Relationship between the objectively-assessed neighborhood area and activity behavior in Swiss youth

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ABSTRACT

Background. Neighborhood attributes are modifiable determinants of physical activity (PA) and sedentary behavior (SB). We tested whether the objectively-assessed built and social environment was associated with PA and SB in Swiss youth and whether sex, age and the socioeconomic position (Swiss-SEP) modified such associations.

Methods. We combined data of 1742 youth (ages 4 to 17) from seven studies conducted within Switzerland between 2005–2010. All youth provided accelerometer data and a home address, which was linked to objective environmental data and the Swiss-SEP-index. Associations between neighborhood attributes and PA were analyzed by multivariable multilevel regression analyses.

Results. The extent of green areas and building density was positively associated with PA in the total sample ($p < 0.05$). Factors representing centrally located areas, and more schoolchildren living nearby tended to increase PA in secondary schoolchildren, boys and those from lower-ranked socioeconomic areas. In primary schoolchildren, the extent of green areas was positively associated with PA ($p = 0.05$). Associations between neighborhood attributes and PA were more pronounced in youth from low socioeconomic areas.

Conclusions. The results indicate that some associations between neighborhood attributes and PA differ by age, sex and socioeconomic area. This should be taken into account when planning interventions to increase childhood PA.

Introduction

There is great concern that physical activity (PA) levels of youth have decreased, while time spent in sedentary activities has increased over the last decades, necessitating public health action to promote active lifestyles and to prevent sedentary behavior. Ecological models postulate multiple environmental influences on PA such as the neighborhood environment (Sallis et al., 2006). A review of more than one hundred studies evaluating the relationship between neighborhood environment and youth PA (Ding et al., 2011) found that proximity to parks was the most consistent factor associated with PA in children. Several studies found that a high land-use mix and the presence of recreational facilities were positively associated with PA levels among adolescents. The same review concluded that objectively-measured environmental attributes were more consistently related to PA than reported environmental characteristics, possibly due to lower measurement errors (Ding et al., 2011). Yet most studies assessing the correlation of neighborhood attributes with PA or sedentary behavior (SB) used self-reported environmental data (Van Der Horst et al., 2007; Ding et al., 2011).

The vast majority of previous studies were conducted in North America or Australia (Ding et al., 2011; Davison and Lawson, 2006), where neighborhood attributes often differ from those in European settings, thereby limiting the generalizability of the findings. A Belgian study concluded that 'high-walkable' neighborhoods in the US might be considered 'low-walkable' neighborhoods by European standards

(Van Dyck et al., 2009). Information from European youth primarily derives from Belgium where associations between objective neighborhood attributes and physical activity have been tested in adolescents. This study found significant associations between walkability and PA in low socioeconomic status (SES) neighborhoods but not in high SES neighborhoods (De Meester et al., 2012; De Meester et al., 2013a). Yet, information in younger age-groups is still scarce and patterns might differ by countries. An international comparison showed that significantly more Swiss than Belgian adolescents accumulated 60 min MVPA per day (Verloigne et al., 2012).

Assessing PA and SB represents a further challenge as self-reported PA and SB in children are of limited validity (Chinapaw et al., 2010; Bringolf-Isler et al., 2012). Thus, objective methods such as accelerometer measurements are recommended (Rowlands and Eston, 2007). Accelerometers are expensive and their use in population studies is time consuming, thus many accelerometer-based studies use only small sample sizes (Ferreira et al., 2007), thereby limiting their power for subgroup analyses. Yet, such analyses may be important for understanding whether the built environment has a differential impact on PA/SB for specific sub-groups (Ding et al., 2011; Boone-Heinonen and Gordon-Larsen, 2011).

We investigated in a large sample of 1742 Swiss youth (1) whether the objectively-assessed neighborhood was associated with accelerometer-based PA levels and SB of Swiss youth and (2) whether such associations were modified by sex, age or the socioeconomic position of the neighborhood.

Methods

Study population and setting

Data for Swiss students participating in seven studies (Brug et al., 2012; Zahner et al., 2006; Niederer et al., 2009; Bringolf-Isler et al., 2009; Genuneit et al., 2011; Von Mutius et al., 2006; Ikaö Bern et al., 2009) were extracted and compiled in a national database (Dössegger et al., 2013). The studies were conducted between 2005 and 2010 and used Actigraph accelerometers to assess PA. Two of the above studies were conducted in primary schools (Niederer et al., 2009; Von Mutius et al., 2006) two in secondary schools (Genuneit et al., 2011; Brug et al., 2012) and three in both (Zahner et al., 2006; Bringolf-Isler et al., 2009; Ikaö Bern et al., 2009). Two studies included primarily rural youth (Von Mutius et al., 2006; Genuneit et al., 2011) and two primarily urban ones (Brug et al., 2012; Niederer et al., 2009) whereas in the others, urban, suburban and rural youth were involved (Zahner et al., 2006; Bringolf-Isler et al., 2009; Ikaö Bern et al., 2009). To be included in this data pool, raw accelerometer data outputs, demographic information and an exact home address had to be available. The individual studies had been approved by the respective ethics committees. All participants or their parents gave written informed consent before participation.

Accelerometer measures

All included studies used Actigraph accelerometers, model AM7164, GT1M or GT3X. Accelerometers measure the acceleration of the body, integrating the measures continuously as "counts" over a predefined time period. Previous studies have shown that the measures of the vertical axis are comparable between the different models (John et al., 2010; Kozey et al., 2010). Nevertheless, in the present study, all of the analyses were adjusted for accelerometer model. All accelerometers were removed for water activities and except for one study not worn during sleeping hours. As the studies used different epoch lengths (15 to 60 s), all files were reintegrated into an epoch of 60 s using ActiLife 4.9 software. Data reduction was conducted using MeterPlus 4.2 software. Non-wearing time was defined as a period of 20 min of consecutive zero counts. Children were included in the study if they had accumulated ≥10 hour wearing time on at least two weekdays and one weekend day. Besides total PA (TPA) in counts per minutes (cpm), moderate to vigorous PA (MVPA) was calculated using age-dependent cut-offs (Freedson et al., 2005) and the cut-off for SB was set at 100 cpm (Trost et al., 2011).

Personal characteristics

Personal characteristics such as sex and age were obtained from questionnaires. Time of data collection was classified as summer (April to September) or winter (October to March).

Environmental data

Environmental data were individually linked to valid addresses. For all neighborhood attributes, different buffer sizes (near, median and distant buffer) were used because no reference sizes exist for European settings. The definitions of the neighborhood attributes, the buffer sizes and the respective descriptive statistics are presented in Table 1. The selection of the neighborhood attributes has been based on previous analyses (Ding et al., 2011; Bringolf-Isler et al., 2010; Frank et al., 2009). These variables were expected to provide information about walkability such as density (population and building), diversity (land use mix) and design (intersection density) (Ewing and Cervero, 2010). We further included greenness (green space and woods), traffic danger (main street density), access to peers (schoolchildren density) and the socioeconomic position of the neighborhood. Arc Map 10 (Esri, 2011) was used to calculate the main street density and the intersection density. Information about population density, building density, mixed land use and the number of schoolchildren living nearby was based on census data (Bundesamt Für Statistik, 2009b; Bundesamt Für Statistik, 2009a). The mixed land use score is a simplified version of a score proposed by IPEN-group (International PA and Environment Network) (Frank et al., 2009). Information on green spaces and wooded areas was based on land use statistics (Bundesamt Für Statistik, 2010). The socioeconomic status of each neighborhood was based on the Swiss neighborhood index of socioeconomic position (Swiss-SEP) (Panczak et al., 2012) The Swiss SEP was validated and has been related to health outcomes and all-cause mortality (Panczak et al., 2012).

Statistical analysis

All analyses were conducted with STATA 11.0 (Statacorp, 2007). Differences in the distribution of variables were analyzed using the Kruskal Wallis-test.

Spearman correlations and factor analyses were computed for all attributes of the near, median and distant neighborhood. To test the respective associations between cpm, MVPA and SB (dependent variables) and each of the environmental factors, multilevel regression models were computed, adjusting for sex, age, season, accelerometer model and study-cluster. MVPA and SB were additionally adjusted for wearing time. School was added as additional level (baseline model). Age was modeled using splines. The baseline regression models were then expanded to include all environmental attributes, unless they were highly ($r > 0.60$) correlated with each other (expanded model). If so, the variable with the highest factor load has been used. The significance value was set at $p < 0.05$ except for the testing of interactions ($p < 0.1$). For subgroup analyses, the fully adjusted regression models were also run stratified by age-group (primary schoolchildren aged 4 to 10 and secondary schoolchildren aged 11 to 17), sex and Swiss SEP-score-division (SEP score ≤5 and >5). Interactions of the association between neighborhood attributes and PA (age-group ∗ neighborhood attributes, sex ∗ neighborhood attributes, SEP-score-division ∗ neighborhood attributes, study-cluster ∗ neighborhood attributes) were tested using the likelihood ratio test.

Table 1
Description of the neighborhood attributes.

Variable name	Variable description	Unit	Near neighborhood Mean (SD) or n (%)	Distant neighborhood Mean (SD) or n (%)
Main street density	Length of main street segments within a radius around the place of residence	Meters per 200/500/1000 m buffer	444.9 (339.3)	9025.2 (5363.5)
Population density	Data available per hectare (ha) and summed up for different buffers	n per 9/25/49 ha	410.4 (361.9)	1666.7 (1464.0)
Building density	Data available per hectare (ha) and summed up for different buffers	n per 9/25/49 ha	53.5 (34.0)	208.9 (132,9.9)
Intersection density	Number of intersections per radius around the place of residence	n per 200/500/1000 m buffer	10.8 (6.6)	193.1 (101.7)
Land use mix	Score indicating the presence or absence of 5 types of land use (residential, entertainment, retail, office, institutional)[a] per buffer. A score of 1 denotes residential only, while a score of 5 indicates a high land-use mix.	Score 1 to 5 per 9/25/49 ha. Score of 1 or 2: Score of 3: Score of 4 or 5:	551 (31.6%) 335 (19.2%) 865 (49.1%)	176 (10.1%) 70 (4.0%) 1496 (85.9%)
Green space (parks, play grounds and meadows)	Number of hectares denoted to green spaces within different buffers	ha of parks, playgrounds, meadows per 9/25/49 ha	1.4 (1.9)	8.0 (8.7)
Woods	Number of hectares denoted to woods within different buffers	ha of parks, playgrounds, meadows per 9/25/49 ha	0.5 (1.1)	5.3 (6.9)
School children density	Data available per hectare (ha) and summed up for different buffers	n per 9/25/49 ha	13.4 (14.7)	90.1 (76.8)
Socioeconomic neighborhood position (Swiss SEP)	Score is based on the median rent per square meter, the proportion of household headed by a person with primary education or less, the proportion headed by a person in a manual or unskilled occupation and the mean number of persons per room. The lowest decile indicates low position.	Deciles of the Swiss SEP-score (The neighborhood boundaries for each building were defined by road network connectivity, resulting in one buffer per child.)	5.4 (2.9)	–

9 ha results from a squared buffer of 3 * 3 ha around the place of residence, 25 ha results form a squared buffer of 5 * 5 ha around the place of residence and 49 ha results form a squared buffer of 7 * 7 ha around the place of residence.
All studies were conducted in Switzerland between 2005 and 2010.
 [a] The same building categories were used in the International PA and Environment Network (IPEN)-score but the IPEN-score is based on floor area, information that was not available for Switzerland.

Results

Sociodemographic characteristics

Questionnaire information on personal factors were available for 2240 youth, 1860 of them had valid accelerometer data. The final sample consisted of 1742 youth who in addition provided a valid home address (Table 2). Older students and girls accumulated less TPA and MVPA and significantly more SB. During the summer season, all participants were significantly more physically active and less sedentary than in winter.

Environmental factors

Building density, population density, intersection density and land-use mix were positively correlated (r = 0.48 to 0.65) and negatively correlated with the amount of green space (r = −0.38 to −0.62) (Supplementary Tables A.1 and A.2). When performing a factor analysis, these characteristics also loaded on one factor, possibly representing centrally located places of residence. In the near neighborhood but not in the distant neighborhood, main street density was independent of variables representing centrally located places of residence. Indicators of the social environment (Swiss SEP

Table 2
Characteristics and physical activity behavior of the study population.

	n (%)	Total PA (cpm) Mean (SD)	MVPA (min/day) Mean (SD)	SB (min/day) Mean (SD)
Total	1742 (100)	601.1 (178.0)	192.4 (84.9)	397.5 (75.6)
Primary school (4 to 10 years)	759 (43.6)	667.0 (175.0)	251.5 (67.3)	328.00 (124.6)
Secondary school (11 to 17 years)	983 (56.4)	550.2 (163.1)***	146.8 (71.9)***	451.1 (113.8)***
Boys	875 (50.2)	645.3 (178.4)	204.5 (84.0)	387.4 (74.9)
Girls	867 (49.8)	557.5 (166.2)***	180.7 (83.9)***	407.7 (75.3)***
Summer	976 (56.0)	627.1 (184.8)	213.8 (82.6)	386.4 (75.5)
Winter	766 (44.0)	568.0 (163.3)***	165.3 (82.9)***	411.6 (75.8)***

PA = physical activity.
cpm = counts per minute.
MVPA = moderate to vigorous physical activity.
SB = sedentary behavior.
All studies were conducted in Switzerland between 2005 and 2010.
 * p ≤ 0.05.
 ** p ≤ 0.01.
*** p ≤ 0.001.

Table 3
Adjusted associations between near neighborhood attributes and physical activity behavior (regression coefficient[a] (95% confidence interval)).

	Unit	Total PA (cpm)		MVPA (min/day)		Sedentary (min/day)	
		Baseline model[b]	Expanded model[c]	Baseline model[b]	Expanded model[c]	Baseline model[b]	Expanded model[c]
Main street density	m per 200 m buffer	−7.9 (−18.1, 2.2)	−6.1 (−17.0, 4.8)	−0.9 (−3.7, 1.9)	−0.9 (−3.7, 2.2)	−1.1 (−5.1, 2.9)	−1.3 (−5.6, 3.1)
Population density	n/9 ha	3.4 (−7.8, 14.7)		2.7 (−0.4, 5.8)		−2.1 (−6.6, 2.3)	
Building density (in model 2 representative for central urban areas)	n/9 ha	12.1 (−0.4, 24.6)	17.3 (2.9, 31.7)*	2.9 (−0.5, 6.4)	4.2 (0.2, 8.2)*	−0.8 (−5.8, 4.1)	−4.2 (−10, 1.5)
Intersection density	n per 200 m buffer	2.4 (−7.4 to 12.2)		1.7 (−1.0, 4.4)		−1.2 (−5.1, 2.7)	
Mixed land use	Score 1–5	8.3 (−9.4, 25.9)		3.2 (−1.7, 8.0)		−2.8 (−9.8, 4.2)	
Green space	ha/9 ha	7.6 (−1.9, 17.0)	12.0 (1.8, 22.7)*	1.4 (−1.2, 3.9)	2.4 (−0.4, 5.2)	−3.6 (−7.4, 0.2)	−4.5 (−8.7, −0.4)*
Woods	ha/9 ha	1.2 (−5.7, 8.1)	3.3 (−3.6, 10.3)	−0.5 (−2.4, 1.4)	−0.1 (−2.1, 2.0)	0.8 (−1.9, 3.6)	0.5 (−2.7, 3.6)
Schoolchildren density	n/9 ha	4.0 (−3.5 11.5)	2.6 (−3.4, 8.6)	−0.4 (−2.5, 1.6)	−0.5 (−2.2, 1.1)	2.3 (−0.7, 5.3)	1.9 (−0.5, 4.2)
Socioeconomic neighborhood position (Swiss SEP)[d]	Deciles 1–10	15.5 (1.0, 30.0)*	11.4 (−3.6, 26.4)	2.0 (−2.0, 6.0)	1.3 (−2.8, 5.4)	4.7 (−1.1, 10.5)	4.4 (−1.6, 10.4)

PA = physical activity.
cpm = counts per minute.
MVPA = moderate to vigorous physical activity.
Green space = parks, playgrounds and meadows.
All studies were conducted in Switzerland between 2005 and 2010.
* $p < 0.05$.
[a] For an increase of one interquartile range (from the 25th to the 75th percentile) of each environmental attribute.
[b] Baseline model: adjusted for sex, age, season of data collection, accelerometer device wearing time and study.
[c] Expanded model: adjusted for baseline model plus all neighborhood attributes shown in the table.
[d] 1 = lowest decile of the Swiss socioeconomic neighborhood position score.

and schoolchildren density) were weakly correlated with the neighborhood environmental attributes.

Associations between the environment and PA or SB

In the near environment among the variables representing centrally located places of residence, building density and green space were associated with PA measures (Table 3). Main street density tended to be negatively associated with TPA, yet not statistically significant. Living in an area with a higher SEP-score was associated with more TPA in the baseline model. Except for green space, none of the near neighborhood attributes was significantly associated with SB.

Results were similar when the attributes of the distant neighborhood were related to PA measures (Supplementary Table B), except for the association between main street density, which tended to be associated with more PA and less SB in the more distant neighborhood.

Interactions by age, sex and Swiss SEP-score-division

Significant interactions between environmental characteristics and PA in the near neighborhood were found by age, sex and SEP-score-division (Fig. 1 and Supplementary Table C). Interactions by SEP-score-division were the most frequent ones. Associations between TPA and main street density, building density and the number of schoolchildren as well as MVPA and building density were stronger in those living in lower socioeconomic neighborhoods. Moreover, a significant negative association between building density and green spaces with SB was found only in youth living in low SEP-index neighborhoods. More green space in the neighborhood had a strongly positive association with TPA and SB in younger children. Older youth tended to be more active in areas with a high building density and in areas where more school-aged children lived. Boys were slightly more active and less sedentary when living in an area of high building density and when more schoolchildren lived
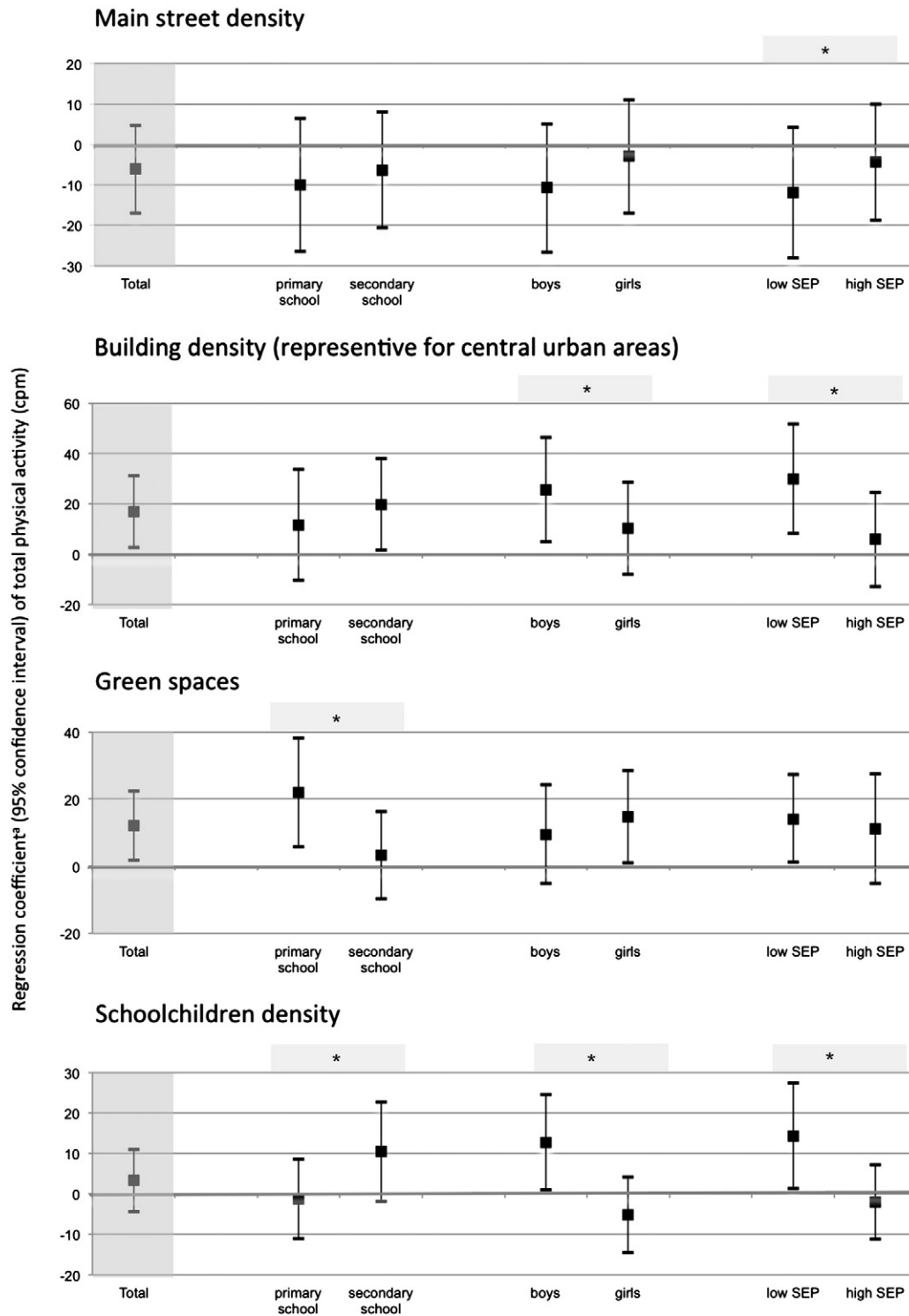
close by. No significant interaction was found by study-cluster in the near environment.

Discussion

This study investigated the relation between youths' objectively-assessed physical and social environment and their PA behavior measured by accelerometers. Neighborhood characteristics representing a centrally located place of residence were correlated among each other, but were independent of main street density and of indicators of the social environment. High building density and more green space in the neighborhood were positively associated with PA. Except for green space, none of the neighborhood attributes was significantly related to SB in the total sample. Subgroup analyses revealed that several of the observed associations were modified by socioeconomic neighborhood, age and sex.

In the present study youth were more physically active in centrally located areas (represented by building density) which is in line with some previous studies showing that access to parks and greater housing density increased objectively measured PA of children (Roemmich et al., 2007). Associations between building density and PA were particularly evident in secondary schoolchildren, boys and youth from low SES areas. This is important as the decrease of physical activity by age and the higher prevalence of obesity in youth from a lower SES status is a concern (Ferreira et al., 2007). Priority in the planning of interventions should thus be given to these vulnerable subgroups. Yet, in urban areas access to parks should be provided, especially for younger children.

Land-use mix score, indicating the degree to which diversity of land use was present in a given neighborhood, was not related to objectively-assessed PA although the factor is correlated to building density. Mixed land use has previously been related to reported walk trip frequency (Frank et al., 2007) and mode of travel to school (Larsen et al., 2009)

Main street density

Building density (representive for central urban areas)

Green spaces

Schoolchildren density

Fig. 1. Stratified analyses by age-group, sex and neighborhood socioeconomic position class for neighborhood. Regression coefficients[a] and 95% confidence intervals for total physical activity are given by environmental attribute. Legend: cpm counts per minute. SEP neighborhood socioeconomic position. [a] for an increase of one interquartile range (from the 25th to the 75th percentile) of each environmental factor. * significant interaction (likelihood ratio test <0.1). All studies were conducted in Switzerland between 2005 and 2010.

in US studies, but not to objectively-measured PA (Ding et al., 2011). Half of the youth in the present study lived in one of the high land-use mix score categories (49.1% in category 4 or 5), limiting discrimination capacity of the present analysis. A recent Belgian study (De Meester et al., 2013b) of adolescents also reported that the perceived land-use mix reached a mean of 3.8 for a score ranging from 1 to 4. A high

land-use mix score might thus be a more typical feature of European urban form.

Neighborhood attributes of different zones around the place of residence were evaluated in the present study. Associations with PA were strongest with indicators of the near environment, which is in line with the observation that children tend to be active close to home and

spend the majority of their physically active time in their immediate neighborhood (Jones et al., 2009).

The role of neighborhood SES in youths' PA is complex and evidence of an association with PA is conflicting (Stone et al., 2012; Voorhees et al., 2009). These discrepancies might reflect the variability of definitions of neighborhood SES and, our limited understanding of how SES relate to measures of physical activity. It might also be due to effect modification as several studies found that associations between neighborhood attributes and PA were different in low and in high SES neighborhoods (De Meester et al., 2012; Owen et al., 2007; Kerr et al., 2006) In the present study, all significant associations between the built environment and PA behavior were found in youth from the lower SEP-score-division. Moreover, also schoolchildren density was only associated with TPA when analyses were restricted to low SEP-score neighborhoods. Schoolchildren density in the near environment may be an indicator of opportunities for unstructured play with peers. In line with this interpretation, Brockmann et al. showed that children from low SES neighborhoods have less access to structured exercise, but profit more from unstructured play for their PA (Brockman et al., 2009). Such findings should be integrated in urban planning, as children living in low SES areas are generally those who are most difficult to reach through PA interventions (De Meester et al., 2013a).

For an individual child, the measured beneficial or negative effect of environmental factors on physical activity is a few minutes or counts. Yet, given the widespread exposure to these environmental factors, their impact on physical activity at a population level may be considerable. In addition, measures of the built environment used in the present study were rather crude, resulting in considerable exposure misclassification and generally leading to an underestimation of the effect estimates.

The present study fills several gaps highlighted in previous systematic reviews (Ding et al., 2011; Davison and Lawson, 2006; Ferreira et al., 2007). It used objectively-measured data both to assess neighborhood characteristics as well as PA. In contrast to many US- and Australian-based studies (Ding et al., 2011), it was conducted in Europe and was based on a sufficiently large dataset to allow for subgroup analysis. Yet, the study also has several limitations. Accelerometer measurements were collected in different studies. Although standardized data reduction methods were applied and the study-cluster and accelerometer device were controlled for, we cannot completely exclude that the heterogeneity of the data collection affected the results. A second limitation is the cross sectional design of the study prohibiting causal inferences. Then, multiple testing might have caused type 1 errors. Finally data on parental perceptions were not available. Yet, the interaction of an individual with the environment and the assessment of parental fears might be as important as measuring the environment itself (Maddison et al., 2009). Thus future studies should combine information from objective neighborhood attributes and parental perceptions.

Conclusions

The physical environment and the social environment were associated with youths' PA. Associations of the built environment with PA were particularly seen in youth from low SES-neighborhood providing a potential to improve PA by urban planning in those who are difficult to reach through other PA interventions. Overall, access to green spaces in the immediate neighborhood seems to be relevant to stimulate physical activity. Future studies should include information about objective neighborhood attributes, individual psycho-social characteristics as well as parental neighborhood perceptions.

Conflict of interest statement

The authors declare that there are no conflicts of interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.pmedr.2014.09.001.

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