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ORIGINAL ARTICLE

Neighbourhood environment and physical activity among young children: A cross-sectional study from Sweden

HANNA WEIMANN[1], JONAS BJÖRK[1], LARS RYLANDER[1], PATRICK BERGMAN[2] & GABRIELE EIBEN[3]

[1]*Division of Occupational and Environmental Medicine, Lund University, Lund, Sweden,* [2]*Department of Sport Science, Linnaeus University, Kalmar, Sweden, and* [3]*Department of Public Health and Community Medicine, University of Gothenburg, Gothenburg, Sweden*

Abstract

Aims: The aims of this study were to investigate the association between the neighbourhood environment and physical activity among young children in a Scandinavian setting, and to assess the influences of seasonal variations, age, sex and parental education. *Methods:* Physical activity was assessed with an accelerometer and neighbourhood resources were estimated using geographic information systems for 205 Swedish children aged 4–11 years. Neighbourhood resources were generated as the sum of three neighbourhood attributes: (a) foot and bike paths, (b) non-restricted destinations and (c) recreational area, all within 300 m of each child's home. Physical activity was assessed as: (a) total volume of physical activity (i.e. counts per minute), (b) sedentary time and (c) moderate to vigorous physical activity (MVPA). The association between neighbourhood resources and physical activity was analysed using mixed linear models weighted by measurement time and adjusted for sex, age, season of activity measurement, type of housing and parental education. *Results:* Children were more physically active in areas with intermediate access to neighbourhood resources for physical activity compared to areas with worst access, while the difference between intermediate and best neighbourhood resource areas was less clear. The association between physical activity and neighbourhood resources was weaker than with seasonal variations but compatible in magnitude with sex, age, type of housing and parental education. Among specific neighbourhood attributes, the amount of foot and bike paths was associated with less sedentary time and more MVPA. ***Conclusions:*** **This study provides some, not entirely consistent, evidence overall for an association between the neighbourhood environment and physical activity among young children in Scandinavia.**

Key Words: *Physical activity, neighbourhood environment, children, sedentary, leisure time, accelerometer, geographic information systems, Scandinavia*

Background

Physical activity is associated with numerous immediate and long-lasting health benefits in children [1], and an increased amount of physical activity generally increases the benefits [2]. Current recommendations on physical activity for children endorsed by the European Commission and the World Health Organization are for a minimum 60 minutes of daily moderate to vigorous physical activity (MVPA) [3,4]. The reported proportion of children actually achieving the recommendation varies across studies, partly due to dissimilar definitions of MVPA [5]. Differences in neighbourhood characteristics could be another reason for the variety of physical activity levels in children. Positive effects of environmental factors in the neighbourhood, for example recreational facilities and parks, have been indicated for both physical activity levels and general health among children [6,7]. A recent review concluded significant positive associations between access, density and proximity to parks and

Correspondence: Hanna Weimann, Division of Occupational and Environmental Medicine, Lund University 221 85 Lund, Sweden. Email: hanna.weimann@med.lu.se

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objectively measured physical activity among children in four out of eight studies included, whereas no significant associations were seen in the other four studies [8].

Socioeconomic factors have been associated with physical activity among children, albeit with conflicting results [9–11], probably partly due to dissimilarities in the factors measured (e.g. income or education). Also seasonal factors may explain some of the differences [12]. This factor could be especially important in a Scandinavian context with large seasonal variations in weather conditions, temperature and hours of daylight [13]. Characteristics of the neighbourhood environment of children are likely to differ between countries and contexts. A majority of previous research that has found a relation between neighbourhood resources and physical activity in children has been performed in North America, while studies reflecting north European contexts are scarce [8,14,15]. The primary aim of our study was therefore to investigate the association between the neighbourhood environment and physical activity among young children in a setting with seasonal characteristics representative of the Scandinavian countries. Secondary aims were to investigate the influences of seasonal variations, age, sex and parental education.

Methods

Study setting and participants

This study includes data collected from September 2009 to March 2010 as part of the European study Identification and Prevention of Dietary- and Lifestyle-Induced Health Effects in Children and Infants (IDEFICS). Ethical approval has been obtained for the IDEFICS study. The IDEFICS study's design and the main characteristics of the overall study sample are described elsewhere [16]. All children (n=1538) participating in the IDEFICS study in Sweden lived in one of three municipalities and were recruited through contact with kindergartens and schools. A convenience sample of 249 out of 801 children living in one of the three municipalities was recruited for a sub-study on physical activity. Information about highest educational level of any parent was collected from a questionnaire and coded according to International Standard Classification of Education [17]. After exclusion due to lack of data on physical activity (n=40), residential address (n=3) or highest education of any parent (n=1), a total of 205 children aged 4–11 years from 168 families were included in the present study.

Physical activity assessments

Physical activity was assessed using a uniaxial accelerometer device. Two technically identical models—ActiGraph GT1M or ActiTrainer (ActiGraph, Pensacola, FL)—were used and were randomly assigned to each child. Each monitor was set to record physical activity in epochs of 15 seconds. At a personal meeting with IDEFICS staff, parents were instructed how to attach the accelerometer to the right hip of the child. The parent was asked to make sure that the child wore the accelerometer at all times, except at night and during activities that included water, for the next three consecutive days. In this study, we assessed physical activity during leisure time only on weekdays (i.e. Monday to Friday, days when children in Sweden are normally in school). Accelerometers were distributed throughout the weekdays. Consequently, some children wore the accelerometer from Thursday to Saturday and some from Friday to Sunday. For these children, only the data collected on the weekdays were included in our analysis. We established leisure time based on data from a 24-hour sleep and diet recall sub-study performed within IDEFICS in which 53 children in the present cohort took part. Leisure time was intuitively defined as the time interval between leaving school until two hours before bedtime, which in the study equalled the time interval from 3:10 p.m. to 6:46 p.m. To derive relevant variables based on the data sampled by the accelerometer, a python program (https://www.python.org/) was used. The program is based on a set of algorithms that summarises and aggregates the variables used in the present study. First, it defines a valid reading, which in this study was defined as a day with a minimum of 600 minutes of data after periods of consecutive epochs during a minimum of 30 minutes with 0 counts deleted (i.e. non-wear time). Second, it extracts data that have been collected during the leisure time period. Third, it calculates the physical activity variables used in the study. In this study, we used three different variables: (a) total volume of physical activity (i.e. counts per minute [cpm]), which was calculated as the mean count during the leisure time period; (b) time spent sedentary, which was calculated as the sum of all epochs with counts <100 cpm; and (c) all time spent on at least moderate intensity physical activity defined as the sum of all epochs with a count >2000 cpm (i.e. MVPA) as used in several studies [10,18,19].

Assessment of neighbourhood characteristics

The study area is a Swedish middle-class suburb with townhouses and villas, as well as a number of

Table I. Number of children (*n*=205) with low, medium and high presence of foot and bike paths, non-restricted outdoor destinations and recreational area in the child's neighbourhood.

	Type of housing											
	Townhouse or villa (*n*=175)						Apartment in a multistorey building (*n*=30)					
	Low		Medium		High		Low		Medium		High	
	Range	*n* (%)	Range	*n* (%)	Range	*n* (%)	Range	*n* (%)	Range	*n* (%)	Range	*n* (%)
Neighbourhood attributes												
(a) Foot and bike paths, km	<1	46 (26)	1–2	78 (45)	>2	51 (29)	<3.6	9 (30)	3.6–4.3	13 (43)	>4.3	8 (27)
(b) Non-restricted outdoor destinations, *n*	0–1	29 (17)	2–4	84 (48)	>4	62 (35)	0–10	8 (27)	11–16	11 (37)	>16	11 (37)
(c) Recreational area, % of total area	<25	42 (24)	25–50	96 (55)	>50	37 (21)	<40	8 (27)	40–51	12 (40)	>51	10 (33)

Data of range and number of children (n) are presented separately upon type of housing.

relatively well-defined residential areas with apartment buildings. The municipal area is 57 km^2 with about 600 inhabitants per km^2. The presence of public lawns and meadows as well as rather hilly forests is fairly high and well distributed throughout the area. During mid-December, the sun sets at 15:25 pm. However, street lighting in the area is extensive and playgrounds, schoolyards, foot and bike paths etcetera are generally illuminated. During the physical activity measurement period, the study area had snow from mid-December to mid-March.

All geographical analyses were performed using ArcGIS v9.3 (ESRI, Redlands, CA). An original geographic information systems (GIS) data file of the study area was obtained from the municipal office. The GIS provided information about built areas and the type of housing, network of foot and bike paths and land use. The municipal office also provided information on the location of public playgrounds and playfields maintained by the municipality. To complement existing geographical information, a manual inventory of the area using aerial photos and street views in Google Earth (Google, Mountain View, CA) was performed during the autumn of 2010 by the first author. The manual inventory included private playgrounds maintained by housing companies and the location of schoolyards. All paths, areas and destinations included in this study are fully accessible to the public throughout the day and at all times of the year. Information about the residential address of each child was collected from the parental questionnaire and was cross referenced to a national registry. The type of housing (i.e. living in a townhouse/villa or in an apartment in a multistorey building) was defined from the GIS data.

From the geographical information, three environmental attributes hypothesised to have an impact as positive resources for physical activity were assessed within a radius of 300 m of each child's home: (a) kilometres of foot and bike paths, (b) number of non-restricted destinations (playgrounds, schoolyards and playfields) and (c) recreational areas (pine forest, leaf forest and open ground) as a percentage of the total area. From this assessment, it was apparent that the ranges of each environmental attribute were different depending on the type of housing. Therefore, the classification of environmental attributes was done separately for children living in a townhouse or villa and for children living in an apartment. Each environmental attribute was classified into three levels—1=low, 2=medium and 3=high presence—aiming to create contrasts between groups while maintaining reasonably even group sizes (Table I). The overall neighbourhood resources for physical activity of each child was defined based on the sum of the three attributes which were combined in a score and thereafter classified into three groups: worst (sum score 3–4; *n*=36), intermediate (sum score 5–7; *n*=121) or best (sum score 8–9; *n*=48). Accordingly, a child categorised as having the worst degree of neighbourhood resources had either all environmental attributes classified at the low level or had two classified at the low and one at the medium level. Similarly, a child categorised in the best group had either all environmental attributes classified at the high level or had two classified at the high and one at the medium level.

Statistical analysis

All statistical analyses were carried out using IBM SPSS Statistics for Windows v20.0 (IBM Corp., Armonk, NY). The association between neighbourhood characteristics and physical activity was analysed using mixed linear regression. All assessments of physical activity used in the analysis models were log transformed to account for asymmetry in the regression residuals. All children, regardless of type of housing, were analysed together in one model. We adjusted the model for age, sex and

Table II. Individual and physical activity characteristics of 205 children aged 4–11 years. Data stratified upon worst, intermediate or best access of neighbourhood resources for physical activity.

	Neighbourhood resources for physical activity		
	Worst (*n*=36)	Intermediate (*n*=121)	Best (*n*=48)
Background characteristics			
Sex, *n* (%)			
Boy	20 (56)	57 (47)	25 (52)
Girl	16 (44)	64 (53)	23 (48)
Age (years), mean (*SD*)	8.1 (1.9)	8.5 (1.6)	8.5 (1.7)
Highest education of any parent,[a] *n* (%)			
Primary, secondary or high school	5 (14)	20 (17)	15 (31)
Post-secondary, <2 years	5 (14)	11 (9)	6 (13)
University, ⩾2 years	26 (72)	90 (74)	27 (56)
Type of housing, *n* (%)			
Townhouse or villa	32 (89)	102 (84)	41 (85)
Apartment in a multistorey building	4 (11)	19 (16)	7 (15)
Body mass index, *n* (%)			
Underweight	2 (6)	19 (16)	9 (19)
Normal weight	29 (81)	83 (69)	36 (75)
Overweight or obese	5 (14)	19 (16)	3 (6)
Physical activity measurement			
Season of activity measurement, *n* (%)			
Autumn (September to October)	3 (8)	24 (20)	21 (44)
Winter (November to January)	23 (64)	45 (37)	19 (40)
Early spring (February to March)	10 (28)	52 (43)	8 (17)
Measurement time (h), mean (*SD*)	8.5 (2.8)	8.0 (2.6)	8.0 (3.0)
Physical activity, mean (*SD*)			
Total volume of physical activity[b]	490 (200)	620 (310)	640 (310)
Sedentary time (% 0–100 cpm)	58 (9)	52 (11)	54 (13)
MVPA (% >2000 cpm)	7.4 (4.3)	10 (6)	11 (6.3)

[a]According to the International Standard Classification of Education (ISCED 1997).
[b]Assessed as counts per minute (cpm).

parental education if physical activity was assessed during autumn (September to October), winter (November to January) or early spring (February to March) and type of housing. To account for differences in accelerometer measurement time, all analyses were carried out using weighted least squares, giving children with longer measurement times more impact on the final results compared to children with shorter measurement times. Among the 205 children, 70 had one sibling and three had two siblings within the study cohort. A significant within family variation of physical activity was identified and was adjusted for by including a random intercept for each family. This action, however, did not alter the overall results. Characteristics of the close neighbourhood environment were primarily analysed using the worst–intermediate–best neighbourhood score, but we also assessed the associations using the three specific environmental attributes disjointedly. Both measures reflect relative resources rather than absolute ones.

Sensitivity analysis

Three different sensitivity analyses were carried out to investigate ambiguities in the material. The following analyses of physical activity were performed, all using the worst–intermediate–best neighbourhood resources score: (1) including only children living in townhouse or villa areas, thereby excluding any differences due to the divergence of environmental attributes between housing types; (2) including only children measured during winter or early spring, diminishing the effect of season; and (3) adjusting for body mass index (BMI) and measurement device (ActiGraph GT1M or ActiTrainer) as fixed variables in the model. This analysis included all children.

Results

Sex, age, type of housing and accelerometer measurement time were relatively evenly distributed across the three neighbourhood groups (Table II). By contrast, there were clear differences in season of activity measurement. A substantially larger proportion of

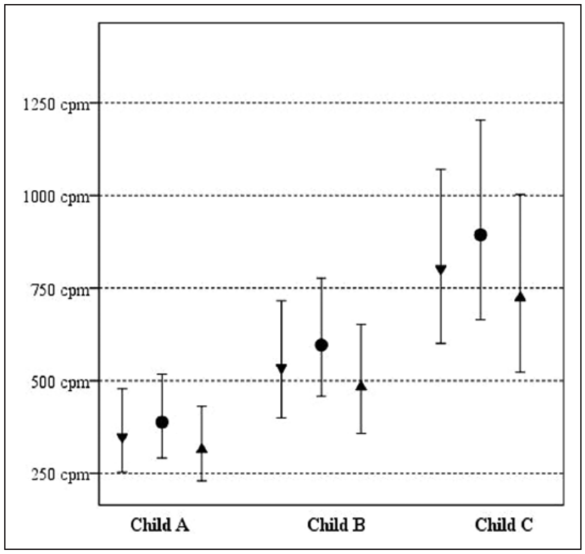

Figure 1. Model-based expected total volume of physical activity (i.e. counts per minute) in relation to best (↓), intermediate (•) and worst (↑) neighbourhood resources for physical activity for three different hypothetical average children (A, B and C) without siblings in the study, where A is a girl, 10 years old, living in an apartment and measured during winter; B is a boy, 8 years old, living in a townhouse or villa and measured during early spring; and C is a boy, 6 years old, living in a townhouse or villa and measured during autumn. Error bars represent 95% confidence intervals for the average estimates.

children in the worst neighbourhood resources group performed the physical activity measurement during winter. For children in the intermediate and best groups, season of activity measurement was more evenly distributed. The distribution between groups regarding season of activity measurement was less marked for the three attributes separately. For presence of foot and bike paths, the percentage of children measured in autumn was 24% in the low, 14% in the medium and 27% in the high group. Corresponding distributions for non-restricted destinations were 19%, 18% and 33%, and for recreational areas 14%, 28% and 23%. Crude comparisons suggested that children in areas with worst neighbourhood resources had lower cpm (p=0.014), higher proportion of sedentary time (p=0.004) and a smaller proportion of MVPA (p=0.013) than did the larger number of children in intermediate areas (Table II). No clear differences between children in intermediate versus best neighbourhood resource areas were discerned (p>0.30).

Differences in physical activity between children living in worst and intermediate neighbourhood resource areas remained but were less marked in the regression models with adjustment for age, sex, parental education season and type of housing ($p \leq 0.03$; Table III). As an example, the total volume of physical activity (i.e. cpm) was estimated to be 1.23 times higher in the intermediate group compared to the worst group (95% CI: 1.02–1.50). Girls had a lower cpm and less MVPA compared to boys ($p \leq 0.01$; Table III), and sedentary time increased with age ($p \leq 0.04$). Highly significant differences in cpm, sedentary time and MVPA were seen with regard to season of activity measurement, with activity levels being substantially higher during autumn (September to October) compared to winter (November to January) and early spring (February to March). Parental education was weakly associated with physical activity, and this was not statistically significant. For type of housing, a significant association was seen only for cpm. Figure 1 illustrates the regression result of physical activity in Table III further by showing the estimated differences in cpm related to neighbourhood resources for physical activity (best, intermediate and worst) for three hypothetical children (A, B and C) with increasing likelihood of being physically active: A, a girl, 10 years old, living in an apartment and measured during winter; B, a boy, 8 years old, living in a townhouse or villa and measured during early spring; and C, a boy, 6 years old, living in a townhouse or villa and measured during autumn. Noticeable in the figure is the lower total volume of physical activity among children with worst neighbourhood resources, in addition to the influences of seasonal variations, age, sex and type of housing. Analyses of the three specific environmental attributes separately showed that children with low access to foot and bike paths had more sedentary time and less MVPA than children with medium or high access ($p \leq 0.04$; Table IV). No clear associations between number of non-restricted destinations or

Table III. Physical activity characteristics during leisure time on weekdays (n=205 children) presented as total volume of physical activity (i.e. cpm), percentage of sedentary time and percentage of active time (MVPA) stratified upon worst, intermediate or best access to neighbourhood resources for physical activity.

	Total volume of physical activity[a]				Sedentary time (% 0–100 cpm)				MVPA (% >2000 cpm)			
	Ratio[b]	95% CI		*p*-Value	Ratio[b]	95% CI		*p*-Value	Ratio[b]	95% CI		*p*-Value
		Lower	Upper			Lower	Upper			Lower	Upper	
Intercept[c]	670	500	910		46	40	53		8.9	6.0	13	
Neighbourhood resources for physical activity												
Worst	ref.				ref.				ref.			
Intermediate	1.23	1.02	1.50	0.03	0.91	0.83	0.99	0.02	1.34	1.04	1.72	0.02
Best	1.11	0.88	1.40	>0.30	0.95	0.86	1.05	0.30	1.32	0.98	1.77	0.07
Sex												
Boy	ref.				ref.				ref.			
Girl	0.85	0.74	0.96	0.01	1.02	0.96	1.08	>0.30	0.74	0.63	0.87	<0.001
Age (number of years exceeding four)	0.979	0.942	1.018	0.29	1.018	1.000	1.036	0.04	0.999	0.952	1.049	>0.30
Highest education of any parent[d]												
Primary, secondary or high School	ref.				ref.				ref.			
Post-secondary, <2 years	1.12	0.86	1.46	>0.30	0.95	0.85	1.07	>0.30	1.09	0.78	1.52	>0.30
University, ⩾2 years	1.16	0.97	1.38	0.11	0.96	0.89	1.04	>0.30	1.18	0.94	1.49	0.14
Season of activity measurement												
Autumn (September to October)	ref.				ref.				ref.			
Winter (November to January)	0.69	0.57	0.90	<0.001	1.23	1.13	1.33	<0.001	0.69	0.54	0.87	0.004
Early spring (February to March)	0.70	0.57	0.85	0.001	1.18	1.08	1.30	<0.001	0.71	0.54	0.92	0.01
Type of housing												
Townhouse or villa	ref.											
Apartment in a multistory building	0.81	0.94	0.98	0.04	1.03	0.94	1.13	>0.30	0.80	0.95	1.03	0.08

Results of mixed linear regression weighted by measurement time.

[a]Assessed as counts per minute (cpm).

[b]The ratio is the relative comparison of total volume of physical activity, sedentary time and MVPA, respectively, versus the reference category of each variable in the model.

[c]Anti-log of the intercept in the mixed linear regression model.

[d]According to the International Standard Classification of Education (ISCED 1997).

Table IV. Physical activity characteristics during leisure time on weekdays (n=205 children) presented as total volume of physical activity (i.e. cpm), percentage of sedentary time and percentage of active time (MVPA) stratified upon low, medium or high access to foot and bike paths, non-restricted outdoor destinations and recreational area in the neighbourhood of each child.

	Total volume of physical activity[a]				Sedentary time (% 0-100 cpm)				MVPA (% >2000 cpm)			
	Ratio[b]	95% CI		p-Value	Ratio[b]	95% CI		p-Value	Ratio[b]	95% CI		p-Value
		Lower	Upper			Lower	Upper			Lower	Upper	
Intercept[c]	690	500	970		46	40	53		9.2	6.0	14	
Foot and bike paths												
Low	ref.				ref.				ref.			
Medium	1.19	0.99	1.43	0.06	0.91	0.84	0.99	0.03	1.33	1.05	1.68	0.02
High	1.20	0.95	1.51	0.12	0.90	0.81	0.99	0.04	1.41	1.05	1.90	0.02
Non-restricted outdoor destinations												
Low	ref.				ref.				ref.			
Medium	1.01	0.83	1.24	>0.30	0.96	0.88	1.05	>0.30	0.98	0.76	1.27	>0.30
High	0.96	0.76	1.21	>0.30	0.98	0.88	1.09	>0.30	0.95	0.70	1.28	>0.30
Recreational area												
Low	ref.				ref.				ref.			
Medium	0.97	0.81	1.17	>0.30	1.04	0.96	1.13	0.29	0.98	0.76	1.24	>0.30
High	0.93	0.75	1.15	>0.30	1.09	0.99	1.20	0.08	0.97	0.74	1.27	>0.30
Sex												
Boy	ref.				ref.				ref.			
Girl	0.86	0.75	0.98	0.03	1.01	0.95	1.07	>0.30	0.77	0.65	0.90	0.002
Age (number of years exceeding four)	0.982	0.943	1.023	>0.30	1.016	0.999	1.035	0.07	1.002	0.953	1.053	>0.30
Highest education of any parent[d]												
Primary, secondary or high school	ref.				ref.				ref.			
Post-secondary, <2 years	1.12	0.85	1.47	>0.30	0.95	0.85	1.07	>0.30	1.10	0.78	1.54	>0.30
University, ⩾2 years	1.19	0.99	1.43	0.07	0.95	0.88	1.03	0.22	1.23	0.97	1.55	0.08
Season of activity measurement												
Autumn (September to October)	ref.				ref.				ref.			
Winter (November to January)	0.67	0.55	0.82	<0.001	1.24	1.13	1.34	<0.001	0.67	0.52	0.85	0.001
Early spring (February to March)	0.68	0.55	0.84	<0.001	1.20	1.09	1.31	<0.001	0.67	0.52	0.88	0.004
Type of housing												
Townhouse or villa	ref.				ref.				ref.			
Apartment in a multistorey building	0.84	0.94	1.02	0.10	1.01	0.92	1.10	0.07	0.82	0.63	1.06	0.13

Results of mixed linear regression weighted by measurement time.
[a]Assessed as counts per minute (cpm).
[b]The ratio is the relative comparison of total volume of physical activity, sedentary time and MVPA, respectively, versus the reference category of each variable in the model.
[c]Anti-log of the intercept in the mixed linear regression model.
[d]According to the International Standard Classification of Education (ISCED 1997).

percentage of recreational area and physical activity were observed.

Results from sensitivity analysis

Sensitivity analysis 1, including only children living in townhouse or villa areas, showed slightly weaker but similar results as presented in the main analysis (results not shown). The second sensitivity analysis included only children measured during winter or early spring. Despite the reduction in power due to the loss of subjects, this analysis (including 157 children) showed a clear difference in physical activity between the group with the worst neighbourhood resources compared to the intermediate group for cpm (1.48; 95% CI: 0.96–2.29; $p=0.08$) as well as for sedentary time (0.82; 95% CI: 0.68–0.99; $p=0.04$) and time in MVPA (1.73; 95% CI: 0.94–3.16; $p=0.08$). When adding BMI and the type of accelerometer measurement device used to the model in sensitivity analysis 3, estimates for the group with the worst neighbourhood resources compared to the intermediate group changed only marginally. *P*-Values remained <0.05 for cpm, sedentary time and MVPA. BMI was not significant in any analyses ($p>0.30$).

Discussion

Principal findings

This study provides some, not entirely consistent, evidence that neighbourhood environments that lack sufficient relative resources for physical activity in close proximity to the children's residences is associated with lower physical activity among preschool and young school children. Access to foot and bike paths seem to be more important for physical activity than access to non-restricted outdoor destinations and recreational areas. The relation between neighbourhood resources and physical activity was weaker than with seasonal variation, but compatible in magnitude with sex, age, type of housing and parental education.

Strengths and limitations

This study comprises data of children in a young age group, rarely investigated with regard to physical activity. It reflects the relationship between physical activity and environmental characteristics of children in a Scandinavian setting, in which very few studies of the same or similar topics have been conducted, consequently adding new knowledge to the field.

The study was limited by generally short measurement times. In agreement with the IDEFICS study protocol, each child was instructed to wear the accelerometer for three consecutive days, and the majority did so. More than three days of measurement is usually recommended [20], but three days should be enough to give a rough indication of average physical activity [21,22]. All analyses presented in this paper were made using the weighted least square function, giving children with longer measurement time a larger impact on the final result. We argue that this action represents the best choice available for the data at hand. We used a 2000 cpm cut-off for MVPA. Being a little conservative for older children but more liberal for younger children, this is a trade-off between several published cut-off points [5]. The study was restricted to weekdays. Characteristics of physical activity in children on weekdays and weekends are essentially diverse [19,23], and the results from this study can therefore not be generalised to weekends. The study was restricted to an area that is relatively homogeneous with regard to geographical and social differences. Nonetheless, we were able to detect meaningful differences in both neighbourhood resources and physical activity.

Accelerometer data were collected over a period of seven months (September to March), making it possible to disentangle seasonal variations in physical activity. It should be noted that environmental attributes that encourage physical activity in children might be more or less attractive over the year due to seasonal differences [24]. Previous studies have shown that physical activity in children is lower during winter compared to other parts of the year [13,18], although the association between seasonal variations and patterns of physical activity may vary in different geographical settings [12]. In our sample, we noted a similar pattern, with the highest levels of physical activity taking place during autumn compared to winter and early spring. Few children were measured during autumn in the areas with the worst neighbourhood resources, but similar associations between resources and physical activity were seen for the second sensitivity analysis, when the analyses were restricted only to children measured during winter and early spring. It is likely that the effect of neighbourhood resources varied depending on season and weather conditions. Unfortunately, this could not be assessed due to the limited sample size.

The categorisation of low, medium and high levels of each of the three environmental attributes was based on different ranges for children living in apartment areas and children living in areas with townhouses and villas. This distinction is based on the explicit assumption that each level represents the environment equally, regardless of the type of housing. However, due to the limited sample size, this assumption cannot be fully tested. To categorize all children equally, regardless of type of housing, would not have been feasible due to the huge skewness in ranges. Most apartment areas in the study area have similar planning, with small playgrounds on nearly every apartment courtyard, whereas the playgrounds in townhouse and villa areas are fewer but larger. Also the characterization of foot and bike paths varies between apartment and villa areas. Had data been accessible, it would have been desirable to include aspects of the quality of the non-restricted outdoor destinations and foot and bike paths. The three environmental attributes used in this study give a broad delineation and estimate of relative neighbourhood resources in the study area. The categorization of neighbourhood resources into worst–intermediate–best was to some extent arbitrary, but the contrasts between children categorized into the worst versus the intermediate and best group were still considered to be of importance (cf. Table I).

The youngest children included in this study were four years old and less likely to go further than about a 5–10 minute walk from home, probably most often accompanied by a parent. A radius of 300 m is therefore a reasonable distance to use to define their neighbourhood. It should, however, be noted that the relevant radius to use in this type of study may vary widely by age. Radius lengths used in previous studies of children of similar ages have, for example, been 100 m [25] and half a mile (about 800 m) [6]. A more comprehensive assessment of potential barriers within the radius areas caused by, for example, major roads and natural blockages, as well as non-lit paths and roads, would potentially have increased the reliability of the data. Not only access but also preferences for different attributes in the neighbourhood environment may vary with age. For older children, there may also be differences between boys and girls with regard to preference of diverse neighbourhood attributes and the intensity of the physical activity generated [26]. The limited sample size made it impossible to assess associations between neighbourhood resources and physical activity for boys and girls of different ages.

We lack information about where the physical activity was actually performed, and some of the activity most certainly took place outside the neighbourhood area or indoors. We chose to include only physical activity collected during leisure time in weekdays, which may have limited the amount of physical activity conducted outside the area. Parental attitudes, as well as their perceptions of safety, also affect children's outdoor activities in the neighbourhood [10,25], but we have no reason to assume that such attitudes differ across the study area.

Results in relation to previous studies

Our study results are consistent with prior studies that have suggested a positive relationship between child physical activity and characteristics in the local neighbourhood environment [6,8,14]. Consequently, previous studies, mostly reflecting settings in North America, may, to a certain extent, also be valid in the Scandinavian context. Similar to a previous study [27], foot and bike paths were the only individual neighbourhood attribute associated with physical activity. In line with a US study using a similar measure of socio-economic status but a subjective measure of physical activity [9], we saw some minor differences in physical activity in relation to highest parental education. This was true for total volume of physical activity (i.e. cpm) and MVPA and to a lesser extent for sedentary time. A plausible explanation for the limited association is that the variability in parental education was fairly low in our study area. BMI did not confound the main findings in our study, as shown in the sensitivity analyses with further adjustments for BMI. Previous studies have shown conflicting results regarding the relation between BMI and physical activity in studies of normal-weight children [24,28].

As shown in numerous studies, girls tend to be less active than boys [11,29] and the amount and intensity of physical activity are likely to decrease with age [5]. This is true in our study as well. Since children's physical activity generally decreases with age, it is of high importance to create and maintain public outdoor environments that could help to establish positive lifestyle behaviours, including high levels of physical activity already at a young age, as well as encouraging both boys and girls to stay active as they grow older [30].

Policy implications and further research

When we analyzed neighbourhood resources for physical activity as a score, a positive association with physical activity was suggested. This association appeared less strong when investigating the environmental attributes (foot and bike paths, non-restricted destinations and recreational areas) individually. One may speculate upon the existence of a possible interactional relation between different attributes, potentially captured by the neighbourhood score used in the present study. This further stresses the need to consider the entire neighbourhood environment when discussing interventions aiming at promoting physical activity among young children.

Enhanced knowledge about environmental factors that may increase intensity, duration and frequency of physical activity in young children should form the basis for planners and politicians to design neighbourhood environments that are suitable for the needs of younger as well as older children of both sexes. It may also stress the need to preserve and maintain existing environments and places that encourage young children to be physically active. Also, in areas with a fluctuating climate similar to the Swedish context, it is of great importance to pay attention to seasonal variations, since the same environmental attributes might be used differently by different children depending on weather conditions, temperature and daylight.

Conclusions

Our findings suggest a positive association between neighbourhood resources for physical activity and physical activity during leisure time in weekdays among young children in Sweden. Further research should seek to identify combinations of environmental characteristics that promote physical activity in children of different ages, with a specific focus on seasonal variations.

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Conflict of interest

The authors declare that there is no conflict of interest.

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