**What is the association between healthy weight in 4 to 5-year-old children and spatial access to purposefully constructed play areas?**

**Abstract**

**Background:** Childhood obesity is a global issue. Understanding associated factors is essential in designing interventions to reduce its prevalence. There are knowledge gaps concerning the leptogenic potential of play areas for very young children and particularly whether there is an association between levels of childhood obesity and play area quality.

**Methods:** A cross-sectional observational study was conducted to investigate whether spatial access to play areas had an association with healthy weight status of 4 to 5-year-old children. Data from the English National Childhood Measurement Programme 2012/13 was used to measure healthy weight status and a geographic information system was used to calculate (a) the number of purposefully constructed play areas within 1km (density), and (b) the distance to nearest play area (proximity), from child’s residential postcode. A play area quality score was included in predictive models. Multilevel modelling was used to adjust for the clustering of observations by school. Adjustment was also made for the effects of gender and deprivation.

**Results:** 77% of children had a healthy weight status (≥2nd and <85th centile). In a fully adjusted multilevel model there was no statistically significant association between healthy weight status and density or proximity measures, with or without inclusion of a play area quality score, or when accounting for the effects of gender and deprivation.

**Conclusions:** Among 4 to 5-year-old children attending school, there was no association between healthy weight status and spatial access to play areas. Reasons may include under-utilisation of play areas by reception age children, their minimal leptogenic influence or non-spatial influences affecting play area choice.

**Background**

Associations between childhood obesity and adult obesity in an individual’s life-course, and the co-morbid conditions linked to both are well documented (Albright, 2008). Childhood overweight and obesity is recognised by the World Health Organisation as a serious global problem with an estimated 41 million children under the age of 5 years affected worldwide (World Health Organisation, 2016). In England, all school children have their weight measured as part of the National Childhood Measurement Programme (NCMP) during their first year of school attendance (age 4 to 5 years) and again at age 10 to 11 years. Prevalence of childhood obesity has increased in England with approximately a fifth of 4 to 5-year-old children and a third of 10 to 11-year-old children currently overweight or obese (Health and Social Care Information Centre, 2015). Understanding factors associated with childhood obesity is paramount in designing interventions that may reduce its prevalence within the population.

In this context, research on childhood obesity has often focused on the influences of the food environment, both at home, school and in the community (Papas *et al.*, 2007). Fewer studies have looked specifically at the association of physical activity and/or childhood obesity and even fewer at the association with access to purposefully constructed play areas or playgrounds. Such environmental assets might be expected to lead to increased physical activity in children (Sallis *et al.*, 2000) and be a protective factor against developing childhood obesity. The WHO highlights the importance of adequately provisioned public spaces to allow children to be physically active (World Health Organisation, 2016). Public play areas are generally free to use, and modern design and manufacturing have been able to enhance their appeal and play value. Play areas also benefit children by being fun and interactive (Potwarka, Kaczynski and Flack, 2008) and stimulate social development and locomotor skills (Quigg *et al.*, 2012).

To date the limited, largely North American, evidence base on the leptogenic influence of play areas has set out mixed conclusions with some studies pointing to a positive influence on healthy weight among children (Potwarka, Kaczynski and Flack, 2008; Veugelers *et al.*, 2008; Singh, Siahpush and Kogan, 2010) and others showing no association (Burdette and Whitaker, 2004; Lovasi *et al.*, 2011). There have been obvious differences in the methodological approaches, geographies, populations and sample sizes studied which may have given rise to these mixed results. Spatial access to play areas is commonly divided into measures of density, such as number of play areas within a specified distance or within a neighbourhood, and measures of proximity, such as distance between residence and nearest play area. Some studies utilised geographic information systems (GIS) to objectively measure these spatial variables (Burdette and Whitaker, 2004; Roemmich *et al.*, 2006; Potwarka, Kaczynski and Flack, 2008; Potestio *et al.*, 2009; Quigg *et al.*, 2010; Lovasi *et al.*, 2011, 2013). Other studies have relied on subjective parental reports of accessibility (Veugelers *et al.*, 2008; Jones *et al.*, 2009; Singh, Siahpush and Kogan, 2010; Alexander *et al.*, 2013; Fan and Jin, 2013; Tappe *et al.*, 2013). Play area appeal is also likely to be influenced by the location, play value, and maintenance of the facility which, combined, create a measure of quality. This is the first study to account for quality in testing for an association between spatial access to play areas and weight status among young children.

A major issue with past childhood studies has been the diverse age range of included children. Some studies have focused on children (Burdette and Whitaker, 2004; Potestio *et al.*, 2009; Lovasi *et al.*, 2011, 2013) (≤10 years), others on adolescents (Veugelers *et al.*, 2008; Singh, Siahpush and Kogan, 2010; Fan and Jin, 2013) (≥10 and <19); some have combined both in the same analysis (Potwarka, Kaczynski and Flack, 2008; Alexander *et al.*, 2013). Although wide age groups make findings more generalisable to a population, they may not be applicable to specific age groups. Different age groups are likely to have different associations between weight status and spatial access to play areas. In addition, play areas will vary in their appeal and suitability to different age groups. Burdette and Whitaker (2004) and Lovasi et al (2011, 2013) are among the few studies to focus specifically on children aged 3 to 5 years old.

Most past studies used a BMI-centile calculation from height and weight measurements to categorise obesity. Studies differ in whether these have been measured by trained professionals (Burdette and Whitaker, 2004; Roemmich *et al.*, 2006, 2007; Veugelers *et al.*, 2008; Jones *et al.*, 2009; Potestio *et al.*, 2009; Quigg *et al.*, 2010; Lovasi *et al.*, 2011, 2013) or reported by parents (Potwarka, Kaczynski and Flack, 2008; Singh, Siahpush and Kogan, 2010; Alexander *et al.*, 2013; Fan and Jin, 2013). Parental reporting of weight, more so than height, has been shown to be inaccurate in this age group compared to measurements by trained professionals (Dubois and Girad, 2007).

On the basis of this brief review of current knowledge, the present study aims to investigate the association between objectively measured healthy weight status in 4 to 5-year-old children attending school, and spatial access to purposefully constructed play areas whilst adjusting for the effects of gender, deprivation, and play area quality.

**Methods**

Ethical approval was granted by the Faculty of Medicine Ethics Committee of the University of Southampton.

A cross-sectional design was used. Anthropometric measurements were obtained from the National Childhood Measurement Programme (NCMP) 2012/13 dataset for reception aged children (4-5 years), living in Southampton. The dataset contains a Body Mass Index (BMI) centile score for each individual. Healthy weight is defined as a BMI-centile between the 2nd and less than the 85th (overweight BMI-centile ≥ 85th and <95th, obesity BMI-centile ≥95th). Variables from the NCMP dataset used in this project were postcode, gender, ethnicity, deprivation score, and BMI-centile. All reception year aged children living in Southampton who had data collected as part of the NCMP in 2012/13 and where that data was complete were included in the study. Participation rate was 93.4% with 195 children having pre-measurement opt out by parents. A total of 2763 records were available for analysis and 18 records were excluded due to residential postcodes outside Southampton. A further 33 records of children classified as underweight (BMI-centile <2) were removed. This left 2712 children for inclusion.

Play area data

Southampton City Council provided geo-referenced vector map data (as polygon ‘shapefiles’) for play areas within the city (updated 2013) and the Index of Multiple Deprivation IMD (2010) score measured at lower super output area level. Play areas were included if they were on Southampton City Council’s play area database and met the definition of being ‘a *designated play space in a defined area, containing at least one purposefully constructed item of play equipment*’. There were 82 play areas meeting this definition. Play area quality was subjectively assessed using Play England’s ‘Playable Space Quality Assessment Tool’ (Inspire, 2009). This is a recognised tool for producing a numerical quality rating based on location, play value and maintenance of a play area (Dover District Council, 2011; Jenkins *et al.*, 2015). Location scores included factors such as observing evidence of use, accessibility, safety, lighting and security. Play value scores included factors such as degree of enticement of equipment, and whether the equipment catered for children of different ages and abilities. Care and maintenance scores included observations of state of repair, health and safety, and presence of litter bins. The tool includes clear guidance for scoring on each category. A single quality assessment was made during a two-week period in June 2014 by RP.

Data Management

Children in the NCMP data were geocoded to residential postcode centroid using the Code Point dataset from Ordnance Survey. A Geographic Information System (MapInfo Professional v11.5 (Pitney Bowes, 2012)) was used to calculate (a) Number of play areas within a Euclidean 1km buffer of residential postcode centroid (a density measure) and (b) the Euclidean distance from residential postcode centroid to the nearest play area (a proximity measure) . A play area was counted if (a) any part of its polygon intersected the 1km buffer or (b) any part of its polygon was nearest to a postcode centroid of a child. A 1 km buffer distance of 1km was chosen representing a typical walking time of 10-15 minutes. Existing studies use buffer sizes ranging from 0.4 to 1 km (Potwarka, Kaczynski and Flack, 2008; Lovasi *et al.*, 2013). Euclidean distances have been found to be highly correlated with network distances in urban areas and their computation is easier (Shahid *et al.*, 2009; Boscoe, Henry and Zdeb, 2012).

Statistical Analysis

Stata/IC version 13.1 (Statacorp, 2013) was used for statistical analysis. Summary statistics were generated for weight status by gender, number of play areas within 1km, near distances to play areas and respective play area quality scores. Random intercept multilevel logistic regression was used to adjust for clustering of healthy weight status by school. Children attending the same school may share weight status similarities due to unmeasured factors specific to within schools due to the clustered data collection process as part of NCMP. Multilevel analysis with schools as clusters can account for these effects. Model one was used to predict healthy weight for play area density and proximity. Model two was an adjusted model predicting healthy weight for play area density and proximity and accounting for the effects of play area quality, gender and IMD quintile. The ethnicity data collected by the NCMP was unreliable (36% of records were ‘unstated’) and therefore no adjustment was made for the effects of ethnicity except in a sensitivity analysis.

Both distance to nearest play area and play area count within 1km were converted to categorical variables to enable recognition of non-linearities in associations with healthy weight status. The categorical cut points for nearest distance and play area count were arbitrarily assigned as near equal divisions based on the range of values. Play area quality scores were converted into a dichotomous variable at the median point identifying ‘high’ or ‘low’ quality to enhance interpretation. Children living without play areas within 1km were assigned ‘low’ quality play area status by default. By convention, significance was set at 5% (0.05).

Sensitivity Analysis

The analysis was repeated separately for overweight status and obesity status to see if results differed by degree of overweight. The analysis was also repeated using quintiles of the distribution for both near distance and number of play areas, excluding children with zero play areas within 1 km, and stratifying by ethnicity in children where this was available (n=1748).

**Results**

Summary statistics are displayed in table 1. Of the sample 52% were male. BMI-centile characteristics divided the population into 77% healthy weight, 13% overweight and 10% obese. The number of play areas within 1 km radius from a child’s residential postcode was normally distributed (mean 4.9; standard deviation 2.0). The range of play area counts within 1 km was 0 to 10 and did not differ significantly with weight status. A total of 52 reception year children had zero play areas within 1 km. Quality scores were normally distributed. The maximum quality score possible was 100. The mean play area quality score at 1 km was 52 (standard deviation 6, range 32-75). The distance to nearest play area had a positively skewed distribution and the median results are displayed. The median distance to nearest play area from residential location was 302.0 metres (range of 8.1 to 1429.9, IQR 178 to 444m). The mean play area quality score for nearest play area was 52 (standard deviation 11, range 30-77).

Table 1: Summary statistics of weight status, gender and spatial access measures within total sample

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Healthy | Overweight | Obese | Total *n* |
| Number of reception year children (%) | 2099 (77) | 350 (13) | 263 (10) | 2712 (100) |
| Number Male (%) | 1080 (76) | 183 (13) | 156 (11) | 1419 (100) |
| Mean Play Area Count 1km | 4.8 (2.0) | 4.9 (2.0) | 5.1 (2.1) | 4.9 (2.0) |
| Mean Quality Score 1km (SD) | 52 (6) | 52 (6) | 51 (6) | 51 (10) |
| Median Near Distance (IQ Range) Metres | 309.5 (185 to 447) | 290.8 (158 to 442) | 277.1 (165 to 414) | 302.0 (178 to 444) |
| Mean Quality Score Nearest (SD) | 52 (11) | 52 (11) | 51 (10) | 52 (11) |
|  |  |  |  |  |

Multilevel logistic regression models for healthy weight status (dependent variable) by play area counts at 1km and nearest distance to play area are shown in tables 2 and 3. There was no statistically significant association between healthy weight status and any category of either spatial measure in any model, with or without the inclusion of play area quality. In the sensitivity analysis, the same was true when the analysis was repeated for both overweight and obesity status separately, when excluding children without a play area within 1 km, and when stratified by ethnicity (results not shown).

Table 2: Multilevel logistic regression model for healthy weight status and spatial density of play areas

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Empty model | Model 1 |  | Model 2\* |  |  |
| Variable | Odds Ratio for **healthy weight** status | Odds Ratio for **healthy weight** status | p-value | Odds Ratio for **healthy weight** status | p-value |  |
| Play Area Count 1 km |  |  | 0.41\*\* |  | 0.69\*\* |  |
| 0 |  | 1.00 (Ref) |  | 1.00 (Ref) |  |  |
| 1-2 |  | 1.16 (0.57-2.36) | 0.69 | 0.98 (0.47-2.03) | 0.96 |  |
| 3-4 |  | 1.16 (0.58-2.33) | 0.68 | 1.05 (0.52-2.13) | 0.89 |  |
| 5-6 |  | 0.95 (0.48-1.90) | 0.89 | 0.89 (0.44-1.78) | 0.73 |  |
| 7-8 |  | 0.89 (0.44-1.79) | 0.75 | 0.84 (0.41-1.70) | 0.62 |  |
| 9-10 |  | 0.91 (0.36-2.34) | 0.85 | 0.86 (0.33-2.33) | 0.76 |  |
| Male Gender |  |  |  | 0.86 (0.72-1.03) | 0.10 |  |
| Deprivation Quintile |  |  |  |  | 0.34\*\* |  |
| 1 |  |  |  | 1.00 (Ref) |  |  |
| 2 |  |  |  | 0.91 (0.72-1.16) | 0.46 |  |
| 3 |  |  |  | 1.15 (0.88-1.50) | 0.30 |  |
| 4 |  |  |  | 1.22 (0.85-1.76) | 0.29 |  |
| 5 |  |  |  | 1.21 (0.77-1.91) | 0.41 |  |
| Play Area Quality High |  |  |  | 1.14 (0.94-1.39) | 0.20 |  |
| Between School Variance (SE) | 0.033 (0.028) | 0.026 (0.026) |  | 0.023 (0.265) |  |  |
| Intra-class correlation | 0.01 | 0.008 |  | 0.007 |  |  |
| Explained variance | --- | 21%\*\*\* |  | 30%\*\*\* |  |  |

\*adjusted for gender, deprivation quintile (quintile 1 = most deprived) and play area quality score, n=2712

\*\*p-value for impact of variable using likelihood ratio test

\*\*\*using the variance in the empty model as reference

Table 3: Multilevel logistic regression model for healthy weight status and spatial proximity of play area

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Empty model | Model 1 |  | Model 2\* |  |  |
| Variable | Odds Ratio for **healthy weight** status | Odds Ratio for **healthy weight** status | p-value | Odds Ratio for **healthy weight** status | p-value |  |
| Near Distance Play Area |  |  | 0.38\*\* |  | 0.67\*\* |  |
| < 300 m |  | 1.00 (Ref) |  | 1.00 (Ref) |  |  |
| ≥ 300 to < 600 m |  | 1.15 (0.94-1.39) | 0.17 | 1.12 (0.92-1.37) | 0.27 |  |
| ≥ 600 to < 900 m |  | 1.37 (0.94-2.00) | 0.10 | 1.25 (0.84-1.85) | 0.28 |  |
| ≥ 900 to < 1200 m |  | 0.91 (0.49-1.67) | 0.76 | 0.86 (0.47-1.59) | 0.63 |  |
| ≥ 1200 m |  | 1.05 (0.33-3.34) | 0.93 | 1.11 (0.35-3.54) | 0.86 |  |
| Male Gender |  |  |  | 0.86 (0.72-1.04) | 0.11 |  |
| Deprivation Quintile |  |  |  |  | 0.27\*\* |  |
| 1 |  |  |  | 1.00 (Ref) |  |  |
| 2 |  |  |  | 0.86 (0.68-1.10) | 0.23 |  |
| 3 |  |  |  | 1.12 (0.86-1.47) | 0.40 |  |
| 4 |  |  |  | 1.17 (0.81-1.68) | 0.41 |  |
| 5 |  |  |  | 1.14 (0.72-1.79) | 0.59 |  |
| Play Area Quality High |  |  |  | 1.04 (0.86-1.26) | 0.67 |  |
| Between School Variance (SE) | 0.033 (0.028) | 0.030 (0.028) |  | 0.025 (0.271) |  |  |
| Intra-class correlation | 0.01 | 0.009 |  | 0.008 |  |  |
| Explained variance | --- | 9%\*\*\* |  | 24%\*\*\* |  |  |

\*adjusted for gender, deprivation quintile and play area quality score, n=2712

\*\*p-value for impact of variable using likelihood ratio test

\*\*\*using the variance in the empty model as reference

**Discussion**

There was no association found between healthy weight status among 4 to 5-year-old children attending school and living in Southampton in 2012/13, and spatial measures of proximity or density of purposefully constructed play areas, with or without the inclusion of a play area quality score, and when controlling for the effects of gender and deprivation, and for the random effect of clustering by school.

Three quarters of all children had a nearest play area within 450m of their residential postcode and a mean of 5 play areas within 1 km, suggesting adequate spatial access for most. However, spatial access does not guarantee utilisation. Mobility of children aged 4 to 5 years, more than older children, is restricted by their parents, and having access to a play areas does not guarantee that they will be used (Zhang, Lu and Holt, 2011). Parents may also be unfamiliar with the location of play areas within their neighbourhood (Potwarka, Kaczynski and Flack, 2008),reducing the impact of spatial density. Playground density has been shown to be associated with physical activity in older but not pre-school children (Buck *et al.*, 2015). As physical activity is known to be associated with healthy weight status of children, our results are in alignment with this previous finding.

Only a small proportion of total physical activity in children may take place in play areas or parks (Lachowycz *et al.*, 2012; Coombes, van Sluijs and Jones, 2013). Quigg et al (2010) found only 1.9% (95% CI=1.4 to 2.4%) of total physical activity in children aged 5-10 years old took place in parks with playgrounds. A significant proportion of physical activity is known to take place in personal garden space (Lachowycz *et al.*, 2012). Garden space tends to increase with affluence and may be a factor in the socioeconomic gradient of childhood obesity since lower socioeconomic groups may not have any personal garden space (Evans and Kantrowitz, 2002). However, some studies have found an increased number of play areas in areas of greater deprivation but of suspected lower quality (Ellaway *et al.*, 2007).We also found an increased number of play areas associated with areas of deprivation but they were more likely to be of higher quality (results not shown). This may be due to targeted public investment into areas with greater deprivation.

Non-spatial factors may influence play area use. Children may be driven to play areas further afield. Tucker found that only 49% of parents took their children to the nearest park, the majority travelling more than 4km. High car use may therefore negate any near distance effects (Potestio *et al.*, 2009; Quigg *et al.*, 2010). Parks with more amenities have been shown to be more important to parents than locality and may influence the desire to drive further afield (Tucker, Gilliland and Irwin, 2007) as could social factors such as meeting up with specific friends. Conversely there may be motivation away from specific sites. Safety is a key issue for parents and may influence their willingness to take their children to an outdoor play area (Tappe *et al.*, 2013). In our study, play area quality did not appear to influence the association between spatial access and healthy weight status. However, it is not possible to extrapolate our results to comment on any association between quality and utilisation.

Strengths of the present study include the large sample size and a high rate of participation of 93.4% in the local NCMP data, which improves validity. It is reasonable to assume that the results could be generalised to reception aged children living in places with similar demographic profiles and with similar play space geography. Whilst the percentage of children who were unavailable to the study was small, it is unknown whether these children could have been different in some way. Parents may have opted their child out of being measured in the NCMP if they believed them to be overweight or obese for fear of negative consequences.

The weight status of reception age children is known to vary with ethnicity and adjusting for this in the current study would have been preferential but was limited by the quality of the NCMP ethnicity data. Stratifying the results by ethnicity where this was available made no difference to the results.

The use of a play area quality score further strengthens this study. Play areas with quality improvements have been shown to increase physical activity amongst children (Quigg *et al.*, 2012). The play area quality scores in the present study had a small standard deviation with 95% having a score between 40 and 64. This may have contributed towards the null findings. Whilst the assessment tool covered location, play value and maintenance, it was notable that the number of items of play equipment was not a component. Play areas with a greater number of pieces may positively influence visitation independently of spatial convenience and other quality assessment tools have incorporated a piece count (Veitch *et al.*, 2013).

A factor unaccounted for in the present study is total usable park space and other park amenities. Play areas can exist independently or in conjunction with other park space. Studies investigating weight status and total park space as a measure of access have generally produced negative results (Potwarka, Kaczynski and Flack, 2008; Potestio *et al.*, 2009; Lovasi *et al.*, 2013) which suggests that its inclusion may not have altered the results of our study.

The influence of school location and its own unique obesogenic and leptogenic built environment was not included in the present study. Wasserman et al found that having parks within 1 mile of school significantly lowered risk of obesity in children aged 4 to 14 years (Wasserman *et al.*, 2014). Reception age children have only just begun to attend school and the influence on reception weight status is likely to be minimal. However, the effect of clustering by school was accounted for by using multilevel modelling in the present study.

The benefit of play areas to maintaining healthy weight among children may occur over a long period of time and is not detected by the cross-sectional nature of the analysis. Any effect size may be small (Potwarka, Kaczynski and Flack, 2008). However, even small effect sizes may be important at a population level (Evans *et al.*, 2012). Longitudinal studies will be needed to fully establish the role of play areas in the maintenance of long-term healthy weight.

The NCMP statistics suggest that a large proportion of children move from being healthy weight at 4 to 5 years of age, to overweight or obese by the age of 10 to 11 years (Health and Social Care Information Centre, 2015). There is a critical period during early childhood, where behaviours such as physical activity, diet and sedentary behaviour are established, and have long-term consequences for weight status (Jones *et al.*, 2009). Promoting play area use may be a solution to increasing physical activity in 4 to 5-year-old children although further research would be needed to investigate the value of this intervention and whether it has beneficial longitudinal effects on healthy weight status (Boonzajer Flaes *et al.*, 2016). In order to design effective interventions to enhance play area use further work to understand the experiences of parents who do not take their children to play areas could be undertaken.

In conclusion, the present study does not sustain an association between spatial access to play areas and healthy weight status among 4 to 5-year-old children who are attending school. Only a small degree of physical activity may occur in play areas and their leptogenic influence is thus likely to be reduced. However, play areas continue to offer opportunity for physical activity, as well as being locations where children can learn to socially interact, develop gross motor skills and have fun.

No specific funding was obtained for the present study.

*Total word count in paper = 3714 (Excluding tables)*

*What is already known on this subject?*  
Previous studies on the association between weight status of children and measures of spatial access to parks and play areas have produced mixed results. Broad differences in methodological approaches, geographies, populations and sample sizes may have given rise to these mixed results. Very few previous studies have investigated the association between healthy weight status of younger children (aged 4 to 5 years) and spatial access to play areas and none have included a play area quality score.

*What this study adds?*  
Living close to play areas does not appear to have an association with healthy weight status of children aged 4 to 5 years old even when taking into account gender, deprivation and play area quality. This could be because having play areas close by does not influence how often they are used, and the nearest play areas may not be the most appealing.

References

Albright, A. (2008) ‘Biological and social exposures in youth set the stage for premature chronic diseases.’, *Journal of the American Dietetic Association*. Elsevier, 108(11), pp. 1843–5. doi: 10.1016/j.jada.2008.09.017.

Alexander, D. S., Huber, L. R. B., Piper, C. R. and Tanner, A. E. (2013) ‘The association between recreational parks, facilities and childhood obesity: a cross-sectional study of the 2007 National Survey of Children’s Health.’, *Journal of epidemiology and community health*, 67(5), pp. 427–31. doi: 10.1136/jech-2012-201301.

Boonzajer Flaes, S. A. M., Chinapaw, M. J. M., Koolhaas, C. M., van Mechelen, W. and Verhagen, E. A. L. M. (2016) ‘More children more active: Tailored playgrounds positively affect physical activity levels amongst youth.’, *Journal of science and medicine in sport / Sports Medicine Australia*, 19(3), pp. 250–4. doi: 10.1016/j.jsams.2015.03.001.

Boscoe, F., Henry, K. and Zdeb, M. (2012) ‘A nationwide comparison of driving distance versus straight-line distance to hospitals’, *The Professional Geographer*.

Buck, C., Tkaczick, T., Pitsiladis, Y., De Bourdehaudhuij, I., Reisch, L., Ahrens, W. and Pigeot, I. (2015) ‘Objective measures of the built environment and physical activity in children: from walkability to moveability.’, *Journal of urban health : bulletin of the New York Academy of Medicine*, 92(1), pp. 24–38. doi: 10.1007/s11524-014-9915-2.

Burdette, H. L. and Whitaker, R. C. (2004) ‘Neighborhood playgrounds, fast food restaurants, and crime: relationships to overweight in low-income preschool children.’, *Preventive medicine*, 38(1), pp. 57–63.

Coombes, E., van Sluijs, E. and Jones, A. (2013) ‘Is environmental setting associated with the intensity and duration of children’s physical activity? Findings from the SPEEDY GPS study’, *Health and Place*. Elsevier, 20, pp. 62–65. doi: 10.1016/j.healthplace.2012.11.008.

Dover District Council (2011) *Open space policy and standards consultation*.

Dubois, L. and Girad, M. (2007) ‘Accuracy of maternal reports of pre-schoolers’ weights and heights as estimates of BMI values’, *International Journal of Epidemiology*, 36(1), pp. 132–138. doi: 10.1093/ije/dyl281.

Ellaway, A., Kirk, A., Macintyre, S. and Mutrie, N. (2007) ‘Nowhere to play? The relationship between the location of outdoor play areas and deprivation in Glasgow.’, *Health & place*, 13(2), pp. 557–61. doi: 10.1016/j.healthplace.2006.03.005.

Evans, G. W., Jones-Rounds, M. L., Belojevic, G. and Vermeylen, F. (2012) ‘Family income and childhood obesity in eight European cities: the mediating roles of neighborhood characteristics and physical activity.’, *Social science & medicine (1982)*, 75(3), pp. 477–81. doi: 10.1016/j.socscimed.2012.03.037.

Evans, G. W. and Kantrowitz, E. (2002) ‘Socioeconomic status and health: the potential role of environmental risk exposure.’, *Annual review of public health*. Annual Reviews 4139 El Camino Way, P.O. Box 10139, Palo Alto, CA 94303-0139, USA, 23, pp. 303–31. doi: 10.1146/annurev.publhealth.23.112001.112349.

Fan, M. and Jin, Y. (2013) ‘Do Neighborhood Parks and Playgrounds Reduce Childhood Obesity?’, *American Journal of Agricultural Economics*, 96(1), pp. 26–42. doi: 10.1093/ajae/aat047.

Health and Social Care Information Centre (2015) *National Child Measurement Programme: England 2014/15 school year*.

Inspire (2009) *Playable Space Quality Assessment Tool*.

Jenkins, G., Yuen, H., Rose, E., Maher, A., Gregory, K. and Cotton, M. (2015) ‘Disparities in Quality of Park Play Spaces between Two Cities with Diverse Income and Race/Ethnicity Composition: A Pilot Study’, *International Journal of Environmental Research and Public Health*, 12(7), pp. 8009–8022. doi: 10.3390/ijerph120708009.

Jones, R. a, Okely, A. D., Gregory, P. and Cliff, D. P. (2009) ‘Relationships between weight status and child, parent and community characteristics in preschool children.’, *International journal of pediatric obesity : IJPO : an official journal of the International Association for the Study of Obesity*, 4(1), pp. 54–60. doi: 10.1080/17477160802199984.

Lachowycz, K., Jones, A. P., Page, A. S., Wheeler, B. W. and Cooper, A. R. (2012) ‘What can global positioning systems tell us about the contribution of different types of urban greenspace to children’s physical activity?’, *Health & Place*. Elsevier, 18(3), pp. 586–594. doi: 10.1016/j.healthplace.2012.01.006.

Lovasi, G. S., Jacobson, J. S., Quinn, J. W., Neckerman, K. M., Ashby-Thompson, M. N. and Rundle, A. (2011) ‘Is the environment near home and school associated with physical activity and adiposity of urban preschool children?’, *Journal of urban health : bulletin of the New York Academy of Medicine*, 88(6), pp. 1143–57. doi: 10.1007/s11524-011-9604-3.

Lovasi, G. S., Schwartz-Soicher, O., Quinn, J. W., Berger, D. K., Neckerman, K. M., Jaslow, R., Lee, K. K. and Rundle, A. (2013) ‘Neighborhood safety and green space as predictors of obesity among preschool children from low-income families in New York City.’, *Preventive medicine*, 57(3), pp. 189–93. doi: 10.1016/j.ypmed.2013.05.012.

Papas, M. a, Alberg, A. J., Ewing, R., Helzlsouer, K. J., Gary, T. L. and Klassen, A. C. (2007) ‘The built environment and obesity.’, *Epidemiologic reviews*, 29(27), pp. 129–43. doi: 10.1093/epirev/mxm009.

Pitney Bowes (2012) ‘MapInfo Professional’.

Potestio, M. L., Patel, A. B., Powell, C. D., McNeil, D. A., Jacobson, R. D. and McLaren, L. (2009) ‘Is there an association between spatial access to parks/green space and childhood overweight/obesity in Calgary, Canada?’, *The international journal of behavioral nutrition and physical activity*, 6, p. 77. doi: 10.1186/1479-5868-6-77.

Potwarka, L. R., Kaczynski, A. T. and Flack, A. L. (2008) ‘Places to play: association of park space and facilities with healthy weight status among children.’, *Journal of community health*, 33(5), pp. 344–50. doi: 10.1007/s10900-008-9104-x.

Quigg, R., Gray, A., Reeder, A. I., Holt, A. and Waters, D. L. (2010) ‘Using accelerometers and GPS units to identify the proportion of daily physical activity located in parks with playgrounds in New Zealand children.’, *Preventive medicine*, 50(5–6), pp. 235–40. doi: 10.1016/j.ypmed.2010.02.002.

Quigg, R., Reeder, A. I., Gray, A., Holt, A. and Waters, D. (2012) ‘The effectiveness of a community playground intervention.’, *Journal of urban health : bulletin of the New York Academy of Medicine*, 89(1), pp. 171–84. doi: 10.1007/s11524-011-9622-1.

Roemmich, J. N., Epstein, L. H., Raja, S. and Yin, L. (2007) ‘The neighborhood and home environments: disparate relationships with physical activity and sedentary behaviors in youth.’, *Annals of behavioral medicine : a publication of the Society of Behavioral Medicine*, 33(1), pp. 29–38. doi: 10.1207/s15324796abm3301\_4.

Roemmich, J. N., Epstein, L. H., Raja, S., Yin, L., Robinson, J. and Winiewicz, D. (2006) ‘Association of access to parks and recreational facilities with the physical activity of young children.’, *Preventive medicine*, 43(6), pp. 437–41. doi: 10.1016/j.ypmed.2006.07.007.

Sallis, J. F., Prochaska, J. J., Taylor, W. C. and others (2000) ‘A review of correlates of physical activity of children and adolescents’, *Medicine and science in sports and exercise*. WILLIAMS & WILKINS, 32(5), pp. 963–975.

Shahid, R., Bertazzon, S., Knudtson, M. L. and Ghali, W. A. (2009) ‘Comparison of distance measures in spatial analytical modeling for health service planning’, *BMC Health Services Research*, 9(1), p. 200. doi: 10.1186/1472-6963-9-200.

Singh, G. K., Siahpush, M. and Kogan, M. D. (2010) ‘Neighborhood socioeconomic conditions, built environments, and childhood obesity.’, *Health affairs (Project Hope)*, 29(3), pp. 503–12. doi: 10.1377/hlthaff.2009.0730.

Statacorp (2013) ‘Stata/IC’. Stata Statistical Software Release 13.

Tappe, K. A., Glanz, K., Sallis, J. F., Zhou, C. and Saelens, B. E. (2013) ‘Children’s physical activity and parents’ perception of the neighborhood environment: neighborhood impact on kids study.’, *The international journal of behavioral nutrition and physical activity*, 10(1), p. 39.

Tucker, P., Gilliland, J. and Irwin, J. D. (2007) ‘Splashpads, swings, and shade: parents’ preferences for neighbourhood parks.’, *Canadian journal of public health = Revue canadienne de santé publique*, 98(3), pp. 198–202.

Veitch, J., Salmon, J., Ball, K., Crawford, D. and Timperio, A. (2013) ‘Do features of public open spaces vary between urban and rural areas?’, *Preventive medicine*, 56(2), pp. 107–11. doi: 10.1016/j.ypmed.2012.11.016.

Veugelers, P., Sithole, F., Zhang, S. and Muhajarine, N. (2008) ‘Neighborhood characteristics in relation to diet, physical activity and overweight of Canadian children.’, *International journal of pediatric obesity : IJPO : an official journal of the International Association for the Study of Obesity*, 3(3), pp. 152–9. doi: 10.1080/17477160801970278.

Wasserman, J. a, Suminski, R., Xi, J., Mayfield, C., Glaros, a and Magie, R. (2014) ‘A multi-level analysis showing associations between school neighborhood and child body mass index.’, *International journal of obesity (2005)*, 38(7), pp. 912–8. doi: 10.1038/ijo.2014.64.

World Health Organisation (2016) *Report of the Commission on Ending Childhood Obesity*.

Zhang, X., Lu, H. and Holt, J. B. (2011) ‘Modeling spatial accessibility to parks: a national study.’, *International journal of health geographics*, 10, p. 31. doi: 10.1186/1476-072X-10-31.