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Determinants of Activity-friendly Neighborhoods for Children: Results From the SPACE Study

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Abstract

Purpose. *To examine the association between children's physical activity and factors of the built environment.*

Design. *Cross-sectional study.*

Setting. *Ten neighborhoods in six cities in the Netherlands.*

Subjects. *Four hundred twenty-two children (age range, 6–11 years; 49% male).*

Measures. *Physical activity diary, neighborhood observations, and anthropometric measures.*

Analysis. *Univariate and multivariate linear regression analyses.*

Results. *According to univariate analyses adjusted for age, sex, body mass index, and highest level of maternal education, physical activity (≥ 3 metabolic equivalents) was significantly ($p < .05$) associated with the proportion of green space, with the residential density, with the general impression of activity-friendliness of the neighborhood, and with the frequency of certain types of residences (e.g., terraced houses), sports fields, water, dog waste, heavy traffic, and safe walking and cycling conditions (e.g., cycle tracks and 30-km speed zones) in the neighborhood. According to adjusted multivariate analyses, physical activity was best predicted by the frequency of parallel parking spaces in the neighborhood and by the general impression of activity-friendliness of the neighborhood ($R^2 = 0.193$).*

Conclusions. *Children's physical activity is associated with certain modifiable factors of the built environment. Longitudinal studies should examine whether there is a causal relationship. (Am J Health Promot 2007;21[4 Supplement]:312–316.)*

Key Words: Physical Activity, Environment Design, Children, Prevention Research. Manuscript format: research; Research purpose: modeling/relationship testing; Study design: nonexperimental; Outcome measure: behavioral; Setting: local community; Health focus: fitness/physical activity; Strategy: built environment; Target population: youth; Target population circumstances: education/income level, geographic location

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INTRODUCTION

The increasing prevalence of pediatric overweight and obesity has raised the awareness of children's decreasing physical activity level.[1–3] To promote physical activity among children, its determinants need to be understood. There is extensive literature on demographic and psychosocial determinants, but literature on built environmental determinants of children's physical activity lags behind.[4,5]

In American and Australian studies, associations between factors of the built environment and children's physical activity have been found.[6–9] However, these associations cannot be easily generalized to the Netherlands, one of the most densely populated countries in the world (483 inhabitants/km^2). The Netherlands has a compact land-use pattern, geared to the needs of nonmotorists. In Dutch cities, where space is especially sparse, house building often gets higher priority in urban planning than playgrounds. Furthermore, sports facilities are moved out of city centers to their boundaries, posing a possible barrier to go there on foot or by bike.[10]

The purpose of the Spatial Planning and Children's Exercise (SPACE) study was to examine the association between factors of the built environment and children's physical activity in the Netherlands. This study should guide public health practitioners, policy makers, and urban planners in modeling neighborhoods into activity-friendly neighborhoods.

METHODS

Design

The SPACE study was a cross-sectional study on children's physical activity in 10 neighborhoods of six cities in the Netherlands. Five of these neighborhoods were selected from a list of 56 disadvantaged neighborhoods designated by the government for spatial restructuring in the near future. The other five neighborhoods were selected to investigate the effects of environmental changes on children's physical activity in the future. These neighborhoods were matched on type and construction period of residences and on socioeconomic status and age distribution of residents. Selection criteria were inclusion of pre– and post–World War II neighborhoods, variation in type of residences (private and rented properties and low- and high-rise buildings) and amount of green space, and presence of at least two elementary schools. Neighborhood boundaries were defined by city councils. The 10 neighborhoods varied in size (mean, 130 [range, 51–228] hectares) and in population density (mean, 8106 [range, 4390–16,278] residents/km^2). All measurements (i.e., physical activity diary, neighborhood observations, and anthropometric measures) were conducted between October 2004 and January 2005. An ethics committee approved the study.

Sample

A cross-section of children aged 6 to 11 years living in the selected neighborhoods was recruited from 20 elementary schools (two schools per neighborhood). Children in this age group were studied because they are more dependent on their neighborhood for their physical activities compared with younger and older children who have smaller (i.e., a block of houses) and larger (i.e., several neighborhoods) radii, respectively, of action.[10] Informed consent was obtained from the parents of 1228 children. Fifty-one percent (n = 625) of the children returned the activity diary. Children failing to complete the diary for at least 4 days (including a weekend day) (n = 104)[11] and children with missing data on body mass index (BMI) (n = 6) or on maternal education (n = 93) were excluded from the analyses. The final sample consisted of 422 children (Table 1). This sample was older than the original sample of 1228 children (mean±SD age, 8.3±1.4 vs. 7.8±1.5 years; $t_{1226} = -5.315$, $p < .001$). No difference was found in weight, sex, or maternal education between the final and original samples.

Table 1

Characteristics of the Sample by Sex

Characteristic	Boys (n = 207)	Girls (n = 215)
Age, y	8.3±1.4	8.3±1.5
Physical activity, h/wk	12.2±5.9	11.5±6.3
Body mass index, %		
Normal weight	78	68
Overweight	15	24
Obesity	7	8
Maternal education, %		
Low	30	26
Medium	53	55
High	17	19

Measures

Dependent Variable. Time (h/wk) spent in performing physical activity of at least a moderate intensity (≥ 3 metabolic equivalents)[12] served as the dependent variable. It was assessed by a 7-day activity diary that was completed by the children, together with a parent. For all waking hours, all activities were noted at the end of each day, including the duration (in minutes) and the corresponding category (i.e., active commuting, activities during school time, organized sports, playing outdoors, and activities at home). Guiding questions and a bookmark with commonly performed activities per category were provided with the booklet.

Independent Variables. Factors of the built environment served as independent variables. They were collected by two trained research assistants who walked together through the neighborhoods after school using a checklist that they completed in unison. The checklist consisted of 54 items in the following eight categories: *type of residences* (10 items; scoring, 1 [none] to 5 [all]), *sports facilities* (12 items; scoring, 0 [nonexistent] to 1 [existent]), *recreation facilities and playgrounds* (7 items; scoring, 0 [nonexistent] to 1 [existent]), *green space and water* (3 items; scoring, 1 [none] to 4 [many]), *safe walking and cycling conditions* (14 items; scoring, 1 [few] to 3 [many]), *garbage and dirt* (2 items; scoring, 1 [few] to 3 [many]), *traffic safety* (5 items; scoring, 1 [few] to 3 [many]), and *general impression of the activity-friendliness of a neighborhood* (i.e., the suitability to play outdoors, walk, and cycle for children) (1 item; scoring, 1–10). The checklist is based on the Neighborhood Environment Walkability Scale (test-retest reliability: intraclass correlation coefficient, 0.58–0.80)[13] but was modified to reflect the Dutch built environment, including factors relevant to children (e.g., playgrounds, school yard, and dog waste), as identified by focus group interviews before the study.

Other independent variables included body height and weight, age, sex, and highest level of maternal education. Body height and weight while wearing indoor clothes (without shoes) were measured by two research assistants with a portable stadiometer and a digital scale. The BMI was calculated as weight in kilograms divided by height in meters squared and was categorized into normal weight, overweight, and obesity.[14]

Statistical Analysis

Univariate and multivariate linear regression analyses were conducted in SPSS 11.5 to examine the association between children's physical activity and factors of the built environment. The following 23 built environmental factors were excluded from analysis because of insufficient variance between neighborhoods: blocks of flats with more than 12 stories, sports halls, athletics tracks, tennis courts, climbing halls, go-kart tracks, skating rinks, skateboard tracks, indoor ski runs, golf courses, school yards, playgrounds (e.g., swings, climbing frame, and sandbox), children's farms, sidewalks, pedestrian crossings, traffic lights, traffic islands, multistory parking lots, speed humps, roundabouts, zones with limited access to cars, trams, and garbage. After crude analyses, all models were adjusted for age, sex, BMI, and maternal education. Factors that reached significance ($p < .05$) in the adjusted univariate analyses were included in the multivariate analyses (forward entry, $p < .05$). All regression

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Table 2

Univariate Models of the Association Between Factors of the Built Environment and Children's Physical Activity

Factor	Range	Crude Analyses B (95% CI)	Adjusted Analyses† B (95% CI)	Multilevel Adjusted Analyses† B (95% CI)
Residential density	237 to 430	0.010 (0.002 to 0.018)*	0.009 (0.001 to 0.017)*	0.015 (−0.011 to 0.042)
Detached houses	1 to 2	1.635 (0.212 to 3.057)*	1.138 (−0.281 to 2.556)	0.757 (−3.497 to 5.011)
Semidetached houses	1 to 4	0.583 (−0.142 to 1.309)	0.277 (−0.439 to 0.993)	0.147 (−1.938 to 2.232)
Terraced houses	1 to 4	1.719 (0.939 to 2.499)*	1.508 (0.726 to 2.290)*	1.201 (−1.161 to 3.563)
Staircase entrance flats	1 to 4	−1.552 (−2.080 to −1.023)*	−1.472 (−1.992 to −0.953)*	−1.503 (−2.720 to −0.286)*
Blocks of flats, stories				
1–3	1 to 3	1.211 (0.495 to 1.927)*	1.233 (0.533 to 1.933)*	1.949 (−0.417 to 4.315)
4–6	1 to 4	0.809 (0.065 to 1.553)*	0.795 (0.064 to 1.525)*	1.171 (−0.731 to 3.074)
7–12	1 to 3	0.255 (−0.433 to 0.942)	0.153 (−0.535 to 0.840)	0.362 (−2.176 to 2.901)
Proportion residents/commercial properties	70 to 90	−0.012 (−0.098 to 0.073)	0.006 (−0.078 to 0.090)	0.009 (−0.319 to 0.337)
Unoccupied houses	1 to 3	−3.567 (−5.087 to −2.047)*	−3.080 (−4.625 to −1.535)*	−2.286 (−5.543 to 0.972)
Sports fields	0 to 1	2.867 (1.572 to 4.163)*	2.804 (1.555 to 4.052)*	2.945 (−0.784 to 6.674)
Swimming pools	0 to 1	−0.806 (−2.013 to 0.402)	−1.124 (−2.323 to 0.074)	−1.290 (−5.598 to 3.199)
Gyms/health clubs	0 to 1	−0.689 (−1.868 to 0.490)	−0.494 (−1.641 to 0.654)	−0.804 (−5.223 to 3.614)
Paved playgrounds	0 to 1	−1.549 (−2.736 to −0.362)*	−1.372 (−2.549 to −0.195)*	−2.171 (−6.092 to 1.748)
Grass fields	0 to 1	−0.865 (−2.251 to 0.522)	−0.903 (−2.245 to 0.438)	0.086 (−4.422 to 4.592)
Parks	0 to 1	−0.455 (−1.639 to 0.729)	−0.234 (−1.401 to 0.934)	−0.502 (−4.690 to 3.689)
Lakes/ponds/canals	0 to 1	0.331 (−1.057 to 1.720)	0.584 (−0.773 to 1.940)	0.798 (−3.663 to 5.528)
Green space	2 to 3	0.976 (−0.386 to 2.338)	0.865 (−0.494 to 2.225)	0.729 (−3.923 to 5.381)
Proportion green space/buildings	5 to 40	0.074 (0.023 to 0.125)*	0.075 (0.024 to 0.125)*	0.078 (−0.075 to 0.231)
Water	1 to 3	2.938 (1.722 to 4.154)*	2.662 (1.453 to 3.871)*	2.001 (−1.437 to 5.439)
Dog waste	1 to 3	−1.359 (−2.288 to −0.430)*	−1.182 (−2.104 to −0.260)*	−1.510 (−4.316 to 1.296)
Cars/motors driving with high speed	1 to 3	−1.206 (−2.333 to −0.079)*	−0.972 (−2.079 to 0.136)	−0.955 (−4.122 to 2.213)
Cars outside parallel parking space	1 to 2	−1.081 (−2.368 to 0.206)	−0.839 (−2.097 to 0.420)	0.245 (−4.224 to 4.713)
Heavy traffic	1 to 3	−2.255 (−3.167 to −1.342)*	−1.896 (−2.814 to −0.978)*	−1.709 (−4.565 to 1.148)
Heavy lorry/bus traffic	1 to 2	−2.807 (−4.057 to −1.557)*	−2.356 (−3.587 to −1.125)*	−2.402 (−6.026 to 1.942)
Cycle tracks	1 to 2	2.665 (0.609 to 4.720)*	2.445 (0.439 to 4.451)*	2.170 (−2.285 to 6.625)
Zebra crossings	1 to 3	−2.086 (−3.115 to −1.057)*	−1.815 (−2.854 to −0.776)*	−1.829 (−4.637 to 0.978)
Parallel parking spaces	1 to 3	2.386 (1.628 to 3.144)*	2.152 (1.408 to 2.897)*	2.123 (0.231 to 4.014)*
Parking lots	1 to 3	3.258 (2.145 to 4.372)*	3.169 (2.055 to 4.284)*	3.342 (0.821 to 5.863)*
30-km Speed zones	1 to 3	2.273 (1.142 to 3.404)*	1.815 (0.700 to 2.929)*	1.026 (−2.027 to 4.080)
Intersections	1 to 3	−1.068 (−1.854 to −0.282)*	−1.035 (−1.825 to −0.246)*	−1.130 (−3.609 to 1.350)
Activity friendliness	5.0 to 7.5	2.050 (1.319 to 2.781)*	1.990 (1.255 to 2.724)*	2.284 (0.393 to 4.175)*

CI indicates confidence interval. B corresponds to the increase or decrease of the number of hours per week of physical activity with an increase of one unit in the particular factor of the built environment, adjusted for other factors in the model.
† Adjusted for age, sex, body mass index, and maternal education.
* $p < 0.05$.

analyses controlled for linearity and colinearity. To adjust for clustering of subjects within neighborhoods, multilevel analyses were also conducted.

RESULTS

On average, children spent a mean±SD of 11.8±6.1 h/wk performing physical activity (≥3 metabolic equivalents), ranging from 7.4±4.5 to 15.5±7.3 h/wk among the 10 neighborhoods ($F_9 = 8.23$, $p < .001$). Overall, there were 20 built environmental factors that were significantly associated with children's physical activity, when adjusted for age, sex, BMI, and maternal education (Table 2).

Children's physical activity was positively associated with the proportion of green space and with the frequency of terraced houses, blocks of flats with fewer than 6 stories, water, cycle tracks, and 30-km speed zones in the neighborhood. It was also positively associated with the frequency of parallel parking spaces and parking lots in the neighborhood, with the residential density, and with the general rating of activity-friendliness of the neighborhood.

Negative associations were found for the frequency of staircase entrance flats (3–4 stories without elevator), unoccupied (boarded up) houses, dog waste, heavy (lorry and bus) traffic, and intersections in the neighborhood. Children's physical activity was also negatively associated with the frequency of zebra (striped) crossings in the neighborhood. Zebra crossings are frequently found in neighborhoods with more heavy traffic ($r = 0.71$, $p < .001$) and intersections ($r = 0.49$, $p < .001$).

In contrast to our expectations, no significant associations were found for

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Table 3

Multivariate Models of the Association Between Factors of the Built Environment and Children's Physical Activity

Factor	Crude Analyses	Adjusted Analyses†	Multilevel Adjusted Analyses†
	B (95% CI)	B (95% CI)	B (95% CI)
Parallel parking spaces	2.159 (1.416 to 2.902)*	1.943 (1.213 to 2.673)*	1.933 (0.474 to 3.392)*
Activity friendliness	1.802 (1.093 to 2.512)*	1.767 (1.050 to 2.484)*	1.776 (−0.015 to 3.566)

CI indicates confidence interval. B corresponds to the increase or decrease of the number of hours per week of physical activity with an increase of one unit in the particular factor of the built environment, adjusted for other factors in the model.

† Adjusted for age, sex, body mass index, and maternal education.

* $p < 0.05$.

sports and recreation facilities, except for sports fields. Furthermore, a negative association was found between children's physical activity and the frequency of paved playgrounds in the neighborhood.

Overall, the adjusted univariate models explained 8.1% to 14.7% of the variance in children's physical activity. Factors that explained most of the variance were the general rating of activity-friendliness of the neighborhood (14.0%) and the frequency of parallel parking spaces (14.7%), parking lots (14.5%), and staircase entrance flats in the neighborhood (14.5%). These four factors were the only factors that remained significantly associated with children's physical activity in the adjusted univariate multilevel analyses.

Table 3 gives the results of the multivariate analyses. Children's physical activity was best predicted by the frequency of parallel parking spaces in the neighborhood and by the general rating of activity-friendliness of the neighborhood ($R^2 = 0.136$ and adjusted $R^2 = 0.132$). When age, sex, BMI, and maternal education were entered in the model, children's physical activity was still best predicted by these two factors ($R^2 = 0.193$ and adjusted $R^2 = 0.182$). Parallel parking spaces remained significantly associated with children's physical activity in the adjusted multivariate multilevel analysis. These spaces are frequently found in neighborhoods with more 30-km speed zones ($r = 0.64$, $p < .001$) and sports fields ($r = 0.62$, $p < .001$), and less heavy lorry and bus traffic ($r = -0.65$, $p < .001$).

DISCUSSION

Summary

In 10 Dutch neighborhoods, the time children aged 6 to 11 years spent in physical activity (≥3 metabolic equivalents) was significantly associated with the proportion of green space, the residential density, the general rating of activity-friendliness of the neighborhood, and the frequency of certain types of residences, sports fields, paved playgrounds, water, dog waste, heavy (lorry and bus) traffic, and safe walking and cycling conditions in the neighborhood. When these factors were combined in a multivariate model, two factors remained significantly associated with children's physical activity (i.e., the frequency of parallel parking spaces in the neighborhood and the general rating of activity-friendliness of the neighborhood). This model explained 19.3% of the variance in children's physical activity.

Limitations

Several methodological shortcomings of the SPACE study need to be mentioned. First, 49% of the children did not return the activity diary. The final sample was significantly older than the original sample. However, it is unlikely that the small age difference caused substantial underestimation or overestimation of the associations found. Second, the cross-sectional design did not allow us to determine whether there is a causal relationship between factors of the built environment and children's physical activity or whether children and their parents self-select into certain neighborhoods. The present study will be repeated after spatial restructuring of 5 of the 10 neighborhoods. Third, the study was performed in 10 neighborhoods with limited variance in the built environment. Any future study should be extended to more rural areas or to other countries to add variance.

Implications

Children's physical activity is associated with certain modifiable factors of the built environment. Modeling neighborhoods into activity-friendly neighborhoods may be an effective strategy to increase children's physical activity level. The California Safe Routes to School program has proved that environmental changes can increase children's active commuting to school.[6] The role of parallel parking spaces in children's physical activity should be investigated further. Children living in high-density neighborhoods might use empty parking spaces during the daytime for playing outdoors. Children may feel safer when playing on the sidewalk because of the barrier that parked cars create. Parallel parking spaces might also reduce the speed of motorists.[15] Furthermore, the perceived quality of the built environment seems important to consider in future studies, as (in contrast to our expectations) no significant associations were found between children's physical activity and the frequency of several sports and recreation facilities and playgrounds. The frequency and availability of these facilities are perhaps not determinants of children's physical activity but rather their (perceived) quality in terms of safety (e.g., visibility from residences, street lighting, fences, and safety tiles), state of repair, and suitability to the wishes and needs of boys and girls of different

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ages. This idea is supported by Sallis and colleagues,[7] who demonstrated that it was not the size (quantity) of school environments but their quality in terms of improvements and the presence of supervision that explained most of the variance in children's physical activity.

Public health practitioners, policy makers, and urban planners might use the general rating of activity-friendliness of a neighborhood to classify neighborhoods (R^2 = 0.140). Whether this measure is valuable in other, more rural, Dutch neighborhoods or in other countries, needs further study.

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