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Understanding variations in the built environment over time to inform longitudinal studies of young children's physical activity behaviour - The BEACHES project

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ABSTRACT

We know relatively little about the role the neighbourhood built environment plays in promoting young children's physical activity, particularly its longitudinal effect either through repeated exposure to the same environment or through change in exposure by moving from one neighbourhood to another. This study characterised the neighbourhood environment of young children in the PLAYCE cohort study over three timepoints from 2015 to 2023. There were statistically significant differences in built environment attributes between timepoints and across socio-economic status, however they did not represent practically significant differences. These findings inform the analysis approach of subsequent research in the BEACHES Project, an international study examining the role of the built environment on child physical activity and obesity using multiple cohorts.

1. Introduction

Being physically active in childhood is beneficial for maintaining a healthy weight, strengthening bone and skeletal health, and promoting motor, cognitive, and social-emotional development (Carson et al., 2017; Christian et al., 2021). Establishing positive physical activity behaviours early in life have been shown to track into adolescence and adulthood (Jones et al., 2013; Malina, 1996). A growing body of evidence has found that well-connected, safe neighbourhoods with access to shops, services, and recreational areas is associated with increased physical activity in adults (Christian et al., 2011; Christian et al., 2017; Foster et al., 2013), however relatively little is known about the role of the built environment on young (under the age of five) children's physical activity.

There is some evidence that the presence of vegetation in the neighbourhood is positively related to young children's physical activity (Christian et al., 2015; Terron-Perez et al., 2021. In addition, greater residential density and more public transport opportunity may support young children's physical activity by creating more walkable neighbourhoods (Zhang et al., 2024). This is based on the assumption that young children are mostly influenced by adult-based relationships with the built environment due to their lack of independence and need to be accompanied by a parent/caregiver. While street connectivity supports physical activity in adults, the evidence is conflicting for children (Ding et al., 2011). Neighbourhoods with low connectivity (i.e., a high number of cul-de-sacs) and thus less traffic may be more supportive of younger children's outdoor play and physical activity (Handy et al., 2008; Aarts

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et al., 2012) than interconnected streets which support active transport in older children.

Longitudinal studies are needed to determine the causal role of the neighbourhood built environment on children's health behaviours such as physical activity (Jia et al., 2021; Daniels et al., 2021; Pedrick-Case et al., 2022). Yet, overall, there is a lack of evidence of the longitudinal effect of the built environment on children's physical activity, either through repeated exposure to the same built environment or through change in exposure to the built environment by moving from one neighbourhood to another (Daniels et al., 2021; Buck et al., 2019). Given changes in the built environment are generally small, studies of residential relocation may provide a more effective study design for understanding the causal impact of change in exposure to the built environment on children's physical activity behaviour (Drewnowski, 2020). This may also be dependent on the level of variation in built environment features within a particular study area. To our knowledge, no studies have examined to what degree: i) the built environment changes over time for children who do not move house ('stayers'); ii) children's exposure to the built environment changes when they move house ('movers'), and iii) changes to the neighbourhood built environment ('movers') or repeated exposure to the same built environment ('stayers') are longitudinally associated with changes in young children's physical activity behaviour. Such findings would provide important information to guide studies of the longitudinal effect of the built environment on children's physical activity and other health outcomes. For example, if between two timepoints children do not move house and the built environment does not change it would only be necessary to create spatial built environment variables for the first time point, saving considerable research resources.

An important consideration in unpacking the role of the changing neighbourhood built environment on young children's physical activity is the influence of socio-economic status (SES). A study investigating the socio-economic disparity in the built environment of 21 Australian cities by measuring liveability factors such as access to shops and services, dwelling density, street connectivity and access to public transport, found that more disadvantaged areas in larger cities had lower liveability scores than less disadvantaged areas (Giles-Corti et al., 2022). Efforts to improve the built environment may increase health inequity as more advantaged neighbourhoods have the economic and political influence to create environments which are more supportive of population health (Schulz and Northridge, 2004). For example, Hirsch et al. (2016) examined the socio-demographic characteristics of neighbourhoods experiencing improvements in walkability (e.g., land use mix, number of walkable destinations) in seven US cities and found evidence of greater improvement in more socio-economically advantaged areas. Further, Leng et al. (2023) found that more developed countries in the global north have had a steady growth of urban tree cover over the past two decades, helping to create more liveable neighbourhoods, which were driven by sustainable urbanisation trends and urban renewal efforts. This contrasts with declining urban tree cover trends in the less developed global south (Leng et al., 2023). To inform future studies, further research is needed to understand the interplay between the built environment and neighbourhood disadvantage.

This study examined longitudinal change in the built environment and the association between the built environment and neighbourhood disadvantage to inform future studies of the causal relationship between young children's exposure to their neighbourhood environment and their physical activity behaviour. The findings will help to inform the statistical analysis of subsequent research as part of the Built Environments and Child Health in Wales and Australian (BEACHES) Project, an international study examining the role of the built environment on child physical activity and obesity using multiple cohorts (Pedrick-Case et al., 2022). The first aim of this investigation was to describe changes in young children's neighbourhood built environments across three timepoints over eight years (2015–2023) for both 'stayers' and 'movers' using data from a BEACHES Project cohort - the PLAYCE cohort study (Christian et al., 2016, 2024). The second aim was to identify whether the attributes of young children's neighbourhood built environments differed depending on the SES of the neighbourhood.

2. Methods

2.1. Sample

The Play Spaces and Environments for Children's Physical Activity (PLAYCE) study cohort were recruited from early childhood education and care services across the Perth metropolitan area in Western Australia. Rolling recruitment and data collection was conducted over three timepoints; timepoint 1 (2015–18) when children were aged 2–5 years, timepoint 2 (2018–21) when children were aged 5–7 years and timepoint 3 (2022–23) when children were aged 7–9 years. Full details of the PLAYCE study methods (Christian et al., 2016, 2024) and participant flow charts (Adams et al., 2024; Christian et al., 2024) have been published.

A total of 384 children were excluded from the current study as they had incomplete socio-demographic data ($n = 258$), incomplete or missing built environment data ($n = 17$) or were a sibling, twin or triplet with the same residential address as a participant ($n = 109$), leaving 1534 children at timepoint 1. All participants were invited to participate in follow-up data collection at timepoints 2 and 3. The sample for this study included eligible children with a residential address that could be geocoded from which spatial data could be generated. Previous sensitivity analyses have been conducted with the PLAYCE cohort comparing sociodemographic characteristics of T1 and T2 participants (Adams et al., 2024; Christian et al., 2024). Representativeness of the cohort appears to have been maintained at timepoint 2 despite fewer respondents.

2.2. Built environment data

Home addresses of study participants were geocoded at each timepoint. At timepoints 2 and 3, children who had not moved house since the previous timepoint were identified as 'stayers' and those who moved house were identified as 'movers'.

Table 1 describes six measures of the built environment which have been identified in previous research as being associated with children's physical activity. While other attributes have been shown to be associated with physical activity, they were not included due to the limitations of obtaining comparable data over multiple timepoints. All measures were based on a 500 m and 1600 m road network service area from each child's home which were developed using ArcGIS 10.8.2 and ArcPro 3.2.0 geospatial software. These service areas represent a walkable distance for adults and were chosen as young children's movements around the neighbourhood are dependent on their parents (Bell et al., 2020).

Data layers for each built environment variable were temporally matched to the three timepoints of the PLAYCE cohort study as outlined in Table 1. For the current study, six built environment attributes (traffic exposure, intersection density, one-way nodes, public transport, residential density, and vegetation) were calculated and compared across three timepoints for children in the PLAYCE cohort study. Vegetation (tree cover) was based on medium and high vegetation classes in Nearmap AI's raster and vector products and segmented from high resolution aerial imagery using a proprietary semantic segmentation model (Nearmap, 2021). All other built environment variables were based on existing standardised measures (Christian et al., 2017; Villanueva et al., 2013) and selected as they have been shown in previous studies to be associated with older children's physical activity levels (Buck et al., 2019; Daniels et al., 2021; Jia et al., 2021) and are more likely to be amenable to change over time.

Table 1
Description of built environment variables.

Built environment variable	Measure[a]	Data source[a]	Year of built environment data layer		
			T1 (2015–18)	T2 (2018–21)	T3 (2022–23)
Low road traffic exposure	Proxy measure for traffic exposure measured by calculating the percentage of total length of roads within the participant's service area which are not main roads, i.e. access roads with a maximum volume of 3000 vehicles per day in built-up areas	Road network data from the Western Australian Land Information Authority (Landgate) and Functional Road Hierarchy Information from Main Roads Western Australia	2017	2020	2022
Street connectivity - Intersection density	Count of three-way (or more) intersections divided by the area (km^2) of the participant's service area	Road network data from the Western Australian Land Information Authority (Landgate)	2017	2020	2022
Street connectivity – One way nodes	Count of one-way nodes (cul-de-sacs) within the participant's service area	Road network data from the Western Australian Land Information Authority (Landgate)	2017	2020	2022
Public transport stops	Number of standard public transport stops (bus, rail) within the participant's service area	Western Australian Public Transport Authority	2017	2020	2022
Residential density (gross)	Number of residential dwellings per hectare of total land use area within the participant's service area	Australian Bureau of Statistics mesh block-derived	2016	2016	2021
Vegetation	Percent of tree cover within the participant's service area	Tree cover segmented from aerial imagery (Nearmap AI)	2016 raster data	2020 raster data	2023 vector data

[a] Existing standardised built environment measures (Christian et al., 2017; Duncan and Boruff, 2023; Nearmap, 2021; Villanueva et al., 2013).

2.3. Neighbourhood socio-economic status (SES)

Postcode-level data from the 2016 Socio-Economic Indexes for Areas (SEIFA) Index of Relative Socio-economic Disadvantage (IRSD) (Australian Bureau of Statistics, 2021a) was used to determine neighbourhood SES. The IRSD is calculated using a weighted combination of disadvantage variables including low income, low educational attainment, high unemployment, long-term health condition or disability, and one-parent families (Australian Bureau of Statistics, 2021a). The ABS assign a score between 1 and 100 to each postcode, where low scores signify lower socio-economic status. Scores are then divided into deciles. For the purposes of this study, each participant's residential postcode IRSD at T1 was further allocated a SES quintile.

2.4. Statistical analyses

Descriptive statistics of built environment attributes were calculated at timepoints 1 (T1), 2 (T2) and 3 (T3) for children who moved house (movers) and did not move house (stayers) between timepoints. Relative change was calculated for variables between timepoints and paired t-tests were performed to determine if there were significant mean differences in built environment variables for stayers and movers between timepoints 1 and 2, and stayers and movers between timepoints 1 and 3. A comparison of data for 'stayers' and 'movers' between timepoints 2 and 3 was not conducted because of the overlapping timeframe and it was not expected there would be any differences compared with timepoints 1 and 2, and 1 and 3. Relative change was calculated for variables between timepoints and paired t-tests were performed to determine if there were statistically significant mean differences in built environment variables for 'stayers' and 'movers' between timepoints 1 and 2, and 'stayers' and 'movers' between timepoints 1 and 3.

The T1 sample was stratified by neighbourhood SES into quintiles. Due to unequal variances and sample sizes between quintiles, Welch's ANOVA was conducted to determine if there was an overall difference in built environment variables between quintiles. Games-Howell post hoc tests determined which quintiles were significantly different to the reference category (quintile 5).

3. Results

At T1, just over half (52.3%) of the sample were boys with an average age of 3.3 years (Supplementary Table 1). Over half of the respondents had a tertiary degree (55.9%) and most lived in less socioeconomically disadvantaged neighbourhoods (32.7% in quintile 5). At T2, 69.0% of 'stayers' had a tertiary degree compared to 59.2% of 'movers', while 35.0% of 'stayers' compared to 31.0% of 'movers' were in the least socioeconomically disadvantaged quintile. Similarly, at T3, more 'stayers' had a tertiary degree (69.0%) compared to 'movers' (63.5%), however more 'movers' were in the least disadvantaged quintile (29.5%) compared to 'stayers' (22.5%).

Of the 174 children who moved house between T1 and T2, almost half (48.3%) moved within 5 km of their previous address. Of the 225 children who moved house between T1 and T3, 122 children (54.2%) moved within 5 km of their previous address. The residential addresses of the sample at T1 were mapped by postcode level socio-economic status (Fig. 1).

3.1. Change to built environment attributes for stayers and movers at T2 and T3

For stayers, there were significant increases in intersection density within 500 m (3.6%; p=<0.001) and 1600 m service areas (4.6%; p=<0.001), residential density at 500 m (5.6%; p=<0.001) and 1600 m service areas (6.0%; p=<0.001), one-way nodes at 1600 m service area (3.8%; p=<0.001), and vegetation cover at 500 m (4.43%; p=<0.001) and 1600 m service areas (4.14%; p=<0.001) between timepoints 1 and

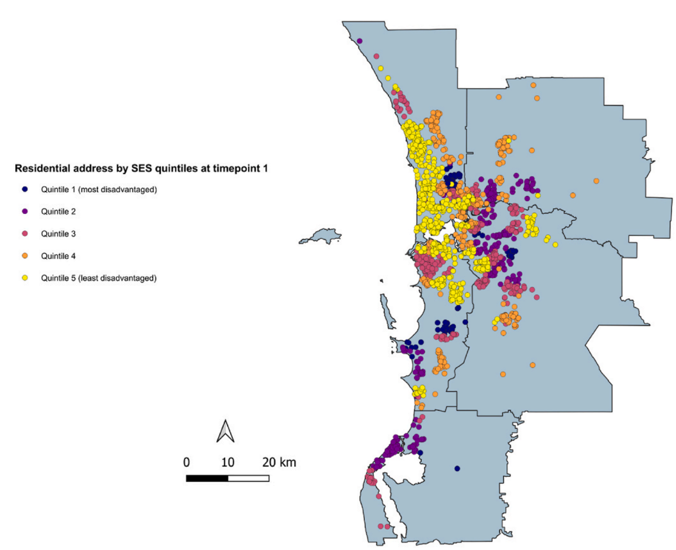

Fig. 1. Residential address by postcode level SES quintiles at timepoint 1.

Table 2
Change in built environment attributes for stayers at T2 and T3.

Built environment measure	T1 n = 469	T2 n = 469	T1-T2			T1 n = 323	T3 n = 323	T1-T3		
	Mean (SD)	Mean (SD)	Difference (SE)	Percentage Difference	p	Mean (SD)	Mean (SD)	Difference (SE)	Percentage Difference	p
500m service area										
Low road traffic exposure[a]	77.09 (17.70)	77.11 (17.47)	0.02 (0.22)	0.02%	0.908	77.08 (17.97)	76.57 (17.75)	−0.51 (0.07)	−0.66%	0.143
Intersection density[b]	78.00 (35.76)	80.77 (37.80)	2.77 (0.42)	3.55%	**<0.001**	77.08 (35.53)	79.98 (37.06)	2.15 (0.54)	2.79%	**<0.001**
One-way nodes[c]	2.66 (2.52)	2.62 (2.49)	−0.04 (0.05)	−1.50%	0.459	2.62 (2.58)	2.61 (2.52)	−0.01 (0.06)	−0.38%	0.802
Public transport[d]	3.70 (3.31)	3.75 (3.26)	0.05 (0.05)	1.35%	0.336	3.60 (3.36)	3.80 (3.29)	0.20 (0.07)	5.56%	**0.009**
Residential density[e]	9.41 (4.63)	9.94 (5.25)	0.53 (0.06)	5.63%	**<0.001**	9.53 (5.77)	10.04 (6.44)	0.51 (0.07)	5.35%	**<0.001**
Vegetation[f]	14.23 (8.34)	14.86 (8.25)	0.63 (0.10)	4.43%	**<0.001**	13.82 (8.18)	13.97 (7.22)	0.15 (0.14)	1.08%	0.304
1600m service area										
Low road traffic exposure[a]	69.39 (10.97)	69.36 (10.68)	−0.03 (0.10)	−0.04%	0.691	69.49 (10.99)	69.13 (10.57)	−0.36 (0.15)	−0.52%	**0.017**
Intersection density[b]	68.63 (25.99)	71.77 (27.49)	3.14 (0.25)	4.58%	**<0.001**	68.68 (26.44)	69.93 (27.68)	1.25 (0.35)	1.82%	**<0.001**
One-way nodes[c]	33.18 (16.78)	34.43 (17.41)	1.25 (0.22)	3.77%	**<0.001**	33.26 (17.49)	34.74 (18.16)	1.48 (0.29)	3.09%	**<0.001**
Public transport[d]	37.93 (22.74)	38.22 (21.51)	0.29 (0.22)	0.76%	0.184	38.48 (23.19)	40.00 (22.18)	1.52 (0.27)	3.95%	**<0.001**
Residential density[e]	8.30 (3.50)	8.80 (3.73)	0.50 (0.03)	6.02%	**<0.001**	8.30 (3.40)	8.76 (3.65)	0.46 (0.04)	5.54%	**<0.001**
Vegetation[f]	15.44 (7.07)	16.08 (7.01)	0.64 (0.08)	4.14%	**<0.001**	14.85 (6.54)	14.74 (5.80)	−0.11 (0.11)	−0.74%	0.356

T1 = 2016–17; T2 = 2016–20; T3 = 2020-22.
Bold p values are statistically significant.
[a] % roads that are not main roads.
[b] Count of 3-way or greater intersections/km.^{2}.
[c] Count of cul-de-sacs.
[d] Count of public transport stops.
[e] Count of residential dwellings per hectare.
[f] % of service area.

2 (Table 2). While these increases were statistically significant, they did not represent a practically significant difference. For example, 0.5 more residential dwellings per hectare would not lead to any noticeable impact on residential density.

Between timepoints 1 and 3, significant increases in intersection density at 500 m (2.8%; $p = 0.001$) and 1600 m (1.8%; $p = <0.001$) were also identified for stayers, as were increases in one-way nodes at 500 m (4.6%; $p = <0.001$) and 1600 m (1.8%; $p = <0.001$), public transport stops at 500 m (5.6%; $p = 0.009$) and 1600 m (4.0%; $p = <0.001$), residential density at 500 m (5.4%; $p = <0.001$) and 1600 m (5.5%; $p = <0.001$). Again, while statistically significant, these differences were not practically significant.

There were a fewer number of significant changes to the built environment for ‘movers’. Between timepoints 1 and 2, residential density significantly decreased by 9.2% ($p = 0.049$) at 500 m and vegetation increased by 9.1% at the 1600 m service area ($p = 0.040$) (Table 3). Public transport stops at the 500 m service areas decreased by 15.6% ($p = 0.027$) between timepoints 1 and 3 and residential density decreased by 8.8% ($p = 0.024$) at 500 m and 6.8% ($p = 0.021$) at the 1600 m service area. Again, while these results were statistically significant, the magnitude of changes would not have been a meaningful practical change in the built environment.

3.2. Built environment variation by neighbourhood SES at T1

Variation in the built environment between neighbourhoods of different SES at T1 is presented in Table 4. There were statistically significant differences in all built environment attributes between the reference quintile 5 (least disadvantaged SES) and at least one other SES quintile. While these differences were small for most attributes, there were some notable differences between the most and least socioeconomically disadvantaged quintiles. The most socio-economically disadvantaged quintile (quintile 1) had the lowest intersection density at 500 m (quintile 1: 66.2 vs. quintile 5: 77.2 intersections/sq km) and 1600 m (quintile 1: 57.9 vs. quintile 5: 70.9 intersections/sq km), highest public transport stops at 1600 m (quintile 1: 44.4 vs. quintile 5: 37.8) and the least vegetation at 500 m (quintile 1: 13.7% vs. quintile 5: 15.7%) and 1600 m (quintile 1 14.7% vs. quintile 5: 16.2%).

4. Discussion

This study examined the variation in the neighbourhood built environment over timepoints and across neighbourhood socio-economic status of PLAYCE study participants in Perth, Western Australia. For children who did not move house between timepoints there were very small but significant increases in residential density, intersection density, public transport stops, and vegetation. For movers, there were significant decreases in public transport stops at 500 m between timepoints 1 and 3 and residential density at both 500 m and 1600 m service areas.

Statistically significant differences in the built environment over time were identified for children who did and did not move house, however the changes were modest and did not represent practically important differences. For example, an increase of one or two intersections in a 1600 m service area would not realistically have an impact on the walkability of the neighbourhood and the physical activity behaviours of its residents. Due to the lack of change in spatial built environment variables over time, these measures only need to be created at one timepoint for future planned longitudinal research using the PLAYCE cohort, thereby saving considerable research resources.

While it was expected that the children who moved house would have greater changes to the built environment over time, this was not supported by the results. However, it should be noted that half of the movers relocated to within 5 km of their previous home and into a similar built environment. Future studies should consider when moving house at what distance there are meaningful changes to the built

Table 3
Change in built environment attributes for movers at T2 and T3.

Built environment measure	T1 n = 174	T2 n = 174	T1-T2			T1 n = 225	T3 n = 225	T1-T3		
	Mean (SD)	Mean (SD)	Difference (SE)	Percentage Difference	p	Mean (SD)	Mean (SD)	Difference (SE)	Percentage Difference	p
500m service area										
Low road traffic exposure[a]	75.55 (17.20)	76.74 (19.53)	1.19 (1.94)	1.58%	0.541	74.75 (18.79)	76.31 (18.49)	1.55 (1.48)	2.07%	0.294
Intersection density[b]	78.37 (39.04)	80.60 (44.40)	2.23 (3.57)	2.84%	0.534	78.86 (37.29)	78.41 (39.91)	−0.44 (2.89)	−0.56%	0.878
One-way nodes[c]	2.72 (2.41)	2.75 (2.59)	0.03 (0.26)	1.10%	0.911	2.76 (2.41)	2.64 (2.39)	−0.11 (0.22)	−3.98%	0.594
Public transport[d]	4.06 (3.81)	3.49 (3.68)	−0.57 (0.36)	−14.04%	0.117	4.18 (3.93)	3.53 (2.96)	−0.65 (0.29)	−15.55%	**0.027**
Residential density[e]	10.17 (5.12)	9.23 (4.65)	−0.94 (0.48)	−9.24%	**0.049**	10.17 (5.09)	9.27 (4.62)	−0.90 (0.39)	−8.85%	**0.024**
Vegetation[f]	14.39 (7.48)	15.29 (9.32)	0.90 (0.78)	6.25%	0.251	13.78 (6.82)	14.53 (7.58)	0.75 (0.59)	5.44%	0.211
1600m service area										
Low road traffic exposure[a]	69.30 (10.75)	69.27 (12.40)	−0.03 (1.06)	−0.04%	0.979	69.41 (11.30)	68.86 (11.39)	−0.55 (0.87)	−0.79%	0.527
Intersection density[b]	67.16 (22.70)	69.23 (26.43)	2.07 (2.10)	3.08%	0.326	69.30 (24.53)	66.77 (25.73)	−2.50 (1.84)	−3.61%	0.175
One-way nodes[c]	34.09 (18.25)	35.62 (21.08)	1.53 (1.87)	4.49%	0.414	34.74 (17.71)	33.82 (19.71)	−0.90 (1.63)	−2.59%	0.580
Public transport[d]	40.44 (23.63)	36.53 (23.03)	−3.91 (2.08)	−9.67%	0.061	39.92 (21.83)	37.68 (20.30)	−2.22 (1.46)	−5.56%	0.130
Residential density[e]	8.68 (3.66)	8.11 (3.67)	−0.58 (0.33)	−6.68%	0.084	8.80 (3.61)	8.20 (3.68)	−0.60 (0.26)	−6.82%	**0.021**
Vegetation[f]	15.21 (6.72)	16.60 (8.24)	1.39 (0.68)	9.14%	**0.040**	14.68 (5.83)	15.11 (6.07)	0.44 (0.43)	3.00%	0.312

T1 = 2016–17; T2 = 2016–20; T3 = 2020-22.
Bold p values are statistically significant.
[a] % roads that are not main roads.
[b] Count of 3-way or greater intersections/km.^{2}.
[c] Count of cul-de-sacs.
[d] Count of public transport stops.
[e] Count of residential dwellings per hectare.
[f] % of service area.

environment to impact children's physical activity levels. In addition, where sufficiently powered, stratifying analyses by stayers and movers would help to further understand the impact of changes in exposure to the built environment on children's physical activity.

It is important to identify differences in the socio-economic status of neighbourhood built environments as it may, in part, explain the negative relationship between children's physical activity levels and socio-economically disadvantaged neighbourhoods (Love et al., 2019). Once stratified by neighbourhood socio-economic status, significant differences in participants' neighbourhood built environment attributes were identified. The most socio-economically disadvantaged neighbourhood quintile had lower intersection density, more public transport stops, and higher residential density, reflecting that these neighbourhoods are in older areas with large block sizes and established public transport routes. While it is evident that there are SES differences between built environment characteristics, these results should be interpreted within the context of low-density cities similar to metropolitan Perth. For example, studies in higher density cities such as Singapore have found that children with higher socioeconomic status have less access to public transport, parks and open spaces (Tan, 2022). Future studies should consider stratifying by neighbourhood SES to better understand the complex relationship between the built environment and young children's physical activity in varied urban settings.

In addition to neighbourhood socio-economic status, other factors may be at play when determining the role of the built environment on young children's physical activity. Parental concerns about safety and poor environmental aesthetics may inhibit young children's physical activity through reduced play opportunities outside of the home (Nathan et al., 2023; Tappe et al., 2013). Moreover, lower income areas may already experience higher crime and poorly maintained neighbourhood facilities (Lovasi et al., 2009) which may further negatively influence parent perceptions of the built environment. A Western Australian study found that the longitudinal relationship between the built environment and recreational walking in adults was mediated by perceptions of attractiveness and safety of the neighbourhood (Christian et al., 2017), highlighting the importance of including perceived as well as objective measures of the built environment in longitudinal studies of the relationship between the built environment and physical activity in early childhood.

Several practical issues arose over the course of this study in acquiring consistent spatial data layers to create comparable built environment measures over timepoints. Generally, data collected by government authorities is not specifically for the purpose of research which limits its accessibility and useability (Hirsch et al., 2016; Geary et al., 2023). It is critical for researchers to build partnerships with data providers to ensure access to consistent and comparable data for longitudinal research to enable stronger evidence of the causal influence of the built environment on children's physical activity and other health outcomes. Despite the time-intensive nature of collecting and analysing built environment measures, this study provides insight into the way neighbourhoods change over time and allows further investigation into assessing the role of the built environment on young children's physical activity.

4.1. Strengths and limitations

This study characterised the neighbourhood environment during early childhood which is an understudied population group in built environment and health research. The findings of this research can be used to inform future studies on whether to create only one timepoint (e.g. baseline) of built environment data, to create built environment measures for every cohort timepoint and/or data driven approaches such as latent classes or profiles of the built environment. Strengths of this study include temporally matching data layers derived from different years to the PLAYCE cohort study survey timepoints (2015–18 timepoint 1; 2018–21 timepoint 2; 2022–23 timepoint 3). In addition,

Table 4
Built environment attributes by neighbourhood SES at timepoint 1.

	QUINTILE 1 (most disadvantaged SES) n = 98	QUINTILE 2	QUINTILE 3	QUINTILE 4	QUINTILE 5 (least disadvantaged SES) n = 516	*p*
		n = 266	n = 316	n = 338		
	Mean (SD)	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**	
500m service area						
Low road traffic exposure[a]	72.93 (18.09)	77.02 (18.79)	75.37 (17.50)	79.81 (20.10)*	75.06 (16.77)	**0.002**
Intersection density[b]	66.25 (23.44)*	69.40 (25.30)*	78.41 (40.40)	90.03 (44.98)*	77.16 (32.70)	<**0.001**
One-way nodes[c]	2.35 (2.02)	3.34 (2.58)*	2.62 (2.34)	2.41 (2.43)	2.71 (2.46)	<**0.001**
Public transport[d]	4.22 (3.19)	3.09 (2.95)*	4.02 (3.62)	3.59 (3.75)	3.76 (3.26)	**0.003**
Residential density[e]	10.39 (4.30)	8.53 (2.84)*	9.78 (3.98)	8.23 (4.17)*	9.30 (3.88)	<**0.001**
Vegetation[f]	13.66 (5.08)*	14.25 (6.71)	14.00 (7.78)*	10.96 (7.27)*	15.67 (8.19)	<**0.001**
1600m service area						
Low road traffic exposure[a]	66.91 (9.97)	68.63 (10.63)	68.68 (9.32)	71.66 (14.05)*	68.02 (9.96)	<**0.001**
Intersection density[b]	57.91 (15.93)*	61.06 (16.83)*	66.41 (27.51)	73.49 (29.31)	70.92 (22.08)	<**0.001**
One-way nodes[c]	32.00 (4.21)	39.19 (18.92)	33.72 (18.87)	28.30 (14.84)*	35.77 (17.71)	<**0.001**
Public transport[d]	44.43 (21.57)*	32.65 (16.85)*	41.89 (26.25)	35.16 (26.38)	37.85 (19.02)	<**0.001**
Residential density[e]	9.18 (4.21)	7.33 (2.10)*	8.33 (3.44)	8.23 (4.17)	8.35 (3.09)	<**0.001**
Vegetation[f]	14.68 (4.36)*	15.31 (4.81)	15.20 (6.73)	13.52 (6.24)*	16.18 (7.16)	<**0.001**

Quintiles are allocated by the Australian Bureau of Statistics using postcode-level SEIFA Index of Relative Socio-economic Disadvantage scores.

P values show an overall difference between quintiles. Bold p values are statistically different. The asterisk indicates if there is a statistically significant difference to Quintile 5 (reference value).

[a] % roads that are not main roads.

[b] Count of 3-way or greater intersections/km.[2].

[c] Count of cul-de-sacs.

[d] Count of public transport stops.

[e] Count of residential dwellings per hectare.

[f] % of service area.

built environment variables were calculated in the same way at each timepoint to enable change in the built environment to be captured accurately. However, given the built environment data layers were provided by external organisations (e.g. Western Australian Land Information Authority; Main Roads Western Australia), it is possible they may have not been created the same way for each year which would have contributed to measurement error and thus influenced the study findings.

A limitation of the study is that the findings can only be generalised to other low-density cities. The Perth metropolitan area, Western Australia has a population of over 2 million residents with a comparatively low population density of 360 people per square kilometre for capital cities of a similar size (ABS, 2015). Most of the urban area is occupied by sprawling suburbs with mostly single-family homes (ABS, 2021b). The built environment attributes included in this study are relevant to the urban form of other low-density cities such as some US cities. Other built environment variables relevant to young children, such as land use mix and park attributes like playground presence, were not included as data layers as they were not available for each of the three timepoints of the PLAYCE cohort. However, the built environment attributes chosen for this study were identified as more amenable to change, were relevant to young children who rely on their parents to move around the neighbourhood and were based on existing cross-sectional evidence of the built environment corelates of older children's physical activity. SES differences between neighbourhoods was only examined at baseline and not longitudinally, however this could be an area of future research. Changes to neighbourhood built environment attributes for children who moved more than once (i.e., between timepoints 1 and 2, and 2 and 3) were not included in this study but could be considered in future research.

5. Conclusion

This study characterised the built environment of young children in the PLAYCE cohort study over three timepoints from 2015 to 2023. Interestingly, there more statistically significant differences between timepoints in neighbourhood built environment attributes for children who stayed in the same residence compared to children who moved house, however the actual differences were not practically important. The most socio-economically disadvantaged neighbourhood quintile had greater exposure to traffic, lower intersection density, more public transport stops, and higher residential density compared to less disadvantaged quintiles.

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CRediT authorship contribution statement

Trina Robinson: Writing – original draft, Methodology, Formal analysis, Conceptualization. **Bryan Boruff:** Writing – review & editing, Methodology, Funding acquisition. **John Duncan:** Writing – review & editing, Methodology. **Kevin Murray:** Writing – review & editing, Methodology, Funding acquisition, Formal analysis. **Jasper Schipperijn:** Writing – review & editing, Methodology. **Andrea Nathan:** Methodology, Writing – review & editing. **Ben Beck:** Writing – review & editing, Methodology, Funding acquisition. **Gareth Stratton:** Writing – review & editing, Methodology, Funding acquisition. **Lucy J Griffiths:** Writing – review & editing, Methodology, Funding acquisition. **Richard Fry:** Writing – review & editing, Methodology, Funding acquisition. **Bridget Beesley:** Methodology, Writing – review & editing. **Hayley Christian:** Writing – review & editing, Methodology, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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