwblhau'r archwiliad, **bydd eich plentyn/plant yn cael ei/eu ofyn i lewni i mewn holiadur ar y cyfrifiadur o'r enw 'Child Health and Activity Tool (CHAT)'.** Bydd yr holiadur yma yn gofyn i'ch plentyn/plant i gofnodi'r math o actifedd a chwaraeon maent yn cymryd rhan ynddo, i helpu gwella deall amser eistedd a gweithgarwch eich plentyn/plant.

Bydd eich plentyn/plant wedi cwrdd â'r ddau aelod o'r tîm yn barod, o'r diwrnod ffitrwydd hwylus cymeron nhw rhan ynddo gyda gweddil ei/eu ddosbarth, mewn astudiaeth arall ag arweinir gan Prifysgol Abertawe a Swan-Linx.

Bydd tocyn teulu (i fyny i 4 person) ar gyfer yr LC2 yn cael eu cynnig fel diolch am cynnig eich amser rhydd tuag at yr astudiaeth yma.

Os oes diddordeb gyda chi a'ch teulu mewn cymryd rhan, ysgrifenwch eich enw, rhif ffôn ac/neu ebost isod, a rhowch y llythyr i eich plenty/plant i rhoi yn ôl i'w athro/athrawes.

Enw rhiant/gwarchodwr(aig): ……………………………

Manylion personol: Rhif ffôn: ………………… **or Ebost:** ………………………..

Fel arall, os ydych chi eisiau unrhyw gwybodaeth ychwanegol, ebostiwch Michael Sheldrick (y prif ymchwilydd) ar y cyfeiriad ebost [redacted]

Diolch.

LC2 ABERTAWE/SWANSEA   SWAN-LINX   The HomeSPACE Study

Swansea University
Prifysgol Abertawe

Applied Sports Technology Exercise and Medicine Research Centre (A-STEM)
Sport and Health Portfolio, College of Engineering

PARTICIPANT CONSENT FORM

(Date: 04/11/2015)

Project Title: HomeSPACE study

Contact Details: Michael Sheldrick-Email:[redacted]
Professor Gareth Stratton- Email:[redacted]
Office Telephone: [redacted]

Luke Martin-Email: [redacted]

Please tick initial box

1. I confirm that I have read and understood the information sheet dated ....../....../...... for the above study and have had the opportunity to ask questions. ☐
2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason, without my medical care or legal rights being affected. ☐
3. I understand that sections of any of data obtained may be looked at by responsible individuals from the Swansea University or from regulatory authorities where it is relevant to my taking part in research. I give permission for these individuals to have access to these records. ☐
4. I agree to take part in the above study. ☐

______________________	____________	__________________
Name of Participant	Date	Signature
______________________	____________	__________________
Name of Person taking consent	Date	Signature
______________________	____________	__________________
Researcher	Date	Signature

Swansea University
Prifysgol Abertawe

Applied Sports Technology Exercise and Medicine Research Centre (A-STEM)
Sport and Health Portfolio, College of Engineering

CHILD ASSENT FORM

Date: 04/11/2015

Project Title: HomeSPACE study

Contact Details: Michael Sheldrick - Email:7[redacted]

Professor Gareth Stratton -Email:[redacted]

Office Telephone: [redacted]

Luke Martin - Email: [redacted]

Please tick initial box

1. I confirm that I have read and understood the information sheet dated ....../....../...... for the above study and have had the opportunity to ask questions. ☐
2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason, without my medical care or legal rights being affected. ☐
3. I understand that sections of data obtained may be looked at by responsible individuals from the Swansea University or from regulatory authorities where it is relevant to my taking part in research. I give permission for these individuals to have access to these records. ☐
4. I agree to take part in the above study. ☐
5. I am happy to complete the CHAT. ☐

If you are currently dealing with any issues which are causing you distress (e.g. neglect abuse etc.), please don't hesitate to call Childline at: **0800 1111**, a free 24 hour counseling service for children which may be able to help.

______________________________	________________	________________________
Name of Person giving assent	Date	Signature
______________________________	________________	________________________
Researcher	Date	Signature

Swansea University
Prifysgol Abertawe

Applied Sports Technology Exercise and Medicine Research Centre (A-STEM)
Sport and Health Portfolio, College of Engineering

PARENT/GUARDIAN CONSENT FORM FOR CHILD

Date: 04/11/2015

Project Title: HomeSPACE study

Contact details: Michael Sheldrick-Email: [redacted]
Professor Gareth Stratton- Email: [redacted]
Office Telephone: [redacted]

Luke Martin-Email: [redacted]

Please tick initial box

1. I confirm that I have read and understood the information sheet dated ....../....../...... for the above study and have had the opportunity to ask questions. ☐
2. I understand that my Child's participation is voluntary and that I am free to withdraw at any time, without giving any reason, without my medical care or legal rights being affected. ☐
3. I understand that sections of data obtained may be looked at by responsible individuals from the Swansea University or from regulatory authorities where it is relevant to my taking part in research. I give permission for these individuals to have access to these records. ☐
4. I agree for my child to take part in the above study. ☐
5. I am happy for my child to complete the CHAT. ☐

______________________________	_________________	_________________________
Name of child	Date	Signature
______________________________	_________________	_________________________
Name of Person giving consent	Date	Signature
______________________________	_________________	_________________________
Researcher	Date	Signature

HomeSPACE-UK project application for ethical approval

College of Engineering
Research Ethics and Governance Committee

<u>APPLICATION FOR ETHICAL COMMITTEE APPROVAL OF A RESEARCH PROJECT</u>

In accordance with A-STEM and College of Engineering Safety Policy, all research undertaken by staff or students linked with A-STEM must be approved by the A-STEM Ethical Committee.

RESEARCH MAY ONLY COMMENCE ONCE ETHICAL APPROVAL HAS BEEN OBTAINED

The researcher(s) should complete the form in consultation with the project supervisor. After completing and signing the form students should ask their supervisor to sign it. The form should be submitted electronically to Coeresearchethics@swansea.ac.uk.

Applicants will be informed of the Committee's decision via email to the project leader/supervisor.

1. TITLE OF PROJECT

HomeSPACE project, investigating the influence of the physical environment of the home on children's physical activity and sedentary behaviour

2. DATE OF PROJECT COMMENCEMENT AND PROPOSED DURATION OF THE STUDY

July 2017-July 2018

3. NAMES AND STATUS OF RESEARCH TEAM

State the names of all members of the research group including the supervisor(s). State the current status of the student(s) in the group i.e. Undergraduate, Postgraduate, Staff or Other (please specify).

Michael Sheldrick: PhD student researcher (DBS checked, certificate number: 001468440434)
Richard Tyler: Postgraduate Sport and Exercise science PhD student (DBS checked, certificate number: 001464235079)
Supervisor: Professor Gareth Stratton (DBS checked).
2nd supervisor: Dr Kelly Mackintosh (DBS checked).

4. RATIONALE AND REFERENCES

With reference to appropriate sources of information (using the Harvard system), describe ***in no more than 200 words*** *the background to the proposed project.*

Physical activity and sedentary behaviour have been associated with physiological and psychosocial benefits [10] and detriments (Carson et al., 2016), respectively, in children. Despite this, few children meet current recommendations for PA or sedentary behaviour (Townsend et al., 2015). Given children spend significant time at home [377], understanding these behaviours in this environment is imperative to inform behaviour change interventions. While, there is an emerging body of evidence investigating the influence of the home environment on children's sedentary behaviour and PA (Maitland et al., 2013; Kaushal & Rhodes, 2014), several gaps in the literature remain [41]. Specifically, studies have measured behaviour across the entire day (Pouliou et al., 2014; Tandon et al., 2012). Thus, including behaviours which occur outside the home, which may be less likely to be influenced by the home. Determining the amount of each behaviour children accumulate while at home will improve researcher's ability to identify home-specific correlates of such behaviours. In addition, to date, research has mostly been limited to Australia and the USA, and there is a paucity of European research, and UK research specifically is lacking. Therefore, this study aims to assess the influence of the home environment on UK children's home specific PA and sedentary behaviour.

5. OBJECTIVES

State the objectives of the project, i.e. one or more precise statements of what the project is designed to achieve.

-To investigate the influence of the physical environment of the home on children's home-based sedentary behaviour and physical activity.

- To validate a set of questions, already validated for use in Australia referring to parent's perceptions, priorities and preferences in terms of housing and leisure activities at home and family.

- Understand seasonal variation in the influence of the home environment on children's physical activity and sedentary behaviour

6.1 STUDY DESIGN

- outline the chosen study design (e.g. cross-section, longitudinal, intervention, RCT, questionnaire etc)

We will use a cross-sectional research approach, which will involve one parent/guardian from a family, independently completing an online home audit tool, validated for use in UK homes. In addition, the children in the family will have their height and weight measured, be asked to wear 2 accelerometers for 7 days and complete a short online questionnaire on their activity habits.

6.2 STUDY DESIGN

- state the number and characteristics of study participants
- state the inclusion criteria for participants
- state the exclusion criteria for participants and identify any requirements for health screening
- state whether the study will involve vulnerable populations (i.e. young, elderly, clinical etc.)
- state the requirements/commitments expected of the participants (e.g. time, exertion level etc)

Inclusion criteria

Eligible participants include families from South Wales with at least one child aged 9 to 13 years of any gender. We aim to recruit 215 families. We will use our contacts in Schools, and recruit a sample of families that reflect the socio-demographics of South Wales. WIMD (Welsh Index of Multiple Deprivation) scores will be used as an indicator of SES.

Expected requirements of participants

All participants will receive a participant information sheet prior to the study commencing.
Child participants (age 9-13 years) will be asked to wear a ActiGraph accelerometer upon awaking for 7 days and an ActivPAL at all times for 7 days and complete a self-report questionnaire on their activity habits and have their height and weight measured for BMI Z-score calculations.
Parents will be asked to complete an online audit of their home and record when the children are at home, using a logbook provided by the research team.
Continuous periods of non-wear time will be recorded by the children, stating the time of removal, and duration when completing water based activities or contact sports (see appendices).
Participants will be given a sleep log to record bed time and wake time for each day.
Participants will be expected to wear the devices for 5 week days and two weekend days.
After the observation period is completed, the children will be asked to bring the equipment back into school for the researcher to collect.

6.3 PARTICIPANT RECRUITMENT

How and from where will participants be recruited?

There will be a multi-channel approach to recruitment. We currently run a successful Swan-linx programme, where over 30 schools take part each year and we will work alongside these schools to recruit participants. Schools, socio-demographically representative of South Wales will be approached for recruitment, to best ensure participating families reflect the typical socio-demographics of South Wales. We will also use the HAPPEN primary schools network, as well as previous families who took part in the HomeSPACE project. Further, we will advertise across the University using the intranet and work alongside the City and County of Swansea and Bridgend Borough Council to recruit using their sport, play and community networks.

Step 1:

In step 1 of recruitment, the lead researcher will request approval from the head teachers, head coaches or community leads to make a visit to pitch for participants to both explain the study and give out packs in envelopes containing participant information. Interested parents will be asked to write down their name and preferred contact details in the space provided on the study letters, and to then return them to their respective community leader, sports coach or teacher. Both a welsh and English language version of the study letter will be provided, printed on each side of the paper.

Step 2:

The researcher will contact interested families via email or phone. Families who agree to take part will receive participant information sheets, at which point a time for the researcher to meet the children in school to hand over the equipment will be agreed.

Step 3:

The lead researcher will offer to meet parents/guardians at the school or sport sessions to explain study process and procedures if necessary. Providing the parent/guardian and the child is happy to proceed, the child is given a pack (including participant consent and assent forms) in school for them take home. Once the forms are completed, the child will be asked to return them to their teacher, ready for the researcher to collect.

Augmenting recruitment:

If required, snowball recruitment methods will be used to augment recruitment. In this case, existing study participants will be asked to inform other potential participants of the study, who can then contact the study team directly to sign up or for further information. Previous participants of the HomeSPACE project will also be contacted directly via email enquiring about their further participation in the project. Given these families have built up some rapport with the researcher, they may feel obliged to participate, however they will be reminded that participation is entirely voluntary and the researcher will not be hurt if they decide not to take part.

We have had experience in recruiting participants via the above steps, successfully recruiting 31 families for a previous study of the HomeSPACE project (see REC approval; PG/2014/34).

Four waves of recruitment will occur over a 1-year period, during each of the four seasons, to account for seasonal variation in weather and children's behaviour. In addition, efforts will be made to ensure assessments are evenly distributed across the year. Each participating family will get entered into a prize draw, where 5 families during each of the 4 waves of recruitment will be given a free family pass for one of the following; Limitless or GoAir, Trampoline parks in Swansea and Cardiff, respectively; Jump, an indoor play area in Cardiff or entry for an Ospreys rugby match. The specific prizes given to each family will depend on where they live and their preferences, subject to availability. The aim of this is to provide an incentive for families to participate.

6.4 DATA COLLECTION METHODS

- describe all of the data collection/experimental procedures to be undertaken
- state any dietary supplementation that will be given to participants and provide full details in Section 6.5
- state the inclusion of participant information and consent forms (in appendices)
- refer to the use of the ACA/ACSM health screening questionnaire where appropriate (usually for maximal effort exercise)

Experimental procedures

Prior to beginning the study, all participants and parents/guardians will be provided with information sheets, and will have the study clearly explained to them. They will be told that participation is entirely voluntary and they can withdraw at any point. Written informed assent for those aged below 16 years and written informed consent for those aged 16 years and above will be obtained from all participants, and parents (see appendices).

Each participant will be given a specific ID number which will be used throughout the study. Devices will be given to the participants by the researcher in school. If possible, the researcher will make the school visit on the day they are expected to wear them. The ActivPAL device will be worn at all times and ActiGraph accelerometer will be worn throughout each day but removed at night. The lead researcher, parent and the school will need to agree on a suitable time for the visit.

UK HomeSPACE audit tool

Upon agreeing to take part in the study, families will be sent an online version of the UK HomeSPACE instrument, which has already been assessed for its feasibility for use by parents with a convenience sample of 4. The audit tool is the first section of the instrument, and parents will be instructed to complete it independently, while walking through each room/area in their home. The audit section is a checklist which includes questions about house and garden size, space and design, and physical activity and media equipment. The audit tool should take approximately 25 minutes to complete. However, this will depend on the size of the home and the number of items present. The participant will be informed of the procedures regarding the home visit in the participant information sheet prior to agreeing to contribute. After which, the parent will be asked to complete an online questionnaire about their perceptions, preferences and priority's in terms of housing and leisure activities at home and family, as well as questions on the family's shared perceptions and thoughts concerning PA from the validated family health climate PA scale (Niermann et al., 2014). Participants will also be asked to provide some demographic background information (e.g. age; gender; postcode; income; education; number, age and sex of children), necessary as such information will help describe the sample, serve as independent variables in a statistical model, and allow us to draw comparisons between groups. The online questionnaire can be completed anywhere within the home. Parents will be able to complete the instrument on a portable electronic device of their choice, but a laptop or a tablet will be recommended, as the instrument fits on these devices better, due to their larger screen size. Having a suitable device of their own would be required to take part in this study. On average, both the audit tool and questionnaire will take around 40 minutes to complete. A small portion of the (n=50) participants will be reminded to complete the questions again, 1 week later via email, taking them approximately 15 minutes to complete. This will allow us to assess the questions for test-retest reliability.

Self-report questionnaire to assess types of physical activity and sedentary behaviour occurring at home

Due to the difficulty in assessing the type of behaviour being performed objectively (Atkins et al., 2012), the type of behaviour will be assessed via an online questionnaire in the presence of the researcher in school. It will be completed on a laptop or tablet provided by the researcher. The researcher will be careful in how they deliver the questionnaire and how they respond to questions to reduce bias. We wish to explore the influence of the home environment on specific types of both sedentary and active behaviours. They will be asked how many hours on a school day and weekend day in the previous week they engaged in each of the following activities; TV viewing, using a Tablet/Smart phone/Portable gaming device, using a computer/playing on a games console for fun, using the computer for doing homework, doing homework without a computer, reading for fun, doing crafts or hobbies sitting, active play indoors, active play outdoors or playing/practicing a musical instrument. They can choose from seven options, coded as: I did not watch TV on school/ weekend days (0); <1 h (0.5); 1 h (1); 2 h (2); 3 h (3); 4 h (4); 5 h or more (5). The options were taken from the US Youth Risk Behavior surveillance system (U.S. Centers for Disease Control and Prevention et al., 2016), deemed valid and reliable for measuring TV and computer use (Schmitz et al., 2004), and are a popular choice for studies assessing screen-time (Wilkie et al., 2016; LeBlanc et al., 2015; Vinas et al., 2016). The questions were taken from the valid and reliable Adolescent Sedentary Activity Questionnaire (Hardy et al., 2007), but adapted slightly for use with children. We have adapted the questionnaire by choosing to assess discretionary video/computer game and use of a computer, with separate questions for portable and fixed media. This will allow us to differentiate between fixed and portable media, helping improve our ability to identify correlates of specific types of screen-time. In addition, the questionnaire covers modern day types of screen-time (I.e., smart phones and tablets), important given screen-time is constantly changing due to technological advances. Moreover, the questions are fixed response, providing guidance, and therefore questions may appear less daunting to a child (Harris et al., 2006) and we've exclusively included home-based activities, popular among children, as we are interested mainly interested in children's home-based activity. For this study, "Home" includes just one single location for each participant, covering the house, and both the front and back garden of the main care giver (I.e., the parent who completed the home audit), therefore homes of other parent/guardians, relatives, friends or neighbours are excluded.

ActiGraph GT3X + BT and GT9X link devices for measurement of sedentary behaviour and physical activity

We will be using ActiGraph GT3X + BT and GT9X link devices for measuring moderate-vigorous-physical activity (MVPA). The ActiGraph acceleromters will be worn by the child on their right hip and will be initialised to collect proximity data at 10s intervals and raw acceleration at 100 hz. The participants will be instructed to remove the receivers overnight and place them on charge so they are ready to be reattached when they woke up in the morning. The same type of ActiGraph device will be used throughout to assess activity, to avoid any potential differences in measurement between types of devices.

Determining the amount of physical activity and sedentary behaviour that children engage in while at home

Previous studies investigating the influence of the home environment on physical activity and sedentary behaviour have measured behavious across the entire day (Pouliou et al., 2014; Tandon et al., 2012). Indeed, this includes time spent in behaviours which occur outside the home, such as at school which may be less likely to be influenced by the home environment. This may, in part, explain the inconsistent findings in the literature to date (Maitland et al., 2013). Therefore, quantifying the amount of sedentary behaviour and physical activity that children accumulate while at home will advance the literature and allow us to identify home-specific correlates of such behaviours. In order to do this, we will ask parents to complete a log, recording when the children enter and leave the home, and time-stamped accelerometer data will be matched to this log (Kneeshaw-Price et al., 2013). Parent's will get sent 3 reminders per day by text to do this. Once in the morning, afternoon and evening.

The ActivPAL device

The ActivPAL will be attached to the mid-thigh of participants by the researcher, in the presence of a teacher, using hypoallergenic fixing tape. This instrument continuously tracks sitting, standing, stepping and is considered the gold standard for detecting sedentary behaviour [473].

Anthropometric measures

Children will have their stature measured to the nearest 0.001m using a portable stadiometer and weight measured to the nearest 0.1 kg using portable electronic weighing scales, during a break or lunchtime with just a teacher and the researcher present. For both measures, the children will be asked to remove all but minimal clothing (i.e. underclothes). In consideration of the school environment, rather than ask the children to remove all but minimal clothing, we will just ask for as much clothing as possible to be removed, particularly footwear and outerwear. Body Mass Index (BMI), can be calculated from stature and weight, and BMI Z-scores derived using the British 1990 growth reference standard [340]. As there is consistent evidence to suggest a relationship between a child's BMI and the amount of sedentary behaviour (Carson et al., 2016) and PA (Poitras et al., 2016) they engage in, the children's BMI could be an important covariate in the analysis.

6.5 DATA ANALYSIS TECHNIQUES

- describe the techniques that will be used to analyse the data

The sample size necessary to find the expect effect was estimated to be n=181 using a valid and reliable online calculator for multiple regression analysis (Soper, 2017), given the lowest effect size of desired interest (medium effect size = F2=0.15; Cohens, 1988), the number of independent variables in the statistical analysis model (28), the minimum level of robust power (1–β=0.80; Cohens, 1988; Noordzij et al., 2010) and the level of significance (P=0.5; Gogtav et al.,2010; Noordzij et al.,2010). To allow for the possibility of missing data (I.e. invalid accelerometer data or drop outs), a total of 215 families will be recruited (+18.79%), decided upon through reviewing the literature for the average amount of missing data in similar studies.

All data will be stored and handled in Microsoft Excel. Data will be transferred and analysed in IBM SPSS statistics 22 (IBM SPSS Statistics Inc., Chicago, IL, USA).

HomeSPACE audit tool and type of behaviour questionnaire data

The audit tool and activity habit questionnaire responses will be sent to a password protected email account in an encrypted password protected PDF file. These data will be exported into SPSS for inferential analysis. Descriptive statistics will be calculated to describe the characteristics of the sample. In addition to the scores which will be calculated for each type of screen-time, an overall screen-time score will be computed by summing the TV, games console/computer and tablet/phone/gaming device score, calculated using weighted averages to account for school and weekend screen-time. A weighted mean score of hours of daily screen-time will be calculated as follows: [(hours of TV on weekdays x 5) + (hours of TV on weekend days x 2) + (hours of game console/computer on weekdays x 5) + (hours of game console/computer on weekend days x 2) + (hours of tablet/phone/portable gaming device on weekdays x 5) + (hours of tablet/phone/portable gaming device on weekend days x 2)]/7. During analysis, this will be presented as a screen-time score, as opposed to total hours spent in screen-time since after 5 hours/day, we cannot quantify the child's actual amount of screen-time. In addition, children who regularly engage in two types of screen-time simultaneously, may over-report total hours spent in screen-time.

ActiGraph GTX1+BT, GT9X link+BT, GT3X+BT wActisleeps and ActivPAL devices

Upon downloading data from both the and ActivPAL and ActiGraph devices, files will be processed using the ActiGraph (ActiLife v 6.11.5) and ActivPAL (v 5.9.1.1) software. The ActivPAL data will be pre-classified (I.e. sitting, standing and stepping), while ActiGraph data intensity will be classified using age specific cut points by Trost et al., (2011), suitable for children aged 5-15 years. By matching the timestamp from the ActiGraph and ActivPAL devices with when the child is recorded to be at home, we will be able to infer the amount of sedentary behaviour and physical activity children accumulate while at home. Data will be exported into a Microsoft Excel where it will be handled and transferred to SPSS statistics.

<u>Analysis</u>

A mixed model regression will be used to determine the amount of each behaviour (Screen-time, Sed, LPA, MVPA and VPA) children accumulate while at home. We will use location logbook, ActiGraph and ActivPAL accelerometer derived variables to determine, where, when and for how long children are active or sedentary while in their home. Separate multilevel regression models will be used to determine the influence of specific elements of the home (e.g., a TV in a bedroom, electronic media density, presence of a garden) on children's PA, screen-time, specific types of behaviour and overall sedentary behaviour. Significant predictors of the home will be placed in the one model to determine the relative significance of the home environment on children's behaviour. Analyses will adjust for sociodemographic factors (e.g., child age and sex, time spent at home and parent socioeconomic status).

Statistical analysis for validation of the families preferences, priorities and perceptions questions in terms of housing and activity

Firstly, to ensure that the data is suitable for exploratory factor analysis (EFA), the following checks will be made (Yong and Sean Pearce, 2013) ; case to variable ratio, there must be at least 5 cases per variable; a correlation matrix will be conducted to assess correlations between individual variables, where correlation coefficients should be above 0.30; Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy test will be used, where values should be above 0.6 as recommended (Hair et al., 2006); and Bartlett's Test of Sphericity will be conducted, where the test should be significant ($p<0.05$). Providing all these conditions are met, and the sample size is at least 100, as recommended (Gorsuch, 1983); (Kline, 1979), EFA will be conducted using principal component analysis (PCA) with oblique rotation on six sets of items: 1) Child activity preferences at Home; 2) Parent Activity Preferences at Home; 3) Importance of Children's Activity at Home; 4) Importance Home Features; 5) Importance of Home Equipment; 6) Supportiveness of Home Space for Activity.

Internal consistency of each factor will be assessed using Cronbach's Alpha with >0.70 considered suitable for exploratory research (Tavakol and Dennick, 2011). Items with values below this, will be removed to improve internal consistency.

The questionnaire section of the instruments completed by a portion of the participants at time 1 and 2 (1 week later) will be analysed for descriptive statistics, where each scale and sub-scale will be summed. Test-retest reliability of the questions will be assessed by comparing the responses from time 1 with time 2, using the interaclass correlation coefficient (ICC, 95% confidence intervals) and spearman rank correlation tests for the continuous and categorical variables respectively. The mean differences between the questionnaire responses at time 1 and 2 will be identified using the chi-squared test and independent t-test for the categorical and continuous variables respectively.

6.6 STORAGE AND DISPOSAL OF DATA AND SAMPLES

describe the procedures to be undertaken for the storage and disposal of data and samples

- identify the people who will have the responsibility for the storage and disposal of data and samples

- Identify the people who will have access to the data and samples
- state the period for which the data will be retained on study completion (normally 5 years, or end of award)

All the data collected will be kept private and confidential. Any hard copies of the consent/assent forms will be kept securely, in the project supervisor's office. The accelerometer data and any additional personal information will be stored on a password protected computer for up to 5 years until they are eventually destroyed by the lead researcher. Responses from the audit tool, and both questionnaires will be sent to a password protected email account in an encrypted password protected pdf file where the data will be stored. Data will then be downloaded for subsequent analysis.

6.7 HOW DO YOU PROPOSE TO ENSURE PARTICIPANT CONFIDENTIALITY AND ANONYMITY?

After data collection, the researcher will remove identifiers in the data set to protect confidential information. Such information will be stored somewhere else, in separate, protected files. In the clean data set, each participant will be identified by their ID numbers and full addresses will be replaced with postcodes. If any unacceptable behaviours are observed during the school visit, the law may not necessarily always allow privacy (Allen et al., 2011). In such circumstances, national regulation states the researcher may be under legal and professional obligation to breach confidentiality and disclose information to the appropriate authorities. At this point we will disclose this information and seek appropriate action from the chair of the REC.

6.8 PLEASE PROVIDE DETAILS OF ANY DIETARY SUPPLEMENTATION (DELETE IF NOT APPLICABLE)

(a) State the full name of the supplement to be used in the study, including proprietary names under which it is also known
(b) Provide full details of the manufacturer and source of origin of the supplement that will be used
(c) Provide details of the composition of the supplement, including details of any potentially active ingredients
(d) State the quantity & frequency (dosage) of supplement administration
(e) State the method/route of supplement administration (e.g. oral)
(f) State the time of supplement administration relative to any form of physical exercise that participants will be asked to undertake as part of the proposed study
(g) State the desired (or hypothesised) effects of the supplement in the context of the proposed study
(h) Provide, with references, a list of known contraindications (i.e. conditions or factors that increases the risk involved in using the supplement) that have been associated with the supplement during resting and exercise indications
(i) Provide, with references, a list of possible side effects (i.e. adverse or unintended, and undesirable, consequences of using the supplement) that might occur after administration of the supplement, during resting and exercise conditions

7. LOCATION OF THE PREMISES WHERE THE RESEARCH WILL BE CONDUCTED.

- list the location(s) where the data collection and analysis will be carried out
- identify the person who will be present to supervise the research at that location
- If a first aider is relevant, please specify the first aider

Parents, schools and the researcher will have to agree upon a suitable time for the researcher to make the school visit to attach the ActiGraph accelerometer and ActivPAL devices to the children, measure their height and weight, supervise the children while they complete the questionnaire on their home-based activity habits and retrieve the assent and consent forms. The ActiGraph will be taken off during contact sports, showering or bathing and at night for charging, ready for the next day. The researcher will return to the school one week later to retrieve all the equipment and pick up the location logbook. The researcher is DBS checked.

8. POTENTIAL PARTICIPANT RISKS AND DISCOMFORTS

- identify any potential physical risk or discomfort that participants might experience as a result of participation in the study.
- identify any potential psychological risk or discomfort that participants might experience as a result of participation in the study.
- Identify the referral process/care pathway if any untoward events occur

The time taken by the participants to complete the HomeSPACE instrument may be a burden.
Wearing both the ActiGraph and ActivPAL may be perceived as burdensome by the child. In addition, the ActivPAL may cause skin irritation as it will be attached to the child’s leg using a hypoallergenic fixing tape, however in general the device is unobtrusive and user-friendly (Scott, Strath and Pfeiffer, 2013). If skin irritation occurs under the ActivPAL, the participant will be instructed to remove it, rinse the area with cold water and attach to it to the other leg, they may need to ask an adult to help. If the irritation continues, they should remove it and let their parent know and they can contact the researcher. The participant will be given 4 dressings for re-attachment in case skin irritation occurs and 4 alcohol wipes to help with attachment and removal of the dressing.

9.1 HOW WILL INFORMED CONSENT BE SOUGHT?

Will any organisations be used to access the sample population?
Will parental/coach/teacher consent be required? If so, please specify which and how this will be obtained and recorded?

Participants will be recruited through the following channels; Schools, the Swansea and Cardiff Swan-Linx programme, the HAPPEN primary schools network, the city and county of Swansea, Bridgend Borough Council, as well as the university intranet and sport and recreation clubs across South Wales.
Firstly, to recruit the lead researcher will request approval from the head teachers, head

coaches or community leads to both pitch for participants and meet with the children to attach the wearable devices. Information packs, including participant information will be placed in envelopes for children to take home. Interested parents will be contacted, where a suitable time for the researcher to meet the children in school will be agreed. A pack containing consent and assent forms will be given to these children to take home with them. Once completed and returned to their teacher, the researcher will make another visit to the school to pick up the forms and attach the wearable devices.

9.2 INFORMATION SHEETS AND CONSENT/ASSENT FORMS

- ☐ Have you included a Participant Information Sheet for the participants of the study? YES/NO
- ☐ Have you included a Parental/Guardian Information Sheet for the parents/guardians of the study? YES/NO
- ☐ Have you included a Participant Consent (or Assent) Form for the participants of the study? YES/NO
- ☐ Have you included a Parental/guardian Consent Form for the participants of the study? YES/NO

10. IF YOUR PROPOSED RESEARCH IS WITH VULNERABLE POPULATIONS (E.G. CHILDREN, PEOPLE WITH A DISABILITY), HAS AN UP-TO-DATE DISCLOSURE AND BARRING SERVICE (DBS) CEHCK (PREVIOUSLY CRB) IF UK, OR EQUIVALENT NON-UK, CLEARANCE BEEN REQUESTED AND/OR OBTAINED FOR ALL RESEARCHERS? EVIDENCE OF THIS WILL BE REQUIRED.

11. STUDENT DECLARATION

Please read the following declarations carefully and provide details below of any ways in which your project deviates from these. Having done this, each student listed in section 2 is required to sign where indicated.

- ☐ ***"I have ensured that there will be no active deception of participants.***
- ☐ ***I have ensured that no data will be personally identifiable.***
- ☐ ***I have ensured that no participant should suffer any undue physical or psychological discomfort (unless specified and justified in methodology).***
- ☐ ***I certify that there will be no administration of potentially harmful drugs, medicines or foodstuffs.***
- ☐ ***I will obtain written permission from an appropriate authority before recruiting***

members of any outside institution as participants.

- ***I certify that the participants will not experience any potentially unpleasant stimulation or deprivation.***
- ***I certify that any ethical considerations raised by this proposal have been discussed in detail with my supervisor.***
- ***I certify that the above statements are true with the following exception(s):"***

Student/Researcher signature: (include a signature for each student in research team)

Date:

12. SUPERVISOR'S APPROVAL

Supervisor's signature:

Date:

Swansea University
Prifysgol Abertawe

College of Engineering
Research Ethics and Governance Committee

PARTICIPANT INFORMATION SHEET
(Version 1.1, Date: xx/xx/20xx)

Project Title: HomeSPACE project: Investigating the influence of the physical environment of the home on children's physical activity and sedentary behaviour

Contact Details: **Lead researcher**: Michael Sheldrick- Email: [redacted]

Project supervisor: Gareth Stratton- Email: [redacted]
Office Telephone: [redacted]

1. Invitation Paragraph

We would like to learn more about your home and how it may affect the amount of time your child spends sitting and in physical activity. Your family is invited to take part in the HomeSPACE study, a new and exciting study involving new technology.

2. What is the purpose of the study?

The study aims to look at how the physical home space influences children's (aged 9-13 years) physical activity and time spent sitting while at home, as well as to determine the validity and reliability of a set of questions referring to parent's preferences, priorities and perceptions in terms of housing and leisure at home. The information we collect will be used in a student's project and will help impact future home and planning design to reduce time spent sitting and to help promote healthy active living in families.

3. Why have I been chosen?

You and your family have been invited to take part, because you have at least one child aged 9-13 years that attends a primary school in South Wales. Participation is completely optional and during the study if either you or anyone else in your family wishes to withdraw from taking part, they are free to do so at any point without any explanation needed.

4. What will happen to me if I take part?

You will be sent an online audit tool that we would like you to complete, while walking around your home. The tool will include questions about house and garden size, space and design and physical activity and media equipment. In addition, you will be asked to complete some questions about you and your family's preferences for housing and activity at home. The tour and questions should take no longer than 30 minutes to complete.

Alongside this, with your permission, your child will be met by the researcher in their school where they will be given two movement recorders, an ActivPAL and an ActiGraph accelerometer, that they will be required to wear for a period of 7 days. They will also have their height and weight measured and complete one questionnaire (5 mins) on their activity habits and another (10 mins) on their health and lifestyle in school. The ActivPAL device will be attached to their thigh, where it will continuously track their sitting, standing and stepping. The

The ActivPAL device

ActiGraph accelerometer will be worn on your child's non-dominant wrist, and it will allow us to calculate the amount of time they spend in physical activity each day. In order to work out how much physical activity and sedentary behaviour children accumulate while at home, we would also be grateful if you could keep a record of when your child is at home throughout the 7 days, using a logbook provided by us.

The ActiGraph accelerometer

5. What are the possible disadvantages of taking part?

It is possible your child will feel burdened with wearing the device, although it is user-friendly and unobtrusive. If they feel uncomfortable at any point, they are free to stop without explanation. Likewise, if you feel uncomfortable with anything you can withdraw at any point. The only other downside to taking part is the time it takes.

6. What are the possible benefits of taking part?

Some children spend a lot of time at home and spend most of it watching TV or playing video games and not much time doing physical activity. Too much time spent sitting particularly doing these things can lead to overweight and obesity, reduced fitness and other problems, but physical activity is good for children and can be fun at the same time. Taking part in this study will help us to understand how the physical home space may affect your child's time sitting, in physical activity and their health. Taking part in this study may be able to increase your awareness of how your home may affect the amount of time your child spends sitting and in physical activity and their health. The results from this study may be able to influence future UK home and planning design to increase children's physical activity. As a thank you for taking part, your child will also receive a report showing their physical activity and sitting information for the week as well as a certificate to certify their participation in the study.

7. Will my taking part in the study be kept confidential?

All the data collected will be kept private and confidential. Each family member will be given a personal identification code. Only the researchers involved in the study will have access to the information via a password protected computer.

8. What if I have any questions?

If you have any further questions about the study please don't hesitate to contact me or another member of the research team (see contact details above). If after the study, you are worried about how any aspect of the research was carried out please contact Andrew Bloodworth, the chair of the college ethics committee.

Study letter – English version

Swansea University
Prifysgol Abertawe

Applied Sports Technology Exercise and Medicine Research Centre (A-STEM)

Dear Parent or Guardian,

The HomeSPACE Study

Your family is invited to take part in a Swan-Linx associated study called HomeSPACE study, which aims to learn more about your home and how it may affect the amount of time your child spends sitting and in physical activity. This study has only been done in Australian homes so far, and now we hope to be the first to try this out in the UK. **The information collected will help impact future home and planning design to reduce time spent sitting and to help promote healthy active living in families.** Taking part in this study may also increase your awareness of how your home environment may affect the amount of time your child spends sitting and in physical activity, and how these are related to their health.

To take part, you will be sent an online audit tool by email, that we would like you to complete while walking around your home on an electronic tablet or smart phone, if you have either one available to you. Otherwise, it can also be completed on a laptop. The audit tool will include questions about house and garden size, space and design, and physical activity and media equipment. There will also be some questions about you and your family's preferences for housing and activities at home. **The audit tool will only take about 30 minutes to complete.** Alongside this, with your and the school's permission, **the researcher will make a visit to your child's school. During the visit, the children will be given 2 activity monitors to wear for 7 days, and complete a quick questionnaires on their activity habits.** In addition, we would also be very grateful if **you could keep a record of when your child is at home, using a logbook that we will provide.** Your child's physical activity and sitting information will then be paired with when they're at home according to the logbook, allowing us to work out how much time your child spends sitting and in physical activity while at home.

Your child may have already met the researcher at the fitness fun day that they participated in with the rest of their class mates as part of another programme led by Swansea university called, Swan-Linx.

For taking part, you will be entered into a prize draw, to win 1 of 2 family day passes (1 adult and 1 child) for the Tree Top Adventure course at GoApe.

As a thank you for taking part, your child will also receive a feedback report showing their physical activity and sitting information for the 7 days and a certificate to certify their participation in the study.

If you would like to take part, please fill out the information below and hand the letter back to your child for them to bring in to school.

Your name: ……………………………………

Contact details: Telephone: ………………………… or Email: …………………………..

Alternatively, if you are interested in taking part or would like any further information you can contact the lead researcher Michael, via email at: [redacted]

Study letter – Welsh Version

Canolfan Ymchwil Chwaraeon, Technoleg, Ymarfer Corff a Meddygaeth Cymhwysol (A-STEM)

Portffolio Chwaraeon ac Iechyd, y Coleg Peirianneg

Annwyl Riant neu Warcheidwad

Rydym yn gwahodd eich teulu i gymryd rhan mewn astudiaeth o'r enw HomeSPACE, sy'n gysylltiedig â Swan-Linx. Yr amcan yw dysgu mwy am eich cartref, a sut gallai effeithio ar faint o amser mae eich plentyn yn ei dreulio'n eistedd ac yn symud. Mae'r astudiaeth hon wedi cael ei chynnal mewn cartrefi yn Awstralia yn unig hyd yn hyn a gobeithiwn ei chynnal yn y DU am y tro cyntaf. **Bydd yr wybodaeth a gesglir yn helpu i ddylanwadu ar ddylunio cartrefi yn y dyfodol â'r nod o leihau amser segur a helpu i hyrwyddo ffyrdd iach ac egnïol o fyw ar gyfer teuluoedd.** Yn ogystal, mae'n bosib y bydd cymryd rhan yn yr astudiaeth hon yn cynyddu eich ymwybyddiaeth o sut mae amgylchedd eich cartref yn effeithio ar yr amser mae eich plentyn yn ei dreulio yn eistedd ac yn symud, a sut mae'r ffactorau hyn yn gysylltiedig â'i iechyd.

I gymryd rhan, byddwch yn derbyn holiadur ar-lein drwy e-bost. Hoffem i chi ei gwblhau ar lechen electronig neu ffôn clyfar, os oes un gennych, wrth i chi gerdded o gwmpas eich cartref. Fel arall, gallwch ei gwblhau ar liniadur. Bydd yr holiadur yn cynnwys cwestiynau am faint eich tŷ a'ch gardd, lle a dyluniad a gweithgarwch corfforol a dyfeisiau electronig. Bydd rhai cwestiynau hefyd am eich dewisiadau chi a'ch teulu o ran tai a gweithgareddau yn y cartref. **Bydd yn cymryd tua 30 munud yn unig i gwblhau'r holiadur.** Hefyd, gyda chaniatâd yr ysgol, **bydd yr ymchwilydd yn ymweld ag ysgol eich plentyn. Yn ystod yr ymweliad, rhoddir dau fesurydd symudiadau i'r plant eu gwisgo am saith niwrnod, gofynnir iddynt gwblhau holiadur cyflym am eu gweithgareddau arferol a chaiff eu taldra a'u pwysau eu mesur. Yn ogystal, byddem yn ddiolchgar iawn pe gallech gofnodi'r amserau pan fydd eich plentyn gartref yn y llyfr cofnodi a ddarparwn.** Wedyn, byddwn yn cymharu'r wybodaeth am weithgarwch corfforol eich plentyn a'r amser mae'n ei dreulio'n eistedd â'r amser mae'n ei dreulio gartref, yn ôl y llyfr cofnodi, a fydd yn caniatáu i ni gyfrifo faint o amser mae eich plentyn yn ei dreulio yn eistedd ac mewn gweithgarwch corfforol gartref.

Efallai fod eich plentyn wedi cwrdd â'r ymchwilydd eisoes yn ystod y diwrnod ffitrwydd y cymerodd ran ynddo gyda gweddill ei ddosbarth fel rhan o raglen arall dan arweiniad

Prifysgol Abertawe, o'r enw Swan-Linx.

Bydd enwau pawb sy'n cymryd rhan yn cael eu cynnwys mewn raffl i ennill un o ddau docyn dydd i'r teulu (1 oedolyn ac 1 plentyn) ar gyfer llwybr antur brigau'r coed yn yr atyniad GoApe.

Os hoffech gymryd rhan, darparwch yr wybodaeth isod a rhoi'r llythyr i'ch plentyn i ddod ag ef i'r ysgol.

Eich enw ……………………………………

Manylion cyswllt: Rhif ffôn: ………………………… neu e-bost: ………………………..

Os oes gennych ddiddordeb mewn cymryd rhan neu os hoffech ragor o wybodaeth, gallwch gysylltu â'r prif ymchwilydd, Michael, drwy e-bostio: [redacted]

Swansea University
Prifysgol Abertawe

Applied Sports Technology Exercise and Medicine Research Centre (A-STEM)
Sport and Health Portfolio, College of Engineering

PARTICIPANT INFORMATION SHEET (9-13 years)
(Version 1.1, Date: __/__/____)

Project Title: HomeSPACE project: Investigating the influence of the physical environment of the home on children's physical activity and sedentary behaviour

The HomeSPACE Study

Project supervisor; Professor Gareth Stratton
Email: [redacted]
Phone: [redacted]

Lead researcher; Michael Sheldrick
Email: [redacted]

We would like to learn more about your home and how it may affect the amount of time you spend sitting and in activity. You are invited to take part in a Swansea University project called HomeSPACE. Some children spend a lot of time at home watching TV or playing video games and not much time doing physical activity. Too much time spent doing these things can lead to overweight and obesity and reduced fitness, but physical activity is good for you and can be fun at the same time. Taking part in this study will help us to understand how your home may affect your time spent sitting, in physical activity and your health. If you would like to take part, you will be met in school by the researcher, where you will have your height and weight measured, be asked to wear 2 movement recorders for 7 days and complete 2 quick questionnaires, one on your health and lifestyle habits and another about the activities you get up to. The movement recorder will measure how much time you spend sitting and moving each day, and by doing the other two tasks you will help us improve our understanding of how your home influences the activities you do. Alongside this, your parent will be asked to keep a record of when you're at home, and by matching this with your physical activity and sitting information, we can work out how much you do of both, when at home. Your information will be kept a secret and only the people who are doing the research will see it. If you have any questions, ask your parents to get in contact with a member of the research team (see above), and we'll be happy to answer them.

As a reward for taking part, you will be entered into a prize draw to win a family day pass (1 adult and 1 child) for the tree top adventure course at GoApe.

You will also receive a colorful report showing your physical activity and sitting information for the week along with a certificate to show that you participated in the study.

Feedback report showing the children's PA and sitting information for the 7 days

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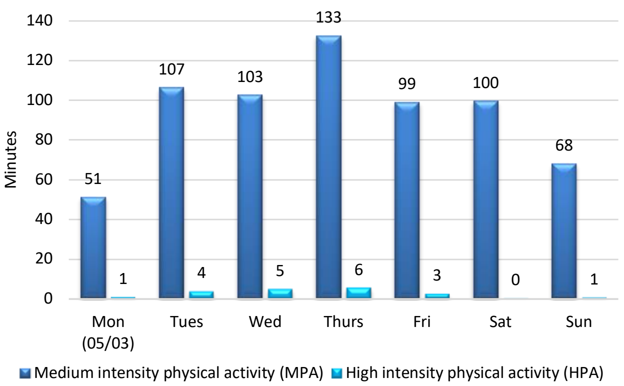
The HomeSPACE study participation report on your physical activity and sitting time for the week starting; 05/03/2018.

As part of the study you wore 2 devices for 7 days; one on your leg that measured your sitting, standing and stepping; and another on your wrist that measured your medium (MPA) and high (HPA) intensity physical activity. The devices are very accurate and are in fact considered the best around for measuring physical activity, sitting and standing. Your physical activity and sitting results for the 7 days collected from these devices are shown below.

Things to remember when looking at your results;

- We've only included your sitting/lying information during waking hours.
- You removed the wrist monitor (physical activity) for karate on Monday between 17.40-19.00, on Thursday between 18.00-21.05 and on Friday between 18.00-17.05,

Your medium (MPA) and high intensity (HPA) physical activity for the 7 days



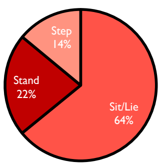
Children your age should be aiming for at least 60 minutes of physical activity every day, but the more, the better. You at achieved at least this amount every full day.

Thursday was your most active day, where you spent 139 minutes in physical activity.

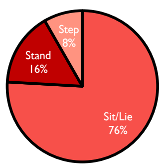
Types of HPA include; Tennis, football, running, skipping.
Types of MPA include; fast walking, cycling with friends, jumping on a trampoline, dancing.

Your stepping, standing and siting/lying while awake and daily step count for the 7 days

Day	Sit/lie (hrs & mins)	Stand (hrs & mins)	Step (hrs & mins)	Step count
05/03-Mon (13.30-22.15)	5.44	1.43	1.17	4934
06/03-Tues	8.45	3.27	2.14	10870
07/03-Wed	9.50	2.18	1.55	8734
08/03-Thurs	6.06	4.28	3.00	12280
09/03-Fri	9.44	3.31	2.09	8700
10/03-Sat	11.46	2.37	1.07	4364
11/03-Sun	9.33	1.54	1.21	5708
12/03-Mon (7.25-14.00)	4.09	1.14	1.11	5442



The % of time you spent standing, sitting and stepping on average per weekday.



The % of time you spent standing, sitting and stepping on average per weekend day.

Tips to help you move more and sit less

Moving more and sitting less will help you maintain a healthy weight, provide you with more energy throughout the day and you'll also be able to concentrate and think better in school. To help with moving more and sitting less you could;

- take regular breaks from looking at a screen. If watching TV get up when the adverts come on. If you're playing computer games, texting or doing anything else using a screen, try to get up and take a break every 30 minutes.
- try standing instead of sitting when you can. Try it for short periods while watching TV or when at school.
- help your parents with household chores more often such as setting the table for food or vacuuming the floors.

Swansea University Prifysgol Abertawe
School of Sport and Exercise Sciences
Ysgol Chwaraeon a Gwyddorau Ymarfer Corff
Lead researcher: Michael Sheldrick
Email: [redacted]

The HomeSPACE Study

The certificate children received for taking part in the study

PARTICIPANT CONSENT FORM (FOR THE ADULT TO COMPLETE)
Date: xx/xx/20xx

Project Title: HomeSPACE project: Investigating the influence of the physical environment of the home on children's home based physical activity and sedentary behaviour

Contact Details: **Lead researcher**: Michael Sheldrick- Email: [redacted]
Project supervisor: Gareth Stratton- Email: [redacted]
Office Telephone: [redacted]

Please put your initials in each box

1. I confirm that I have read and understood the information sheet dated ....../....../...... (version number ....) for the above study and have had the opportunity to ask questions. ☐
2. I understand that my participation is voluntary and that I am free to withdraw at any time, with giving any reason, without my medical care or legal rights being affected. ☐
3. I understand that sections of any data obtained may be looked at by responsible individuals from Swansea University or from regulatory authorities where it is relevant to my taking part in research. I give permission for these individuals to have access to these records. ☐
4. I am happy for all the data collected in this study to be included, anonymously, in any future publications within academic journals. ☐
5. I am happy to complete the online audit tool, while walking around my home. ☐
6. I am happy to complete the questions around activity in my home ☐
7. I am happy to complete a logbook, recording when my child is at home. ☐
8. I agree to take part in the above study. ☐

Name of Participant (adult)	Date	Signature
Name of Person taking consent (if different from researcher)	Date	Signature
Researcher	Date	Signature

Swansea University
Prifysgol Abertawe

Applied Sports Technology Exercise and Medicine Research Centre (A-STEM)
Sport and Health Portfolio, College of Engineering

PARTICIPANT ASSENT FORM (FOR THE CHILD TO COMPLETE)

Date: xx/xx/20xx

Project Title: HomeSPACE project: Investigating the influence of the physical environment of the home on children's home based physical activity and sedentary behaviour

Contact details: Lead researcher: Michael Sheldrick-Email: [redacted]
Project supervisor: Professor Gareth Stratton- Email [redacted]
Office Telephone: [redacted]

Please put your initials in each box

1. I confirm that I have read and understood the information sheet dated ....../....../...... for the above study and have had the chance to ask questions. ☐
2. I understand that my participation is entirely up to me and that I am free to stop at any time, without getting in trouble. ☐
3. I am happy to complete an online questionnaire on my activity habits. ☐
4. I am happy to complete an online health and lifestyle questionnaire ☐
5. I am happy to have my height and weight measured. ☐
6. I am happy to wear one movement recorder on my leg at all times for 7 days ☐
7. I am happy to wear one movement recorder on my wrist at all times for 7 days ☐
8. I understand that some of the information collected will be looked at by other people associated with the study from Swansea University and others in the field of science, and I give permission for this. ☐
9. I understand that the information may be used in reports and publications online, but with your name kept a secret. ☐
10. I am happy to take part in this study ☐

If you are currently dealing with any issues which are causing you distress (e.g. neglect abuse etc.), please don't hesitate to call Childline at: **0800 1111**, a free 24 hour counseling service for children which may be able to help.

Name of Person giving assent (child)	Date	Signature
______________________	____________	______________________
Researcher	Date	Signature

Swansea University
Prifysgol Abertawe

Applied Sports Technology Exercise and Medicine Research Cent

The HomeSPACE Study

PARTICIPANT INFORMATION BOOK

Assigned participant identification number: _______

Contact details:

Project supervisor

Professor Gareth Stratton

Email: [redacted]

Phone: [redacted]

Lead researcher

Michael Sheldrick

Email: [redacted]

Participant logbook

Please write down in the tables below the time you take the movement recorders off. Also record when you put it back on. Also, write down why you have taken it off (e.g. swimming).

Day of the week (abbreviate if necessary)	Time removed movement recorder (e.g. 5.30 pm)	Time you put movement recorder back on	 Reason for removal

Day of the week (abbreviate if necessary)	Time removed movement recorder (e.g. 5.30 pm)	Time you put movement recorder back on	 Reason for removal	Comments We would like to know if you've had skin irritation, accidentally worn the device upside down or any other information

We would also like to write down in the table below when you go to sleep and wake up. Please only fill in the white boxes.

Day of the week	Time you go to sleep (e.g. 9.15 pm)	Time you wake up (e.g. 8.30 am)	 Comments
Fri (29/06)			
Sat (30/06)			
Sat (30/06)			
Sun (01/07)			
Sun (01/07)			
Mon (02/07)			
Mon (02/07)			
Tues (03/07)			
Tues (03/07)			
Wed (04/07)			
Wed (04/07)			
Thurs (05/07)			
Thurs (05/07)			
Fri (06/07)			

Important: We would like you to record the time you actually go to sleep rather than when you get into bed and when you wake up rather than when you got out of bed (these times may be the same some days). Please do this first thing in the morning.

ActiGraph movement recorder guide

You will be given a ActiGraph movement recorder that we would like you to wear on your non-dominant wrist (your non-writing hand). This movement recorder will measure your light, medium and high intensity physical activity.

You will be given the pictured movement recorder.

Step 1. How do I wear the movement recorder?

You will be given a movement recorder that we would like you to wear on your non-dominant wrist. It's important that you've done the strap up tight enough so that it's secure on your wrist with the logo facing up when viewed

Step 2. How do I know the movement recorder is working?

There should be a small running man in the top left-hand corner, see photo to the right. This shows that it's switched on and recording your movement.

Step 3. When should I remove the movement recorder?

You should wear the movement recorder continuously, while awake, showering and sleeping, removing it only when taking a bath or doing water based activities like swimming and contact sports such as rugby and martial arts.

ActivPAL movement recorder guide

You will be given an ActivPAL movement recorder that is attached to your thigh using special tape. This movement recorder will record the amount of time you spent sitting, standing, stepping and your step count.

You will be given the pictured movement recorder.

We would like you to wear it on your thigh like in the picture.

Step 1. When should I remove the movement recorder?

We would like you to wear the ActivPAL at all times (24hrs), including washing, showering and contact sports. It's water resistant but please do not wear it swimming or in the sea in case it falls off.

Step 2. What do I do if the ActivPAL is irritating my skin?

Your skin may become irritated under the ActivPAL due to the adhesive tape, if this happens you should remove it, rinse the area and attach it to the other leg (ask an adult to help you). If the irritation continues, you should remove it and let either your parent/guardian or a teacher know and they can contact the researcher.

Step 3. How do I know if the ActivPAL is switched on working?

The ActivPAL will flash a green light every 6 seconds. If you stop seeing this flashing green light please let either your parent/guardian or a teacher know and they can contact the researcher.

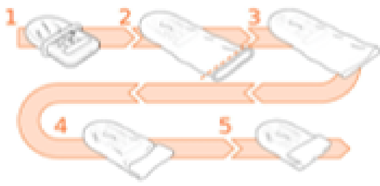
Step 4. How do I attach and remove the ActivPAL?

It's not difficult to either reattach the device or remove it but there are a number of important points to remember, on the next page are instructions on how to both remove and attach the device. If you don't feel confident doing it yourself, please ask an adult to help you.

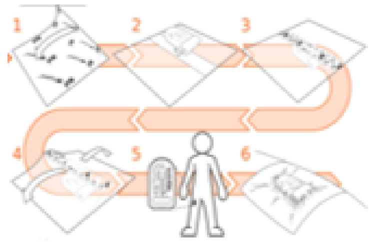
ActivPAL device instructions

How to attach the ActivPAL device

1. First, the ActivPAL must be waterproofed. The picture to the right should help with this. Place the sleeve (provided in your pack) over the curved edge of the device, so that the ActivPAL is positioned at the very bottom of the sleeve. Then roll the sleeve down, until it reaches the base of the device and fold up any excess sleeve up on the side without text. Make sure it's folded up tight, to prevent any water from getting into it.



2. To attach the ActivPAL to your thigh, first sit on a chair as will make it easier to find the top of your thigh (the crease between your leg and upper body). The photo below will help with the next steps.



3. The device should go on the middle of the front of your right thigh (halfway between your knee and your hip). Wet this area with an alcohol wipe (provided) and let the area dry for a few seconds.
4. Then position the device in the correct position on the thigh (in the middle and halfway between your knee and your hip), making sure the side with the green light flashing is facing upwards and the curved part is facing up (towards you).
5. Then remove the back (the side with the text on) of the dressing (provided in your pack).
6. Once you've removed the backing, you will see/feel that there is a sticky side and a non- sticky side. Place the sticky side over the ActivPAL (the side without the numbers) and press it down hard on your leg, starting from the middle out towards the edges. This is to make sure the device is stuck in place, the picture on the right will help you with this.

7. Then peel the both sides off from the numbered edges and smooth out the air bubbles and wrinkles.

If you need to change the dressing

During the 7 days, you may need to change the adhesive dressing which attaches the devices to your thigh. To do this:

- Remove the monitor from your thigh (note that this may cause some slight discomfort) and peel the sticky dressing off the device.
- With an alcohol wipe provided, thoroughly wipe down the monitor and the area of your leg where the monitor was attached and follow the same procedure as explained above.

***If you require assistance re-attaching the ActivPAL, or if you experience any skin irritationn whilst wearing it, let your parent know and they can get in touch with the researcher**