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Cross-sectional associations between high-deprivation home and neighbourhood environments, and health-related variables among Liverpool children

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ABSTRACT

Objectives: (1) To investigate differences in health-related, home and neighbourhood environmental variables between Liverpool children living in areas of high deprivation (HD) and medium-to-high deprivation (MD) and (2) to assess associations between these perceived home and neighbourhood environments and health-related variables stratified by deprivation group.

Design: Cross-sectional study.

Setting: 10 Liverpool primary schools in 2014.

Participants: 194 children aged 9–10 years.

Main outcome measures: Health-related variables (self-reported physical activity (PA) (Physical Activity Questionnaire for Older Children, PAQ-C), cardiorespiratory fitness, body mass index (BMI) z-scores, waist circumference), home environment variables: (garden/backyard access, independent mobility, screen-based media restrictions, bedroom media) and neighbourhood walkability (Neighbourhood Environment Walkability Scale for Youth, NEWS-Y).

Explanatory measures: Area deprivation.

Results: There were significant differences between HD and MD children's BMI z-scores ($p<0.01$), waist circumference ($p<0.001$) and cardiorespiratory fitness ($p<0.01$). HD children had significantly higher bedroom media availability ($p<0.05$) and independent mobility scores than MD children ($p<0.05$). MD children had significantly higher residential density and neighbourhood aesthetics scores, and lower crime safety, pedestrian and road traffic safety scores than HD children, all of which indicated higher walkability ($p<0.01$). HD children's BMI z-scores ($\beta=-0.29$, $p<0.01$) and waist circumferences ($\beta=-0.27$, $p<0.01$) were inversely associated with neighbourhood aesthetics. HD children's PA was negatively associated with bedroom media ($\beta=-0.24$, $p<0.01$), and MD children's PA was positively associated with independent mobility ($\beta=0.25$, $p<0.01$). MD children's independent mobility was inversely associated with crime safety ($\beta=-0.28$, $p<0.01$) and neighbourhood aesthetics ($\beta=-0.24$, $p<0.05$).

Conclusions: Children living in HD areas had the least favourable health-related variables and were exposed to home and neighbourhood environments that are

Strengths and limitations of this study

- To the best of our knowledge, this is the first UK study to explore the influence of neighbourhood characteristics on children's self-reported physical activity (PA) using the Neighbourhood Environment Walkability Scale for Youth (NEWS-Y) neighbourhood walkability survey.
- The Physical Activity Questionnaire for Older Children (PAQ-C) is a well-established and validated PA self-report tool, but responses may have been subject to social desirability biases, and its lack of equivalence to time spent in moderate-to-vigorous PA prohibited discussion of results in relation to public health PA guidelines.
- The findings of this study relate to a relatively small sample of children living in areas of medium-to-high deprivation in Liverpool, and so generalising the results to other locations should be done with caution.

unconducive to health-promoting behaviours. Less access to bedroom media equipment and greater independent mobility were strongly associated with higher PA in HD and MD children, respectively. Facilitating independent mobility and encouraging outdoor play may act as effective strategies to enhance PA levels and reduce sedentary time in primary school-aged children.

Health inequalities are defined as the differences in health status or in the distribution of health determinants between different population groups.[1] Health inequalities exist across England with children from highly deprived communities generally at risk of poorer health.[2] Ecological models of health behaviour postulate that multiple environmental influences such as the social environment, physical environment and public policies can be affected by deprivation.[3]

Such influences impact on lifestyle behaviours relating to being physically active, reducing sedentary time and eating nutritionally healthy foods, all of which are important to offset risk factors for cardiometabolic conditions that have their origins in early childhood.[4] [5] Prevention of disease and poor health are needed for children to reduce the risk of chronic disease later in life.[6]

Regular physical activity (PA) is important for the improvement and maintenance of children's musculoskeletal,[7] and psychological health,[8] and is also a modifiable component of obesity and cardiorespiratory fitness, both of which are inversely associated with cardiometabolic disease risk in children.[9–13] In line with other developed countries, the UK Government agencies highlight the need for children to accumulate at least 1 h of moderate to vigorous intensity of PA each day, and reduce time spent in sedentary behaviours.[14] Current UK PA prevalence data, however, suggests that most children fail to achieve PA guidelines, and that, though figures vary between measurement approaches, activity levels are often lowest among high-deprivation (HD) children.[15] [16] However, comparatively few studies use an area-level measure of deprivation, and reported associations between deprivation and children's PA have generally been based on data from the USA[17] [18] and Australia[19–21] which limits generalisation to children in the UK.

The home environment plays a key role in shaping children's health behaviours and, in particular, their PA.[22] Home environments that are conducive to health-promoting behaviours (eg, presence of garden/backyard and restrictions on sedentary time) are associated with higher levels of child PA[23–25] and reduced sedentary time.[26] [27]

Neighbourhood environments are also recognised as key determinants of children's PA[28] [29] and weight status.[30] Neighbourhood environments can influence the extent to which modes of PA, such as outdoor play and active travel, can be engaged in by children independent of adult supervision (ie, independent mobility).[31] [32] For example, children's outdoor play, which is associated with higher levels of PA[33–35] and healthy weight status,[36] is often restricted by parents in response to neighbourhood safety concerns.[37–39] Regardless of a child's gender, restrictive behaviours from parents are associated with lower PA levels.[40] [41] Moreover, restricting children's outdoor play, and limiting children to the home environment, is likely to result in children engaging in disproportionate levels of sedentary time,[42] consequently increasing risk of obesity,[43] reduced cardiometabolic health and compromised psychosocial wellbeing.[44]

Children residing in areas of HD are more likely to be exposed to neighbourhood and home environments that are unconducive to PA due to increased neighbourhood safety concerns,[18] [45] and a lack of home features such as gardens or backyards.[46] Liverpool is the sixth largest city in England and is ranked as the most-deprived,[47] with over 90% of Liverpool's 470 000 population living in areas of HD.[48] The disproportionate health inequalities of the city's inhabitants are reflected in the below average life expectancy of Liverpool adults, and the 23% obesity rates among children aged 10–11 years which exceed the national average of 18.9%.[48] Little though is known about the relationships between home and neighbourhood environments, and health variables and behaviours of children living in this deprived community. Further information on how these factors influence children's health could inform future health-promotion strategies designed to improve health outcomes in children from deprived communities. Moreover, stratifying analyses and investigating associations by indices of multiple deprivation (IMD) level may present a clearer picture as to potential target areas for future population-specific intervention studies. This study, therefore, is aimed (1) to investigate differences in health-related, home and neighbourhood environmental variables between Liverpool children living in areas of HD and medium-to-high deprivation (MD) and (2) to assess associations between these perceived home and neighbourhood environments and health-related variables stratified by deprivation group.

METHOD
Participants and setting
Participants were Liverpool school children aged 9–10 years. Of the 125 primary schools in Liverpool, 76 were provided with information regarding the study and were invited to participate. Eleven schools expressed an interest and 10 schools (13.6%) agreed to take part, of which seven were located in areas of HD.[47] All children (n=549) aged 9–10 years in participating schools received a survey pack which contained parent and child information sheets, consent and assent forms, a parental questionnaire, and medical screening form. Completed informed parental consent and child assent were returned from 217 children (39.5% response rate). The ethnic origin of the consenting children was 84.1% white, which reflects the ethnic demography of the city's school-age population. The data collection took place between January and April 2014.

Measures and procedures
Area-level deprivation
Area-level deprivation was calculated using the 2010 IMD.[47] The IMD is a UK Government measure comprising seven areas of deprivation (income, employment, health, education, housing, environment and crime). Deprivation scores were generated using the National Statistics Postcode Directory database from parent-reported home postcodes. Higher area deprivation was represented by higher IMD scores. The mean IMD score for England is 23.64, and the IMD cut-off value for the most nationally deprived tertile is 26.83,

which was lower than the IMD scores of 68% of the study sample. Therefore, a 50th centile IMD score of 35.63 was calculated for the sample, and one IMD median-split categorical variable was created to provide two groups to represent children living in areas of HD (median IMD score 49.76) or high-to-medium deprivation (MD) (median IMD score 22.86).

The research team visited schools to carry out anthropometric measurements, fitness assessments and administer questionnaires to children in classrooms. The children were informed that the questionnaires were not tests, and were asked to answer all questions as honestly as possible, not to confer with others, and to ask a researcher if they were unsure about any of the questions. Parental questionnaires were completed at home and returned to the school along with the consent forms.

Health-related variables
Physical activity and cardiorespiratory fitness
PA was assessed using the Physical Activity Questionnaire for Older Children (PAQ-C).[49] The PAQ-C is a valid and reliable measure of general PA levels,[50 51] and is considered a suitable tool for PA surveillance in young people.[52] The questionnaire comprises nine items assessing PA at various times of the week. Each statement is scored on a five-point scale ranging from low (1) to very high levels of activity (5), with the overall PAQ-C score calculated as the mean of the nine PA items.[49] Cardiorespiratory fitness (CRF) was assessed using the Sports Coach UK 20 m multistage shuttle run test (20mSRT).[53] Total number of completed shuttles was retained for analysis.

Anthropometrics
Stature and sitting height were measured to the nearest 0.1 cm using a portable stadiometer (Leicester Height Measure, Seca, Birmingham, UK). Leg length was calculated by subtracting sitting height from stature. Body mass was measured to the nearest 0.1 kg using calibrated scales (Seca, Birmingham, UK). BMI was calculated from height and weight as a proxy measure of body composition (kg/m^2), and BMI z-scores were assigned to each child.[54] Age-specific and sex-specific BMI cut points were used to classify children as normal weight or overweight/obese.[55] Gender-specific regression equations[56] were used to predict children's age from peak height velocity. This calculation was used as a proxy measure of biological maturation. Waist circumference was measured at the midpoint between the bottom rib and the iliac crest to the nearest 0.1 cm using a non-elastic measuring tape (Seca, Birmingham, UK). All measurements were taken by the first author and a research assistant using standard procedures.[57]

Home environment
Access to sedentary devices was assessed through children responding to three separate survey questions asking whether they had access in their bedroom to (1) a television, (2) a computer, (3) a games console (yes/no responses).[58] Responses were summed (range 0–3) with higher scores representing greater bedroom media availability. Sedentary behaviour restriction was assessed through parents reporting how frequently they restricted their children from viewing TV, playing computer games, and using a computer or tablet. Five response options were available: never (1), rarely (2), sometimes (3), often (4), very often (5), and a composite score was generated using the sum of the three items (range 3–15).[59] To assess independent mobility, parents reported how frequently their child was allowed to play outdoors anywhere within the neighbourhood, walk or cycle to friends' houses, and play outdoors after dark. Response options were: never (1), rarely (2), sometimes (3), often (4), very often (5), and a composite score was generated using the sum of the three items (range 3–15).[59] Parents reported whether children had access to a garden or backyard at home (yes/no responses).

Neighbourhood environment
The Neighbourhood Environment Walkability Scale for Youth (NEWS-Y)[60] was used to assess parental perceptions of neighbourhood design features that may support young people's active neighbourhood recreation and transportation. The 67-item instrument has demonstrated acceptable to good test–retest reliability (ICC=0.56–0.87)[60] and has been used previously in child PA research.[61] The NEWS-Y is organised into nine subscales representing land-use mix-diversity, neighbourhood recreation facilities, residential density, land-use mix-access, street connectivity, walking/cycling facilities, neighbourhood aesthetics, pedestrian and road traffic safety, and crime safety. Items were averaged with higher scores denoting higher walkability. Higher neighbourhood scores indicated a more walkable environment for all items except pedestrian and road traffic safety, and crime safety items, where higher scores indicated lower walkability.[60] An overall neighbourhood environment score was also generated from the sum of z-scores for each of the nine.

ANALYSES
Survey packs were initially checked for missing responses, then scored following validated procedures for each survey. Where participants had less than one-third of missing responses to a composite variable, these were imputed with the variable mean score (N=7), and where there were more than one-third of missing responses to a composite variable, these were coded as missing. This imputation approach has been used before in previous PA studies involving children.[62] Dependent variables were health-related variables (PAQ-C, CRF, BMI z-scores, waist circumference), home environment variables: (garden access, independent mobility, screen-based media restrictions, bedroom media) and NEWS-Y

scores (neighbourhood walkability). The independent variable was IMD group. Preliminary analyses highlighted that there were no interactions between IMD groups and gender and so girls and boys were grouped together for the main analyses. To analyse study aim 1, analysis of covariance (ANCOVA) tests assessed IMD group differences in health-related variables, adjusted for CRF (BMI z-score and waist circumference analysis), BMI z-score (CRF analysis) and somatic maturation (PAQ-C analysis); χ^2 with OR as a measure of effect examined IMD group differences in garden/backyard access. Multivariate ANCOVA (MANCOVA) assessed IMD group differences in home and neighbourhood environment variables, adjusted for age. Cohen's d values were calculated as a measure of effect size for ANCOVA, MANCOVA and χ^2 tests. To address study aim 2, and test for differences in relationships between the IMD groups, linear regression analyses stratified by IMD group examined associations between home and neighbourhood environments and health-related variables (BMI z-score, waist circumference, fitness, PAQ-C). Independent mobility was also used as a dependent variable in a further linear regression model to explore its associations with the neighbourhood environment. For both linear regression analyses, simple associations were first explored using correlations, and significant predictor variables were retained and entered into the final models guided by a socioecological framework of active living.[63] All analyses were conducted using SPSS V.20 (SPSS Inc, Chicago, Illinois, USA).

RESULTS

Of the 217 children who returned written parental informed consent and participant assent, six participants were not present on the day of testing, and a further 17 children had incomplete data, due to either partially completed questionnaire items or not taking part in anthropometric and/or fitness assessments. Thus, results were available from 194 children (107 girls) (35.3% response rate), of which 169 children (87 girls) (30.8%) had complete data. The descriptive characteristics of the participants are presented in table 1. There were no significant differences between children included in analyses and those excluded.

Objective 1

There were significant differences between HD and MD children's BMI z-scores (p<0.01, d=0.3), waist circumference (p<0.001, d=0.3) and CRF (p<0.01, d=0.3; table 2).

Table 1 Characteristics of the study population (N=194)

Variable	HD, mean (±SD) or %			MD, mean (±SD) or %		
	All (N=98)	Boys (N=42)	Girls (N=56)	All (N=96)	Boys (N=45)	Girls (N=51)
Age (years)	10.00 (0.32)	10.04 (0.31)	9.97 (0.32)	9.92 (0.29)	9.91 (0.28)	9.93 (0.29)
Height (cm)	140.00 (7.38)	142.17 (6.24)	138.38 (7.80)	138.21 (7.15)	138.79 (7.32)	137.71 (7.02)
Body mass (kg)	36.67 (9.07)	38.54 (8.24)	35.28 (9.49)	33.30 (7.41)	33.02 (6.09)	33.55 (8.46)
BMI (kg m²)	18.53 (3.47)	18.98 (3.41)	18.20 (3.52)	17.30 (2.77)	17.01 (1.92)	17.54 (3.34)
BMI z-score	0.53 (1.29)	0.84 (1.30)	0.30 (1.25)	0.10 (1.17)	0.19 (0.92)	0.01 (1.36)
Weight status						
Overweight/obese (%)	33.7	35.7	32.1	15.6	6.7	23.5
Waist circumference (cm)	65.05 (8.44)	67.75 (8.59)	63.02 (7.81)	62.60 (6.72)	61.60 (6.05)	63.48 (7.21)
Maturity offset (y)	−2.54 (0.92)	−3.39 (0.44)	−1.90 (0.60)	−2.74 (0.93)	−3.58 (0.44)	−2.00 (0.52)
Deprivation score	51.27 (12.88)	53.75 (13.05)	49.42 (12.55)	22.02 (8.16)	21.13 (8.28)	22.81 (8.05)
CRF	35.14 (18.74)	44.02 (20.40)	28.48 (14.27)	41.28 (19.60)	52.42 (19.06)	31.45 (14.14)
PAQ-C	3.45 (0.70)	3.46 (0.69)	3.44 (0.71)	3.46 (0.70)	3.68 (0.70)	3.26 (0.65)
Bedroom media	1.39 (1.04)	1.31 (1.14)	1.46 (0.96)	1.75 (1.02)	1.64 (1.09)	1.84 (0.95)
Sedentary behaviour restriction	9.33 (2.81)	9.42 (3.34)	9.27 (2.34)	9.56 (1.97)	9.500 (2.30)	9.60 (1.67)
Independent mobility	7.19 (2.78)	7.23 (2.61)	7.16 (2.94)	6.21 (2.62)	6.32 (2.80)	6.11 (2.48)
Land-use mix-diversity	2.97 (0.67)	2.99 (0.66)	2.96 (0.68)	3.00 (0.69)	3.12 (0.69)	2.90 (0.68)
Recreation facilities	2.35 (0.60)	2.47 (0.63)	2.25 (0.56)	2.39 (0.49)	2.42 (0.50)	2.36 (0.49)
Residential density	83.12 (25.39)	85.90 (27.73)	80.77 (23.26)	96.17 (21.80)	94.29 (22.98)	97.77 (20.86)
Land-use mix-access	3.13 (0.47)	3.09 (0.49)	(3.16 (0.45)	3.25 (0.38)	3.30 (0.36)	3.20 (0.39)
Street connectivity	2.88 (0.69)	2.88 (0.71)	2.88 (0.68)	2.92 (0.54)	3.02 (0.57)	2.83 (0.51)
Walking/cycling facilities	2.94 (0.53)	2.91 (0.58)	2.96 (0.48)	3.04 (0.54)	3.06 (0.51)	3.02 (0.56)
Neighbourhood aesthetics	2.05 (0.75)	2.00 (0.73)	2.10 (0.77)	2.93 (0.62)	2.90 (0.64)	2.95 (0.61)
Pedestrian and road traffic safety	2.66 (0.43)	2.60 (0.45)	2.71 (0.41)	2.45 (0.43)	2.36 (0.41)	2.52 (0.44)
Crime safety	2.96 (0.69)	2.81 (0.81)	3.07 (0.57)	2.59 (0.56)	2.59 (0.49)	2.59 (0.61)
Walkability score	−0.10 (3.35)	−0.32 (3.66)	0.08 (3.10)	0.16 (2.98)	0.40 (2.68)	−0.04 (3.22)

BMI, body mass index; CRF, cardiorespiratory fitness; HD, high deprivation; IMD, indices of multiple deprivation; MD, medium deprivation; PAQ-C, Physical Activity Questionnaire for Older Children.

Table 2 ANCOVA of health-related variables by deprivation group, adjusted for CRF (BMI z-score and waist circumference analysis), BMI z-score (CRF analysis) and somatic maturation (PAQ-C analysis)

Variable	HD mean (95% CI) (N=98)	MD mean (95% CI) (N=96)	p Value	d
BMI z-score	0.49 (0.25 to 0.73)	0.14 (−0.10 to 0.39)	**0.002**	0.4
Waist circumference	64.73 (63.25 to 66.22)	62.92 (61.42 to 64.42)	**<0.001**	0.3
CRF	35.89 (32.13 to 39.65)	40.52 (36.72 to 44.32)	**0.002**	0.3
PAQ-C	3.46 (3.32 to 3.60)	3.45 (3.31 to 3.59)	0.22	0.0

ANCOVA, analysis of covariance; BMI, body mass index; CRF, cardiorespiratory fitness; d, effect size; HD, high deprivation; MD, medium deprivation; PAQ-C, Physical Activity Questionnaire for Older Children.

With regard to home environment variables, HD children had significantly higher bedroom media availability (p<0.05, d=0.4) and independent mobility scores than MD children (p<0.05, d=0.4). The odds of MD children having garden or backyard access were greater than the odds of HD children having it (OR=4.88; 95% CI 2.28 to 10.43 p<0.001, d=0.7; table 3). MD children had significantly higher residential density (p<0.01, d=0.6) and neighbourhood aesthetics scores (p<0.001, d=1.3), and lower crime safety (p<0.001, d=0.7) and pedestrian and road traffic safety scores (p=0.001, d=0.5) than HD children, all of which indicated higher walkability (table 4).

Objective 2

Linear regression analysis of the health-related variables demonstrated a significant inverse association between neighbourhood aesthetics and HD children's BMI z-scores (β=−0.29, p<0.01), and waist circumferences (β=−0.27, p<0.01; table 5). HD children's PAQ-C scores were negatively associated with bedroom media (β=−0.24, p<0.01), and MD children's PAQ-C scores were positively associated with independent mobility (β=0.25, p<0.01). MD children's independent mobility was inversely associated with crime safety (β=−0.28, p<0.01) and neighbourhood aesthetics (β=−0.24, p<0.05).

DISCUSSION

This study aimed (1) to investigate differences in health-related, home and neighbourhood environmental variables between Liverpool children living in areas of HD and MD and (2) to assess associations between these perceived home and neighbourhood environments and health-related variables stratified by deprivation group. Results indicated differences in health-related variables between children living in HD and MD areas. Moreover, parents' perceptions of neighbourhood walkability were associated with HD children's BMI and waist circumference (HD), and MD children's independent mobility (MD).

Higher waist circumference and overweight prevalence rates were observed among the HD children compared with their MD peers, which is consistent with previous research.[30] If compared with children living in low deprivation areas, these differences may have been more pronounced[64] given that the majority of children in the present study lived in highly deprived areas. It is suggested that these differences in body weight are significantly influenced by lower socioeconomic conditions that are typically prevalent in HD areas.[65] Limited access to adequate parks, playgrounds and recreational facilities in highly deprived areas may reduce opportunities for PA and consequently increase the risk of higher weight status.[66] However, as no significant differences were found in PA or perceived recreational provision between HD children and MD children, these differences in waist circumference and weight status may also be related to other factors not examined in this study such as dietary intake.[46 67] The combined effect of PA and dietary behaviour on weight status though is highly complex and not well understood.[68] Indeed, healthy behaviours (ie, regular PA) may compensate for unhealthy ones (ie, poor diet) which would offer some explanation for the inconsistency across studies. Further research examining the concurrent effect of PA and diet on weight status by deprivation is warranted.

Neighbourhood aesthetics were inversely associated with waist circumference and BMI z-scores. Parents of children living in less aesthetically pleasing neighbourhoods (ie, limited green spaces, high volumes of street litter and graffiti) are likely to perceive the

Table 3 MANCOVA of home environment variables by deprivation group, adjusted for age

Variable	HD mean (95% CI) or % (N=88)	MD mean (95% CI) or % (N=88)	p Value	d
Garden/backyard	40.2% OR=4.88 (2.28 to 10.43)	59.8%	**<0.001**	0.7
Sedentary behaviour restriction	9.34 (8.82 to 9.85)	9.56 (9.05 to 10.07)	0.55	0.1
Bedroom media	1.65 (1.43 to 1.86)	1.25 (1.03 to 1.47)	**0.01**	0.4
Independent mobility	7.18 (6.62 to 7.75)	6.21 (5.65 to 6.77)	**0.02**	0.4

d, effect size; HD, high deprivation; MD, low deprivation; MANCOVA, multivariate analysis of covariance.

Table 4 MANCOVA of neighbourhood environment variables by deprivation group, adjusted for age

Variable	HD mean (95% CI) (N=82)	MD mean (95% CI) (N=87)	p Value	d
Land-use mix-diversity	2.99 (2.84 to 3.14)	2.99 (2.85 to 3.14)	0.96	0.0
Recreation facilities	2.35 (2.23 to 2.47)	2.37 (2.26 to 2.49)	0.76	0.1
Residential density	82.04 (76.97 to 87.10)	96.45 (91.53 to 101.37)	**<0.001**	0.6
Land-use mix-access	3.17 (3.08 to 3.25)	3.24 (3.16 to 3.33)	0.22	0.2
Street connectivity	2.91 (2.77 to 3.04)	2.93 (2.80 to 3.05)	0.87	0.0
Walking/cycling facilities	2.94 (2.83 to 3.06)	3.03 (2.92 to 3.14)	0.31	0.2
Neighbourhood aesthetics	2.04 (1.89 to 2.19)	2.92 (2.77 to 3.06)	**<0.001**	1.3
Pedestrian and road traffic safety	2.66 (2.56 to 2.75)	2.44 (2.35 to 2.53)	**0.001**	0.5
Crime safety	3.01 (2.87 to 3.14)	2.59 (2.46 to 2.72)	**<0.001**	0.7
NEWS-Y score	−0.10 (−0.79 to 0.59)	0.61 (−0.51 to 0.83)	0.59	0.1

d, effect size; HD, high deprivation; MD, medium deprivation; NEWS-Y, Neighbourhood Environment Walkability Scale for Youth.

neighbourhood environment as an unsafe area for their child to be alone in, and in turn, place greater restrictions on their outdoor PA[69] which may lead to increased sedentary time indoors, and reduced energy expenditure. Grafova[70] used interviewer observation to investigate associations with neighbourhood aesthetics and reported that children living in neighbourhoods with greater physical disorder in terms of litter and building upkeep were more likely to have a higher BMI than children living in more aesthetically pleasing neighbourhoods. Conversely, Evenson et al[71] found no relationship between US girls' BMI and perceptions of their neighbourhood as aesthetically pleasing. These results were based on adolescent girls' perceptions rather than parents', and weight status was assessed using BMI rather than waist circumference and BMI z-score. This heterogeneity in methods and definitions used to assess environmental perceptions and weight status between studies is a key reason for such inconsistencies throughout the literature.[72 73]

While favourable aesthetics (eg, less noise and well-maintained recreational areas) may improve children's enjoyment and satisfaction of outdoor neighbourhood play and, in turn, contribute to enhanced PA levels, the present study found no association between neighbourhood aesthetics and children's self-reported PA, and thus, concurs with previous studies.[74 75] Children residing in less aesthetically pleasing neighbourhoods may simply become used to its aesthetic features, and so will not be discouraged from engaging in PA there.[76] Recent US and European studies have reported both positive[69] and negative[77] associations between neighbourhood aesthetics and objectively measured child PA. Associations are known to differ between study area and also between objective and self-report PA measures.[78 79] Our findings further demonstrate the inconsistent effect of neighbourhood aesthetics on children's PA, and reinforce the need for further research using standardised methodologies. In particular, adopting standardised environmental measures in future research will improve study comparisons and build evidence for environmental investment and policy change.[29]

In agreement with recent longitudinal research,[22 80] home environmental factors (ie, independent mobility and media equipment availability) were more strongly associated with both HD and MD children's PA relative to neighbourhood environmental factors, though associations differed between IMD groups. The findings of this study suggest that home environmental factors are potentially more important targets than features of the built environment for future interventions aimed at increasing PA levels in UK children. We observed no significant associations between neighbourhood environment and children's PA, which is consistent with the findings of others.[65] Evidence supporting the influence of environmental factors, particularly walkability and crime-related safety, is variable due to non-standardised definitions of environmental factors and disparities in findings between countries which is a key issue for neighbourhood environments research.[74 81]

For HD children, greater bedroom media availability was associated with less self-reported PA. This supports a recent study where increased access to bedroom screen-media equipment was associated with less objectively assessed light and moderate-vigorous PA.[82] These findings indicate that the home media equipment environment may have potent negative behavioural effects, especially for HD children, by providing a greater opportunity to engage in sedentary pursuits.[27] Moreover, it may well increase children's exposure to unhealthy food marketing which is associated with higher unhealthy food intake and BMI,[83 84] although dietary factors were not within the scope of this study. Consistent with previous findings, children living in areas of HD had greater access to bedroom media equipment compared with children living in MD areas.[36] This apparent paradox between HD and high access to relatively expensive media equipment among Liverpool children has been reported previously.[85] Screen-based activities may be appealing to HD children who have less opportunity to participate in more expensive leisure activities.[86] Conversely, HD children's parents in this study reported greater concerns about neighbourhood safety (ie, greater fear of crime and road traffic safety) relative to

Table 5 Multiple regression analyses of health and neighbourhood related variables stratified by IMD group

Variable	Predictor	HD			MD		
		B (95% CI)	SE	β	B (95% CI)	SE	β
BMI z-score	Constant	1.50 (0.74 to 2.25)	0.38	–	0.72	0.58	–
	Neighbourhood aesthetics	–0.50 (–0.85 to –0.15)**	0.18	–0.29	–0.21 (–0.60 to 0.17)	0.19	–0.12
Waist circumference	Constant	71.64 (66.73 to 76.55)	2.47	–	62.82 (56.18 to 69.45)	3.34	–
	Neighbourhood aesthetics	–3.10 (–5.38 to –0.83)**	1.15	–0.27	–0.01 (–2.23 to 2.21)	1.12	–0.00
PAQ-C	Constant	3.75 (3.23 to 4.26)	0.26	–	3.20 (2.73 to 3.66)	0.23	–
	Bedroom media	–0.17 (–0.30 to –0.04)**	0.07	–0.24	–0.12 (–0.26 to 0.01)	0.07	–0.181
	Independent mobility	0.03 (–0.03 to 0.08)	0.03	0.10	0.07 (0.01 to 0.12)**	0.03	0.25
Independent mobility	Constant	9.87 (6.81 to 12.93)	1.54	–	12.60 (8.78 to 16.41)	1.92	–
	Neighbourhood aesthetics	–0.35 (–1.12 to 0.43)	0.39	–0.09	–0.97 (–1.81 to –0.14)**	0.42	–0.24
	Crime safety	–0.62 (–1.43 to 0.20)	0.41	–0.15	–1.4 (–2.32 to –0.38)**	0.49	–0.28

*$p \leq 0.05$; **$p \leq 0.01$; ***$p \leq 0.001$.
B, unstandardised β coefficient; BMI, body mass index; HD, high deprivation; IMD, indices of multiple deprivation; MD, medium deprivation; PAQ-C, Physical Activity Questionnaire for Older Children; β, standardised β coefficient.

MD children's parents. Thus, it is possible that the HD children were afforded relatively greater access to media devices to keep them occupied indoors, which was perceived as a safe environment.[87]

MD children who experienced fewer restrictions on their outdoor play and independent mobility reported higher levels of PA in comparison with MD children who experienced greater restrictions on their outdoor play. This is consistent with positive associations reported previously between independent mobility and PA in Canada,[88] Australia[35 89] and the UK.[90 91] Children with higher levels of independent mobility are likely to play outside and travel actively around the neighbourhood with friends frequently compared with children who face restrictions on their outdoor play and are driven to school, friends' houses, or structured activities.[92 93] Stone *et al*[88] found that children who were granted at least some independent mobility had more positive PA profiles across the school week, over the weekend, and during the after-school period than children who faced independent mobility restrictions.

HD children reported higher levels of independent mobility relative to MD children. Despite parents of HD children reporting less favourable walking environments, their children had fewer restrictions placed on their outdoor play. These counter-intuitive findings concur with previous research reporting greater outdoor play prevalence among HD children relative to MD children.[94 95] Parental neighbourhood safety concerns are less likely to affect the independent mobility levels of UK children living in HD neighbourhoods, as these children are less likely to be sports club members, due to financial costs of membership,[96] and may also have no garden or backyard to play in.[46] In agreement with this view and that of recent research,[97] we found that MD children were 4.88 times more likely to have access to a garden or backyard than HD children. Furthermore, more deprived residential areas typically have lower street connectivity, which although associated with lower walkability, may also reduce traffic volumes, providing safer places for children to play.[69]

Parents of MD children were more likely to allow their children to play outdoors if they perceived the neighbourhood as safe, which is consistent with previous studies.[37 39 70 98] Foster and colleagues[99] found that parental fear of strangers was inversely associated with children's independent mobility, regardless of whether the social and built environment was supportive of children's PA. A high child presence around the neighbourhood is thought to reduce parental safety concerns and generate an acceptance among parents that it is socially accepted to let children play out in the neighbourhood, resulting in increased independent mobility.[99–101] Increasing children's independent mobility to play outdoors in the neighbourhood environment with friends, rather than restricting children to the home environment, has the potential to reduce sedentary time[102] and increase additional time for PA.[42 91 103] Further research

is warranted to explore the intertwined relationship between parental neighbourhood perceptions, social norms and children's independent mobility.

HD home environments provided more opportunities for sedentary behaviour and less opportunity for PA. There were, though, fewer parental restrictions placed on HD children's PA in the neighbourhood environment, despite parents of HD children reporting less favourable walking environments. Moreover, parental perceptions of the neighbourhood environment related differently to PA outcomes in children of this age, with children living in more aesthetically pleasing and safer neighbourhoods afforded more autonomy over their outdoor play. Neighbourhood environment factors including aesthetics, proximity to recreational facilities, and street design are all particularly difficult factors to alter and to assess their efficacy regarding PA behaviour change.[104] Conversely, home environmental factors such as independent mobility, parental PA encouragement, and sedentary behaviour restrictions are much more modifiable. Facilitating independent mobility and encouraging outside play may serve as an effective strategy to enhance daily PA levels and reduce sedentary time in primary school-aged children,[35 41] particularly among those not engaged in structured sport participation.[105] Greater understanding of children's perceptions of the social and built environment, and how these factors influence levels of active play and travel would help with future intervention design. Our findings also highlight the importance of understanding parental environmental perceptions given parents' gate-keeping role with respect to children's PA. Future formative research exploring parents' perceptions regarding health-promoting neighbourhoods as well as methods to encourage specific types of parent PA support and independent mobility to promote child PA would be valuable, and could inform future intervention strategies.[106 107]

The use of self-reported PA and neighbourhood environment data was a limitation of this study. The PAQ-C though, is a well-established and validated tool which continues to be recommended in youth PA research.[52 108 109] The survey may have been subject to social desirability biases and its lack of equivalence to time spent in moderate-to-vigorous PA prohibited discussion of results in relation to public health PA guidelines. The NEWS-Y survey records parental neighbourhood perceptions and as such may also be open to bias from respondents. It is, though, a comprehensive tool to assess the neighbourhood environment, which has previously been shown to have acceptable reliability and to be significantly correlated with PA in youth.[60] The cross-sectional study design of this study does not allow for causality to be determined, and the findings are generalisable only to children living in areas of medium-to-high deprivation in Liverpool. Deprivation classifications were based on area-level measures which reflect a range of deprivation markers, but may not have accurately reflected the actual deprivation level of all participating families. Moreover, the relatively small sample size and low participant response rate may have biased results, for example, active participants may have been more likely to agree to take part in the study. Despite these limitations, the findings add to the growing body of literature regarding the effects of the home and neighbourhood environment on children's activity behaviours. Study strengths include the use of a comprehensive socioecological conceptual framework to underpin the study, and a collection of validated measures to assess health-related variables and parent environmental perceptions. Moreover, to the best of our knowledge, this is the first UK study to explore the influence of neighbourhood characteristics on children's self-reported PA using the NEWS-Y survey. Replication of these methods in other cities may well provide opportunity to generate a UK-wide representation of factors explored in this study. Food intake is also strongly related to anthropometric variables, but was not explored in this study, and should be considered in future studies.

In summary, children living in the most-deprived areas of Liverpool appear to be at greatest risk of unfavourable health-related variables, and are exposed to home and neighbourhood environments that are not conducive to health-promoting behaviours. These findings indicate that children living in highly deprived areas represent an important target group for future interventions designed to promote children's PA. Additional research is warranted to inform future interventions to improve the home and neighbourhood environments of UK children living in deprived residential areas. Home environmental factors were more strongly associated with self-reported PA relative to neighbourhood factors, but the magnitude of these associations varied between deprivation groups. The study demonstrated that having less access to bedroom media equipment and greater independent mobility was strongly associated with higher PA. Facilitating independent mobility and encouraging outdoor play may act as an effective strategy to enhance daily PA levels and reduce sedentary time in children aged 9–10 years. Specific environmental modifications, such as improving neighbourhood aesthetics and crime safety may influence parents in respect of their decisions to grant children autonomy to play in the neighbourhood environment. Parents often perceive a 'trade-off' between ensuring children's safety and fostering their independent mobility.[110] Exploring parents' further views and perceptions towards children's PA and outside play via formative exploratory research may serve as an effective approach to inform the design, recruitment and implementation of future child PA interventions.

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