Title; Clusters of activity-related social and physical home environmental factors and their association with children's physical activity and sedentary behaviour

Abstract

Purpose; Understanding which physical activity (PA) and sedentary behaviour correlates cluster in children is important, particularly in the home, where children spend significant time. Therefore, this study aimed to assess clustering of social and physical activity-related factors at home, and whether these clusters are related to home-based sitting and PA in children. A secondary aim was to explore whether the clusters were associated with child, parent and family characteristics.

Methods; Altogether, 235 children (55% girl, mean age = 10.2 ± 0.7 years) and their parents took part. Physical (e.g., PA and electronic media equipment, house and garden size, layout) and social (e.g., activity preferences, priorities, parental rules) home environmental factors were obtained via the HomeSPACE-II audit and self-report, respectively. Principal component analysis (PCA) was used to identify clusters of physical and social environmental factors. Backward regression analysis and partial correlations were used to examine relationships between clusters, children's (55% girl, mean age = 10.2 ± 0.7 years) device-measured home-based activity behaviours and background characteristics.

Results; The findings show that physical and social environment activity-related factors at home cluster. The clusters were associated with several background characteristics, with socioeconomic factors appearing to be particularly influential. The clusters were also associated with home-based activity behaviours in the hypothesised directions.

Conclusion; Interventions which target clusters of social and physical factors at home, especially among low-socioeconomic status (SES) families, are warranted.

Key words; Physical activity, sitting, home, clusters, physical environment, social environment, correlates

Introduction

Physical activity (PA), irrespective of intensity, is an important preventative measure for obesity and many other health risk factors in children (1). Although moderate-to-vigorous intensity physical activity (MVPA) has been shown to be the most beneficial to health (1), those meeting the government recommended levels of at least 60 minutes of MVPA, on average, every day (2) remain low (3). Specifically, in Wales, only a third of children have been classified as sufficiently active (4). Moreover, children also spend a significant amount of time in sedentary behaviours (7-8 h daily) (5), characterised by 'an energy-expenditure below 1.5 metabolic equivalents (METs), while in a sitting, lying or reclining posture' (6). Screen-time is the most prominent of these (>5 h daily) (7), and has been adversely associated with obesity and overall cardio metabolic health (8). Further, *how* sedentary time is accumulated may also be important, as more frequent breaks in sedentary time have been shown to improve short-term metabolic indicators in children (9). While research has shown significant health consequences of excessive sedentary time and infrequent sedentary breaks in adults (10), 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 (11), high levels of sedentary time, particularly of a prolonged nature (12), are a public health concern.

Ecological models emphasise the influence of the environment on PA and sedentary behaviour (13). Outside of school, children spend a large proportion of time in their neighbourhood and home environments. While the influence of the neighbourhood environment on children's PA and sedentary behaviour has received much attention (14–16), less is known about the impact of the home environment (17). However, the availability of household and bedroom media equipment are consistent physical environment correlates of screen-time (17,18). Moreover, PA equipment has been shown to promote PA (19,20) and discourage sedentary behaviour (17,20). Musical instruments have also been inversely related to sedentary time (21). Further, qualitative research has identified that house and garden size influences children's PA and sedentary behaviour at home (22). Parents play a particularly important role in influencing their children's PA and sedentary behaviour (17); parental PA levels, support and co-participation are all identified as important correlates of children's PA (23,24), whereas parental screen-time and electronic media rules are consistent correlates of children's sedentary behaviour (17,18). This evidence supports the notion that both the physical and social home environment have an important influence on children's PA and sedentary behaviour (17,18).

Although studies have assessed individual physical and social environment activity-related factors, only a limited number of studies have examined clustering or the co-occurrence of such factors (25,26). Understanding which social and physical factors with a known influence on children's PA and sedentary behaviour cluster or co-occur is important, as the co-occurrence of PA and sedentary behaviour correlates is likely to have a synergistic effect (27), similar to the synergistic effect of multiple unhealthy behaviours on overweight and obesity observed in studies (28–30). Moreover, identifying which social and physical factors cluster may enable more efficient interventions, by informing strategies which target multiple factors simultaneously. Given that children spend more time at home than anywhere else

(31,32), clusters of such factors within the home environment may be particularly important. There is some evidence that physical and social environmental factors cluster at home (25,26). Specifically, at least two studies have shown that low parental screen-time and high PA equipment availability cluster (25,26). Moreover, low media equipment availability and greater family rules have also been found to cluster (25). However, these studies also examined factors outside the home as well as dietary behaviours. Investigating clustering of activity-related social and physical factors solely within the home, would provide a more nuanced understanding for home-based interventions aiming to promote active living in families.

To determine how clusters may arise and which groups are most in need of intervention, it is important to identify the background characteristics associated with the potential clusters. Previous studies have shown child BMI as well as parental education, age and ethnicity to relate to clusters of diet and activity-related parenting practices (26,33). Children's activity preferences, parental income, family situation and deprivation have been shown to be important influences on children's PA and sitting behaviour in the literature (18,34,35), therefore we hypothesise they may be associated with the potential clusters of physical and social activity-related environmental factors. To establish the importance of each cluster to children's PA and sedentary behaviour, associations between the clusters and children's PA and sedentary behaviour will be explored. Given ecological models posit that behaviour is most likely influenced by the environment in which it occurs, investigating sedentary behaviour and PA at home will be important (13). Yet, to the authors knowledge, no study has investigated how clusters of social and physical activity-related factors at home relate to children's objectively measured home-based PA and sedentary behaviour.

The main aim of this study was to investigate clustering of social and physical activity-related factors within the home, and whether these clusters are related to home-based sitting, sitting

breaks, MVPA 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. We hypothesise that the social and physical activity-related factors within the home will cluster, and that healthy clusters will positively relate to healthy behaviours at home (MVPA, TPA, sitting breaks) and negatively relate to unhealthy behaviours at home (sitting time).

Methods

Participants

The HomeSPACE study is a cross-sectional observational study investigating the influence of the home environment on children's home-based PA and sedentary behaviour (32,36). Participants were recruited for this study via primary schools. Between November 2017 and July 2018, 11 out of 23 socio-demographically representative primary schools which were contacted provided headteacher consent to participate in the study. From these schools, the 890 children from school years 5 and 6 (9-11 years old) were provided with project information. Participation was incentivised; families were offered entry 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 all 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 University ethics committee.

The physical home environment

Physical factors within the home which are hypothesised to influence children's PA and sedentary behaviours at home (22) were assessed using the validated HomeSPACE-II instrument (37). Parents were asked to walk around each room/area in their house and garden and use the audit to record the presence, amount and accessibility of 41 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 easy 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. 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).

Social and individual factors

Family priorities and preferences for home-based activity (38) and parental media rules (39) were assessed with questions demonstrated to be valid and reliable. The first question asked three items on perceived parental importance of activities: "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: (1) 'almost always' (2) 'mostly' (3) 'about equal' (4) 'mostly' (5) 'almost always'. For each activity preference 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).

Objectively measured home-based physical activity and sedentary behaviour

Children wore an ActiGraph GT9X (Pensacola, Florida, USA) and activPAL3 micro (PAL Technologies, Glasgow, UK) to assess PA (TPA and MVPA) and sedentary behaviour (sitting and sitting breaks), respectively. Sitting breaks were considered as transitions from sitting to standing/stepping (6). The monitors were fitted at school by trained researchers 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.). Although most diaries were completed by the parents, 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 (40), 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 (32), 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 ($\geq$ 5 h) and invalid data (41,42). Diary-reported non-wear time considered feasible were also removed. In addition, based on inspections of the data and methods used elsewhere (43), $\geq$ 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 (44), as wrist-worn accelerometers have been shown to improve compliance [39] and have comparable validity to hip-worn accelerometers (46). Devices were set to collect data at 30 Hz (47), 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 (48), applied to the vector-magnitude, were used to categorise MVPA ($\geq$818 counts/5-secs) and TPA ($\geq$162 counts/5-secs). Non-wear periods, identified as >90 minutes of consecutive zero counts (49), were removed.

198 To calculate home-based PA and sedentary behaviour, time at home was imported into both
199 the ActiLife and Processing PAL software, respectively, and matched with time-stamped
200 data. To be included in the analyses, participants were required to have satisfactorily
201 completed home logs, and at least 1 day that had ≥ 3 h of data at home (50) when the device
202 was worn for ≥75% of the time (51). Sickness days were also removed. ActivPAL and
203 ActiGraph data in minutes, divided by waking wear time at home in minutes, were multiplied
204 by 60 to produce outcome variables expressed as averages/h (52).
205

206 Children personal information and anthropometric measures

207

208 Within school, trained researchers measured children's stature and body mass to the nearest
209 0.1 cm and 0.1 kg (53), using a portable stadiometer (Seca 213 portable, stadiometer,
210 Hamburg, Germany) and electronic weighing scales (Seca 876, Hamburg, Germany),
211 respectively. Subsequently, body mass index (BMI) was determined, and BMI z-scores were
212 calculated using the WHO (World Health Organization) growth reference charts (54).
213

214 House and garden size estimates

215

216 Using geographic information system techniques (GIS), Ordnance Survey MasterMap
217 (OSMM) (55) and AddressBase Premium (ABP) (56), house and garden size were assessed
218 for each postcode unit. For homes (min – max: 4 - 82), the building footprint area was
219 determined in OSMM and non-residential buildings defined by ABP were filtered out. Using
220 the same process, garden size (front and back combined) for homes (min – max: 2 – 82)
221 defined by OSMM (57) was calculated. 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.

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 coded as 1 (defined as ethnic minorities). Parents 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. Welsh Index of Multiple Deprivation (WIMD) scores (58) were also generated from postcodes. For descriptive purposes, socio-economic status (SES) tertiles were derived according to WIMD scores; low (1–636), medium (636–1272) and high (1272–1909). 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 (59).

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 (60). The scree plot (60) and eigenvalues (> 1) (61) were used to determine the number of components. Items with component loadings of ± 0.4 (62) and no cross loadings above ± 0.50 (63) 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 discussed within the author team and a consensus was achieved based on theoretical rationale. The final solution was significant in the Bartlett test of sphericity (60), had a KMO value above 0.5 (61), and components explained ≥ 50% of the total variance (64). To calculate cluster scores, the home factors were multiplied by their component loadings and summed for each component (26). 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). As there were sometimes more than one child per family taking part (n =7), there was the potential of home-level clustering. Therefore, all analyses were adjusted for home clustering. All analyses were also corrected for 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.

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 and in MVPA per hour, 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%) 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%).

299 *Table 1. Participant characteristics and descriptive statistics.*
300

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
% of children meeting overall MVPA guidelines (ActiGraph) **	97%	214
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 ($m^{2)}$	145.0 (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%	
Movie/TV streaming service subscription (% yes)	77%	
Number of smartphones		213
1-2	25%	
3-4	62%	
5-6	12%	

7-8	0.5%	
>8	1%	
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)	235
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**	40.3 (5.9), 67%	
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=very unimportant; 5=very important; *% proportion of time at home; **=Displayed for descriptive purposes only ***=Displayed as tertiles for descriptive purposes only. MVPA: moderate-to-vigorous intensity physical activity; BMI: body mass index; WIMD: Welsh index of multiple deprivation; SES: socio-economic status. TPA: total physical activity; PA: physical activity.

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 ('positive 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 five 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 six, 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 (64). The five retained clusters explained 62.9% of the variance in the original items.

Table 2. 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: Positive 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 smartphone 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. PA: physical activity.

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%.

Associations between clusters and child, parental and family background characteristics

The regression analyses assessing associations between the background characteristics and clusters are presented in Table 3. The 'low accessibility and availability of electronic media equipment' cluster was associated with a greater child preference for PA activities at home (β = 0.17, p = 0.02), being an ethnic minority (β = -0.21, p = < 0.01) and high-educated parents (β = 0.23, p = < 0.01). The 'positive PA physical environment' cluster showed associations 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). The 'positive social and physical PA environment' cluster showed associations with a greater child greater preference for PA activities at home (β = 0.40, p = <0.01) and a lower BMI (β = -0.18, p = 0.01). Finally, 'high smartphone availability and access to digital TV' (Cluster six) was associated with more people at home (β = 0.22, p = <0.01), living in a rented house (β = -0.16, p = 0.05), and a lower WIMD value (β = 0.17, p = 0.03).

Table 3. Child, family and parental characteristics associated with cluster scores.

Variable	Cluster 1: Low accessibility and availability of electronic media equipment [1]		Cluster 2: Positive PA physical environment [2]		Cluster 3: Positive screen-time social environment [3]		Cluster 4: Positive social and physical PA environment [4]		Cluster 6: High smartphones availability and access to digital TV [5]	
	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 home clustering, 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 $p \leq 0.05$. [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. BMI: body mass index; WIMD: Welsh index of multiple deprivation; PA: physical activity.

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 positive 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 smartphone 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 4. 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: Positive 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 home clustering, 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. *correlation is p ≤ 0.05 (2-tailed). MVPA: moderate-to-vigorous intensity physical activity; TPA: total physical activity; PA: physical activity.

Discussion

The primary aim of this study was to investigate the clustering of physical and social factors related to activity within the home, and whether these clusters are related to home-based sitting, sitting breaks, MPVA and TPA in children. A secondary aim was to explore whether these clusters were associated with child, parent and family characteristics. 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 direct comparisons with other studies. As hypothesized, we found evidence for clustering of physical and social factors within the home. The clusters were also shown to be associated with several parental, child and family characteristics, particularly socioeconomic factors. The only unhealthy cluster was more likely to be found in low SES groups, while the healthy clusters were more likely to be found in high SES groups. Further, the healthy and unhealthy clusters were positively associated with favourable (MVPA, TPA and sitting breaks) and negative behaviours (sitting time), respectively.

411 The strong associations observed between the clusters and socioeconomic factors is consistent
412 with other studies which have found socioeconomic indicators to be important factors defining
413 population sub-groups in relation to youth obesity risk (25,65). Specifically, parental education
414 is thought to point to a broader context in which parental practices are implemented (66). The
415 'low accessibility and availability of electronic media equipment' cluster (cluster 1) may reflect
416 a supportive parental context, and it was more likely to be found in high-educated parents, but
417 also in ethnic minority groups and children with a preference for PA at home. Another healthy
418 cluster, the 'positive PA physical environment' (cluster 2), was also more likely to be found in
419 families with a higher income. Conversely, according to the literature unhealthy clusters are
420 more likely to be found in socioeconomically deprived groups [i.e., low SES groups]
421 (25,26,67). Our finding that WIMD scores, another commonly used measure of SES, were
422 negatively associated with the occurrence of the 'high smartphone availability and access to
423 digital TV' cluster (cluster 6) is consistent with this. These findings may reflect the long-
424 standing relationship between SES and health, whereby those socioeconomically better off
425 usually lead healthier lifestyles (68). This is partially explained by the disparities in social
426 support, income and the cumulative effect of stress between different SES groups, however the
427 specific mechanisms are complex (69). Taken together, these findings suggest that low SES
428 households are an important group to target in interventions seeking to create healthier physical
429 and social home environments in relation to children's PA and sitting.
430
431 The 'positive social and physical PA environment' cluster (cluster 4), characterised by positive
432 physical activity and screen-time related social factors and a high PA equipment presence at
433 home, is congruent with studies that have found low parental sedentary behaviour and high PA
434 equipment accessibility to co-occur (25,26). This type of cluster may arise because the
435 perceptions/strategies exhibited are indicative of a parenting style that reflects a healthy

lifestyle based on habits formed in life and health beliefs (70). The role modelling of a healthy lifestyle may positively influence children's health cognitions and choices (71), 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 (cluster 3), children with a preference for PA were more likely to be found in this cluster. Indeed, PA and screen-time supportive practices specifically are likely to affect children's understanding of the importance of PA and limiting screen-time and consequently their activity preferences (72). 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 'positive PA physical environment' cluster (cluster 2) 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 (cluster 4), 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 (32). 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 (73).

The 'high smartphone availability and access to digital TV' cluster (cluster 6), which also included lower availability and accessibility to musical instruments, 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), and 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 (74,75). 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 (76), less time to supervise children's active play (77) and lack access to structured PA and play areas (78), 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 associated with less home-based sitting. Three of the four factors forming this cluster have been associated with increased screen-time (17,18), a particularly prevalent sedentary behaviour. Therefore, the combination of the factors may be having an important synergistic effect on children's sitting at home.

The novel clustering approach used in the present study, provides an insight into how physical and social factors within the home cluster, thereby enabling more effective interventions through targeting multiple synergistic factors simultaneously. Given the healthy clusters were less likely to occur in low SES families, they are most in need of intervention. Interventions should seek to educate socioeconomically deprived parents on the importance of regular PA and limiting sedentary behaviour for health. There was evidence of favourable social and physical environmental factors clustering, which would suggest that positive changes to parental attitudes towards active play and screen-time may mean they are more receptive to intervention strategies involving changes to the physical environment. Since the high smartphone availability and access to digital TV cluster was the most influential cluster in

terms of its relationship with children's behaviour, delaying smart phone purchases and removing TVs from children's bedrooms seem most important. Parental activity preferences were included in two clusters, and child activity preferences were associated with three clusters. Therefore, strategies which reduce the whole family's preference for sedentary activities will also be important, and given the influence on the clusters, this may further facilitate the formation of healthier home environments.

The strengths of this study include, but are not limited to, the use of the validated audit to comprehensively assess the home physical environment (37), the investigation of home-specific environmental factors and home-based behaviours, as well as the device-based 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 (79,80). 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 (81). The factors were chosen based on theoretical rationales and whether they have been related to children's PA and sedentary behaviour in previous studies. Moreover, the underrepresentation of low SES families may mean the results limit the generalisability of the findings. Although, the proportion of high SES families is similar to others (19,82). Whilst the response rate was modest compared with other studies (83–85), this likely reflects the requirement of both the child and parent to take part. The cross-sectional nature, and therefore the inability to infer causal relationships, the highly active sample (97% of children met overall MVPA guidelines [>60 min.day $^{-1}$]) and the reliance on self-report data for identifying social factors and periods when the child was at home, were also limitations. Although beyond the

scope of the current study, associations between clusters within the home and behaviours across the entire day should be assessed in future work. Further, this study focussed on the home environment, because it is an important sphere of influence on children's PA and sitting, and clustering in this environment had not been explored previously. However, future research should explore the clustering of individual factors and factors within the school environment, which is another important setting to improve children's health.

Conclusion

In conclusion, the findings provide evidence of clustering or co-occurrence of some physical and social environmental factors related to activity in the home. The clusters were shown to be associated with several parental, child and family characteristics. Socio-economic factors seem to be particularly influential. with three of the five clusters being associated with such variables in the expected directions. Specifically, the only unhealthy cluster and four healthy clusters were more likely to occur in low and high SES groups, respectively. Positive (MVPA, TPA and sitting breaks) and negative (sitting time) behaviours were associated with healthy and unhealthy clusters, in the hypothesised directions, 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.

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