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ORIGINAL ARTICLE

Association of objectively measured and perceived environment with accelerometer-based physical activity and cycling: a Swiss population-based cross-sectional study of children

Bettina Bringolf-Isler[1,2] · Christian Schindler[1,2] · Kees de Hoogh[1,2] · Bengt Kayser[3] · L. Suzanne Suggs[4] · Alain Dössegger[5] · Nicole Probst-Hensch[1,2] · The SOPHYA Study Group

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Abstract

Objectives We tested whether objectively assessed neighbourhood characteristics are associated with moderate-to vigorous physical activity (MVPA) and cycling in Swiss children and adolescents and assessed the mediating role of the perception of the environment.

Methods The cross-sectional analyses were based on data of 1306 participants aged 6–16 years of the population-based SOPHYA study. MVPA was measured by accelerometry, time spent cycling and the perceived environment by questionnaire. Objective environmental parameters at the residential address were GIS derived. In all analyses, personal, social and environmental factors were considered.

Results MVPA showed significant positive associations with perceived personal safety and perceived access to green spaces but not with respective objective parameters. Objectively assessed main street density and shorter distance to the next public transport were associated with less cycling in adolescents. Parents' perceptions did not mediate the observed associations of the objectively assessed environment with MVPA and cycling.

Conclusions Associations between the environment and physical activity differ by domain. In spatial planning efforts to improve objective environments should be complemented with efforts to increase parental sense of security.

Keywords Accelerometer · Physical activity · Cycling · Perceived neighbourhood · Objectively assessed neighbourhood · Children · SOPHYA

Introduction

Physical activity (PA) levels in youth decreased over the last decades, and there is a concern that children and adolescents do not meet the physical activity recommendations of at least 60 min of moderate-to-vigorous intensity physical activity (MVPA) (WHO 2011). Reasons are multifaceted and changes in the environment possibly play a key role (D'Haese et al. 2015). Such changes could be real but may also reflect a shift in perceptions. Both can have an impact on children's PA behaviour and are not necessarily correlated (Prins et al. 2009). People can be influenced by the objective environment subconsciously (Kremers et al. 2006), but an activity friendly environment does not cause an increase in PA if it is not used (Giles-Corti and Donovan 2003). If the objective environment influences parental perceptions, it can have an indirect impact on children's PA. Pathway analyses allow studying

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✉ Bettina Bringolf-Isler
bettina.bringolf@swisstph.ch

[1] Swiss Tropical and Public Health Institute, Socinstrasse 57, 4051 Basel, Switzerland

[2] University of Basel, Basel, Switzerland

[3] Institute of Sport Sciences, University of Lausanne, Lausanne, Switzerland

[4] Institute of Public Communication, University della Svizzera italiana, Lugano, Switzerland

[5] Swiss Federal Institute of Sport SFISM, Magglingen, Switzerland

the separate contributions and interrelations of objective and subjective factors.

According to socioecological models (Sallis et al. 2006), the complexity of the environment–physical activity association is further increased by the interactions between the individual characteristics and those of their environment. On the one hand, environmental effects may differ by sociodemographics (Bringolf-Isler et al. 2014). On the other hand, an individual's social and cultural background may influence its perception of the environment. For example, people with a higher socio-economic background (SES) perceived identical objective environments as safer and more attractive than persons of lower socio-economic status (Kamphuis et al. 2007).

These complex interactions between individual characteristics and the objective versus perceived environment can influence behaviour. Spatial activity patterns (Burgi et al. 2016) and PA behaviour differ between children from low- and high-SES neighbourhoods (Brockman et al. 2009), irrespective of their individual SES (Burgi et al. 2016). Youth from low SES neighbourhoods in Europe tends to spend more time with unstructured PA. In contrast, peers from higher SES neighbourhoods have the financial means to be more active in sport clubs (Bringolf-Isler et al. 2016; Brockman et al. 2009; De Meester et al. 2012; Lamprecht et al. 2015), and their PA thus depends less on the environment of their neighbourhood (Bringolf-Isler et al. 2014). The moderating effects of the socio-economic neighbourhood position (SEP) alongside cultural differences as well as urbanicity therefore have to be taken into account towards improved understanding of the association between the built environment and PA (Van Dyck et al. 2010). Furthermore, Giles-Corti and colleagues pointed out that environmental effects likely also vary by PA domain (Giles-Corti et al. 2005). According to a review summarising built environment correlates of cycling among children and youth, most of the 12 included studies focused on the commute to/from school. Little is known about factors associated with cycling for other purposes. The only environmental factor consistently associated with cycling was the distance of the trip (Larouche 2015). In Switzerland, the proportion of cycling adolescents decreased in the last decades (Bundesamt für Statistik 2017). For cycling, space and safe traffic conditions are needed to foster the development of adequate cycling skills (Van Dyck et al. 2010).

In light of the decline in children's PA, it is important to identify subgroup-specific barriers to be physically active, in order to tailor interventions. Environmental interventions are promising as they reach a large proportion of the population and have greater potential for long-term impact than behaviour change interventions (Sallis et al. 2006). Several studies tested associations between PA and the environment, but most of them studied either GIS-based data or perceptions, but not both (Ding et al. 2011). In general, self-reported PA or small accelerometer samples were used, even though objective measurement of (MVPA is recommended for youth (Rowlands and Eston 2007). Most studies were conducted in adolescents and in the USA or Australia (De Meester et al. 2012; McGrath et al. 2015), thereby limiting the generalizability of the findings.

The aim of the present study was to test whether objectively assessed neighbourhood characteristics are associated with children's and adolescent's MVPA and cycling habits, and whether such an association is mediated by the perceived environment considering the individual's and their neighbourhood characteristics. It also aimed to assess potential moderating effects by individual and social characteristics.

Methods

Study population and setting

The analyses used data from the cross-sectional SOPHYA study (Bringolf-Isler et al. 2018a, b; Gubelmann et al. 2018). In SOPHYA, physical activity was measured in a representative sample of Swiss children (6 to 11 years) and adolescents (12 to 16 years) to identify barriers for an active lifestyle. Recruitment was based on national inhabitant registry data of the Federal Statistical Office in Switzerland. The study's base population are children and adolescents born between 1998 and 2007 and living in Switzerland. In a first part of the study, a telephone interview about sport behaviour and sociodemographics was conducted between February 2013 and February 2015 (Lamprecht et al. 2015). After the interview, the families were asked whether they were interested in a second assessment that used accelerometers. A random sample of those families was re-contacted between December 2013 and June 2015 for accelerometer measurements and a short questionnaire. The present study sample consisted of families participating in both parts. All parents gave written informed consent for their own and their children's participation. Adolescents filled in an additional consent form. The study was approved by the ethics committee of the Canton of Basel (147/13). It was performed in accordance with the ethical standards delineated in the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

Telephone interview

The telephone interview was conducted by a professional field research institute (LINK institute, Lucerne,

Switzerland) using computer-aided telephone interviews. Information collected included age, sex, household income and sport behaviour.

Objectively assessed physical activity

Accelerometers and instructions for their use were sent to the participants by post after an oral instruction by phone. All participants wore an Actigraph accelerometer model GT1M or GT3X (ActiGraph, Pensacola, Florida, USA) for seven consecutive days fixed to the right hip with an elastic band. The accelerometers had to be removed for water activities and during sleeping hours. After the measurement, the accelerometers were mailed back to the study team. The initialization of the devices, the downloading of the data and their analyses were conducted using ActiLife 6.2 software (ActiGraph, Pensacola, Florida, USA). Epoch length was set at 15 s, and non-wearing time was defined as a period of 60 min of consecutive 0 counts. For both accelerometer types, only the vertical axis was considered. Mean moderate-to-vigorous physical activity (MVPA) volume over 1 week was calculated multiplying the mean of the weekdays by 5 and the mean of the weekend day by 2 and dividing the sum by 7. For the definition of MVPA, age-dependent cut-offs were used (Freedson et al. 2005) with thresholds for moderate activity of 4 METs (Troiano et al. 2008).

Parental questionnaire: perceived neighbourhood data and cycling

A parental questionnaire asking about the PA behaviour of the child during the measurement week (e.g. how they commuted to school), health indicators and the perceived neighbourhood was sent to the families together with the accelerometer. One question asked how much time the child spent cycling (hours/week) during the measurement week and was the basis for defining cycling as one of the study endpoints. The perception of the neighbourhood was assessed using the Australian CLAN study questionnaire (Children Living in Active Neighbourhoods) (Carver et al. 2008). The parents were asked about their perceptions of road safety, incivilities and personal safety of their children. Each question responses included a five-point scale ranging from strongly disagree (scored as − 2) to strongly agree (scored as + 2). In a previously conducted test–retest analysis (Carver et al. 2008), the items reached reliabilities of .41 to .81. This is consistent with results found in a pretest conducted in the preparation of the SOPHYA study. The single items were grouped into scores for road safety ranging from − 6 to + 6, incivilities (− 8 to + 8) and personal safety of the child (− 10 to + 10). A final question asked about access to parks and playgrounds used in a previous study (Bringolf-Isler et al. 2008). The single questions are listed in Table 2. According to reverse scoring of questions on road safety and incivilities, on personal safety ("I am worried that my child might be assaulted when out alone in our neighbourhood"), and on the single item "my neighbourhood is generally free from litter, rubbish or graffiti" a high score indicates an adverse situation.

Objective neighbourhood data

Objective neighbourhood data were linked to the residential address of participants. Neighbourhood attributes were selected based on previous analyses (Bringolf-Isler et al. 2014; Frank et al. 2009) to cover similar aspects between the objective and perceived neighbourhood environment (Table 2). For all GIS analyses, ArcMap 10.2.1. (ESRI, Redlands, CA, USA) was used. For objectively assessed road safety, the length of main streets (in m) within a 200 m radius was derived from Swiss Topo Vector 25 (Bundesamt für Landestopographie der Schweiz 2000). As a measure of aesthetics and incivilities, the crime rate per 100,000 inhabitants (Bundesamt für Statistik 2014) was used. Objectively assessed personal safety was captured by the following four variables: the walkability index (see below), the number of dead ends within a radius of 200 m, the number of schoolchildren within a radius of 200 m (Bundesamt für Statistik 2014), and the distance of the shortest route to the nearest bus, tram or railway station (Bundesamt für Landestopographie der Schweiz 2000). The walkability index is a commonly used and previously described measure to test the pedestrian friendliness of an area (Frank et al. 2009). It is calculated using the z-scores of the residential density, the land use mix and the street connectivity at a 1 × 1 resolution. The land use mix was extracted from Corine landcover (European Environment Agency 2006) and classified areas into "residential", "industrial or commercial units" and "entertainment". For greenness, the satellite-derived normalised difference vegetation index (NDVI) for the year 2014 were extracted (Weier and Herring 2000). Information about the socio-economic neighbourhood was based on the Swiss neighbourhood index of socio-economic position (SEP) (Panczak et al. 2012). The Swiss SEP divides Swiss areas into socio-economic deciles. The deciles from 1 to 5 were defined as low, and the deciles 6 to 10 as high socio-economic neighbourhoods. The Swiss SEP was validated and is related to all-cause mortality (Panczak et al. 2012). The boundaries of the language regions reflect the definition of the Federal Office of Statistics (Bundesamt für Statistik 2012).

Statistical analyses

All analyses were conducted with STATA 14.0 (Statacorp, 2015). Differences in MVPA and time spent cycling according to sociodemographics and neighbourhood characteristics were assessed using linear regression models adjusted for sex and age. Associations of MVPA and cycling (dependent variables) with the items of the perceived and the objectively assessed environment were assessed using linear regression models adjusted for individual (age, sex, household income) and neighbourhood characteristics (SEP, language region, urbanicity) and for measurement-related factors (season, accelerometer wearing time and device (GT1M versus GT3x)). To remove skewness from the residuals, MVPA was log-transformed and a square root transformation was used for time spent cycling. For all items and scores of the perceived and for all parameters of the objectively assessed environment, interactions with individual and neighbourhood characteristics were tested by entering relevant interaction terms into the regression models. Interaction terms with $p < 0.1$ were considered as noteworthy. Pathway analyses applying the product of coefficient method were used to assess the mediating effect of perceived environment in the association between the objectively assessed environment and children's MVPA (Fig. 1). The following associations were estimated: (a) associations between parameters of the objective environment and children's MVPA or cycling (*c*-path), (b) associations between parameters of the objective environment and their respective perception scores as potential mediators (*a*-path), (c) associations of the environmental perception scores with children's MVPA or cycling upon adjustment for the respective objective environmental parameters (*b*-path) and d) associations between parameters of the objective environment and children's MVPA or cycling upon adjustment for the respective environmental perception scores (c'-path). All analyses were adjusted for individual, neighbourhood and measurement factors. The mediating effect was calculated by multiplying the coefficient of the *a*-path with that of the *b*-path (= indirect effect). The statistical significance of a potential mediating effect was assessed using the Sobel-Test (Sobel 1982).

Results

Of the 2032 families contacted for accelerometer measurements and the questionnaire-based survey about health and the perceived environment, 421 families revoked their interest in participating. For 291 participants, the acceptance criterion of at least 3 weekdays with 10 h each and at least 1 weekend day with 8 h for valid accelerometer data was not fulfilled (due to technical problems for 39 participants and insufficient compliance of 252 participants). Valid measurements of 1320 youth aged 6 to 16 years were retained. Among these, 14 did not complete the questions about the perceived environment and cycling time was missing for 10, resulting in final analysis samples of $n = 1306$ for correlates of MVPA and $n = 1296$ for cycling.

On average, children and adolescents spent about 80 min in MVPA and cycled for about 1 h/week. Accelerometer-based MVPA decreased with age. Boys and children living in the German-speaking part of the country accumulated more MVPA than girls and peers from the other language regions (Table 1). MVPA increased with household income, yet the highest MVPA was accumulated in children whose parent(s) did not want to indicate their income. Lowest MVPA was measured in winter. For cycling, an association with age was observed: adolescents spent more time cycling per week than children. Cycling was significantly more prevalent in boys, in children living in the German-speaking part of Switzerland, and for those living in rural areas. Children and adolescents cycled more in summer and less in winter compared to spring and autumn.

Parental perceptions of neighbourhood safety are presented in Table 2. Perceptions were generally more favourable if families lived in high SEP areas, in German-speaking regions or in non-urban areas (online supplementary Table 1). Log-transformed MVPA of children was positively associated with the parent's perceived personal safety score and the perceived access to green spaces. For cycling, the association with parental perceptions was less consistent. While no overall association of the perceived environment score with cycling time was observed, there was a positive association if, according to parents, there was heavy traffic in the local street and if stranger danger was not a concern.

The prevalence of objectively assessed neighbourhood factors also varied by geographic region: road safety, low crime rate and green spaces reached more favourable levels in high SEP areas, in the German-speaking part and in non-urban areas (online supplementary Table 2). The correlation between the scores for the perceived environment and the corresponding parameters of the objectively assessed environment were weak to non-existent ($r = -0.04$ to 0.3) (online supplementary Table 3).

None of the objective environmental factors exhibited a significant association with log-transformed MVPA in the total sample (*c*-path). Some associations between the parameters of the objectively assessed environment and the respective score of the perceived environment were found (*a*-path). But the objectively assessed environment had no substantial impact on the perceived environment—MVPA

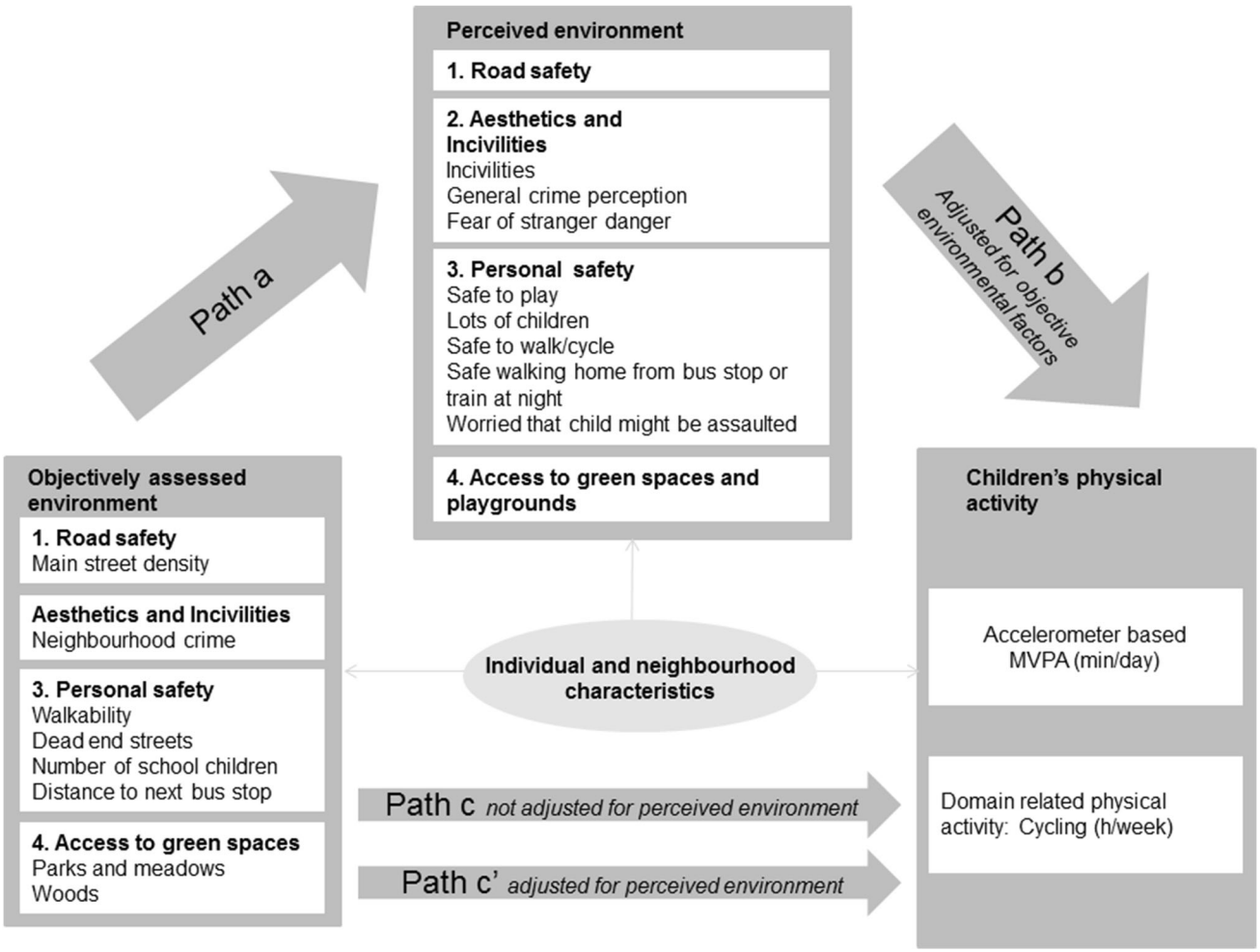

Fig. 1 Mediation effects of the perceived environment on the associations between children's moderate-to-vigorous physical activity and cycling and the objectively assessed environment. Swiss children's objectively assessed PHYsical Activity 2014, Switzerland. *c*-coefficient: estimates of the associations between each items of the objective environment and children's physical activity (MVPA and cycling). *c*′-coefficient: estimates of the association between the items of the objective environment and children's physical activity (MVPA and cycling), adjusted for the items of the perceived environment. *a*-coefficient: estimates of the association between items of the objective environment and the items of the perceived environment. *b*-coefficient: estimates of the association between the items of the perceived environment and children's physical activity (MVPA and cycling), adjusted for the items of the objective environment. The *c*-path describes the direct effect of the objective environment on children's physical activity, the *a*-path * *b*-path the possible indirect effect. The total effect $c = c' + a * b$. MVPA = moderate-to-vigorous physical activity

associations (*b*-path), and the perceived environment had no impact on the objectively assessed environment—MVPA association (*c*′-path), suggesting the absence of any mediating effects by how parents perceived their residential neighbourhood (Table 3).

With regard to the association of the objective environment with MVPA, a noteworthy interaction between walkability index and SEP was found. Walkability was positively associated with MVPA in low SEP areas 7.9 (− 1.8; 17.8), but negatively in high SEP areas − 4.5 (− 11.9; 2.9); *p* for interaction = 0.08 (Fig. 2).

Equivalent analyses were conducted for time spent cycling as outcome (Table 4). The only significant association between the different parameters of the objective environment and time spent cycling (*c*-path) was found for access to public transport (inverse association). The association was unaffected by adjustment for perceived environment. Main street density was negatively associated with cycling in adolescents − 0.0002 (− 0.0004; − 0.00000), but not in children 0.00002 (− 0.0001; 0.0002) (*p* for interaction = 0.09). As for MVPA above, walkability was negatively associated with cycling in areas with a high SEP − 17.5 (− 35.1; − 0.2), while positive associations were observed in areas with a low SEP 22.9 (− 1.9; 44.0) (*p* for interaction = 0.005)

None of the associations between the objective environment and MVPA or cycling were mediated by the respective scores of the perceived environment; all estimates of indirect paths effects were non-significant.

Table 1 Distribution of physical activity and cycling, by individual and neighbourhood characteristics

	n (%)	Accelerometer-based moderate-to-vigorous physical activity Mean min/day (SE[c]) *n* = 1306	*n*(%)	Time spent with cycling (h/week) Mean (SE[c]) *n* = 1296
Overall				
All	1306 (100)	78.5 (1.0)	1296 (100)	1.1 (0.1)
Age				
6 to 11 years (ref)	838 (64.2)	93.2 (1.0)	831 (51.2)	0.9 (0.0)
12 to 16 years	468 (35.8)	52.2 (1.3)***	465 (48.8)	1.3 (0.1)***
Sex				
Boy (ref.)	671 (51.4)	88.4 (0.9)	664 (51.2)	1.2 (0.6)
Girl	635 (48.6)	68.0 (0.9)***	632 (48.8)	0.9 (0.6)***
Household income[a]				
< 6′000 CHF (ref.)	272 (20.8)	75.1 (1.4)	267 (20.6)	1.0 (0.1)
6′000 to 9′000 CHF	409 (31.3)	78.9 (1.2)*	407 (31.4)	1.2 (0.1)
9′000 and more	475 (36.3)	79.3 (1.1)*	472 (36.4)	1.0 (0.1)
No information	150 (11.5)	80.6 (1.9)*	150 (11.6)	1.2 (0.1)
Language region[a]				
German	907 (69.5)	80.6 (0.9)	901 (69.5)	1.3 (0.1)
French	250 (19.1)	75.9 (1.6)**	247 (19.1)	0.6 (0.1)***
Italian	149 (11.4)	70.0 (2.1)***	148 (11.4)	0.5 (0.1)***
Urbanicity				
Urban	250 (19.1)	80.9 (1.5)	249 (19.2)	0.9 (0.1)
Agglomeration	633 (48.5)	79.0 (0.9)	628 (48.5)	1.0 (0.1)
Rural	423 (32.4)	77.7 (1.2)	419 (32.3)	1.3 (0.1)***
Swiss socio-economic neighbourhood index[a]				
Low (score 1 to 5)	612 (46.9)	77.2 (1.0)	604 (46.6)	1.0 (0.1)
High (score 6 to 10)	694 (53.1)	79.6 (0.9)	692 (53.4)	1.2 (0.1)
Season[b] of measurement[a]				
Spring (ref.)	376 (28.8)	82.5 (1.2)	372 (28.7)	1.3 (0.1)
Summer	180 (13.8)	85.8 (1.8)	179 (13.8)	1.6 (0.1)**
Autumn	322 (24.7)	78.1 (1.3)	321 (24.8)	1.1 (0.1)
Winter	428 (32.8)	73.3 (1.1)***	424 (32.7)	0.7 (0.1)***

Swiss children's objectively assessed PHYsical Activity 2014, Switzerland

*p value ≤ 0.05

**p value ≤ 0.01

***p value ≤ 0.001

[a]Age and sex adjusted

[b]*Spring* March–May, *summer* June–August, *autumn* September–November, *winter* December–February

[c]*SE* standard error

Discussion

This study analysed whether objectively assessed neighbourhood characteristics are associated with children's and adolescent's MVPA and cycling habits, and whether such an association is mediated by the perceived environment considering the individual's and their neighbourhood characteristics. According to the results of this study, youth overall MVPA in the total sample did not depend on the objective environment, but rather on their parent's perception of the neighbourhood, in particular their perception of personal safety and access to green spaces. In contrast, the level of cycling did depend on objectively assessed road safety as well as the distance to the next stop of a

Table 2 Independent association of parents' perceived neighbourhood with offspring's physical activity and cycling

	"Agree" or "strongly agree" %[a]	Increase of ln(MVPA[b]) in min/day per unit increase in the perceived environment score Coefficient (95% CI[c])	Increase of (cycling time)[5] in h/day per unit increase in the perceived environment score Coefficient (95% CI[c])
1. Road safety score of − 6 to + 6 based on three 5-point items scored from − 2 to + 2		0.00 (− 0.01; 0.00)	0.01 (− 0.01; 0.02)
There are major barriers to walking/cycling in my local neighbourhood that make it hard for my child to get from place to place (e.g. freeways, major roads)	22.0	0.00 (− 0.01; 0.02)	− 0.01 (− 0.04: 0.02)
There is heavy traffic in our local streets	33.5	− 0.01 (− 0.02; 0.00)	0.04 (0.01; 0.07)*
Road safety is a concern in our area	15.6	− 0.01 (− 0.03; 0.01)	0.01 (− 0.02; 0.05)
2. Aesthetics and incivilities score of − 8 to + 8 based on four 5-point items scored from − 2 to + 2		− 0.01 (− 0.01; 0.00)	0.00 (− 0.02; 0.01)
My neighbourhood is generally free from litter, rubbish and graffiti	91.9	0.01 (− 0.01; 0.03)	− 0.01 (− 0.05; 0.03)
There is a high crime rate in our neighbourhood	1.9	− 0.01 (− 0.03; 0.01)	− 0.02 (− 0.08; 0.04)
I am worried about troublemakers hanging around my neighbourhood	3.5	0.00 (− 0.02; 0.02)	0.03 (− 0.02; 0.08)
Stranger danger is a concern of mine	16.6	− 0.01 (− 0.03; 0.00)	− 0.03 (− 0.07; 0.00)*
3. Personal safety score of − 10 to + 10 based on five 5-point items scored from − 2 to + 2		0.01 (0.00; 0.01)**	0.01 (− 0.00, 0.02)
It is safe for my child to play or hang-out in the street outside our house	81.4	0.03 (0.01; 0.04)**	0.03 (− 0.01; 0.07)
Lots of children play or hang-out in our street	57.7	0.02 (0.00; 0.03)*	0.02 (− 0.01; 0.05)
My neighbourhood is safe for my child to walk/cycle around the block alone in the daytime	83.7	0.01 (− 0.01; 0.03)	0.02 (− 0.02; 0.06)
My child would be safe walking home from a bus stop or train at night	51.1	0.02 (0.01; 0.04)**	− 0.02 (− 0.05; 0.02)
I am worried that my child might be assaulted when out alone in our neighbourhood	6.83	− 0.02 (− 0.04; 0.00)*	− 0.03 (− 0.07; 0.01)
4. Access to parks and playground: 5-point item (from − 2 to + 2)	82.9	0.02 (0.01; 0.04)**	0.02 (− 0.02; 0.06)
My child can play on a playground, park or other public places (play street, schoolyard) in its neighbourhood without supervision			

Swiss children's objectively assessed PHYsical Activity 2014, Switzerland

Adjusted for age, sex, household income (< 6000 CHF, 6000 to 9000 CHF, > 9000CHF, socio-economic neighbourhood index (SEP) (score from 1 to 10), language region (German, French, Italian), urbanicity (urban, agglomeration, rural), season (spring, summer, autumn, winter) and for the MVPA model also for accelerometer wearing time and device type (GT1M and GT3X)

For road safety and aesthetics, a higher score denotes less favourable environments, and for the personal safety and access to parks and playgrounds, a higher score denotes a more favourable environment

*p value ≤ 0.05

**p value ≤ 0.01

***p value ≤ 0.001

[a]Response to statement about neighbourhood was "strongly agree" (+ 2) or "agree" (+ 1)

[b]*MVPA* moderate-to-vigorous physical activity

[c]*CI* confidence interval

public transport. Pathway analyses disclosed no mediating effects of parent's neighbourhood perception in associations of the objectively assessed environment with MVPA and cycling, respectively.

Several sociodemographic factors were significantly associated with MVPA. There was a decrease by age and an increase by SES, boys and German-speaking youth being more active than girls and peers from the other

Table 3 Mediation effects of parents' perceived environment on the associations between the objectively assessed environment and children's log-transformed moderate-to-vigorous physical activity

		Total effect	Direct effect	Indirect effect		
		c-path All values for * 1000 coefficient (95% CI[b])	*c*′-path All values for * 1000 coefficient (95% CI[b])	*a*-path All values for * 1000 coefficient (95% CI[b])	*b*-path Coefficient (95% CI[b])	*ab*-path All values for * 1000 coefficient (SE[c])
Road safety						
Main street density	(*m*/200 m buffer)	0.0 (− 0.0; 0.1)	0.0 (− 0.0; 0.01)	2.3 (1.8; 2.9)***	− 0.004 (− 0.01; 0.02)	− 0.008 (0.00)
Aesthetics and incivilities						
Crime rate	*n*/100,000 inhabitants	0.1 (− 0.5; 0.6)	0.1 (− 0.4; 0.6)	11.0 (7.1; 14.8)***	− 0.006 (− 0.01; 0.001)	− 0.07 (0.00)
Personal safety						
Walkability	*z* score (1000 m)	0.2 (− 5.7; 6.1)	0.6 (− 5.3; 6.5)	− 44.4 (− 109.7; 20.8)**	0.009 (0.004; 0.01)***	− 0.39 (0.31)
Dead ends	*n*/200 m buffer	11.3 (− 4.0; 26.6)	9.9 (− 5.3; 25.2)	160.0 (− 7.5; 327.5)	0.009 (0.004; 0.01)***	0.001 (0.84)
Number of school children	*n*/200, buffer	− 0.0 (− 0.3; 0.3)	− 0.0 (− 0.06; 0.02.)	2.3 (− 0.6; 5.1)	0.009 (0.004; 0.14)***	0.02 (0.01)
Distance to the next bus stop	In *m*	0.0 (− 0.0; 0.1)	0.0 (− 0.0; 0.1)	0.3 (− 0.2; 0.8)	0.008 (0.004; 0.01)***	0.008 (0.002)
Access to playgrounds						
Green space (NDVI[a])	Score/1000 *m* buffer	− 17.2 (− 196.7; 162.3)	− 28.5 (− 207.6; 150.6)	456.1 (− 139.2; 1051.4)	0.25 (8.3; 41.2)**	11.2 (8.4)

Swiss children's objectively assessed PHYsical Activity 2014, Switzerland

Mediation effects in % are not given because none of the main effects was significant

All analyses adjusted for age, sex, household income, socio-economic neighbourhood index (SEP), language region, urbanicity, season, accelerometer time and device type

c-coefficient: estimates of the associations between each parameter of the objective environment (e.g. main street density) and children's log-transformed moderate-to-vigorous physical activity

c′-coefficient: estimates of the association between the parameter of the objective environment (e.g. main street density) and children's log-transformed moderate-to-vigorous physical activity, adjusted for the score of the perceived environment as potential mediator (e.g. the road safety score as perceived by parents) *a*-coefficient: estimates of the association between parameter of the objective environment (e.g. main street density) and the scores of the perceived environment (e.g. the road safety score as perceived by parents)

b-coefficient: estimates of the association between the score of the perceived environment (e.g. the road safety score as perceived by parents) and children's log-transformed moderate-to-vigorous physical activity, adjusted for the parameter of the objective environment (e.g. main street density)

The *c*-path describes the direct effect of the objective environment on children's log moderate-to-vigorous physical activity, while the product of *a*- and *b*-path coefficients provides an estimate of the possible indirect effect. The total effect equals the sum of the direct and the indirect effect

*p value ≤ 0.05

**p value ≤ 0.01

***p value ≤ 0.001

[a]*NDVI* normalised difference vegetation index

[b]*CI* confidence interval

[c]*SE* standard error

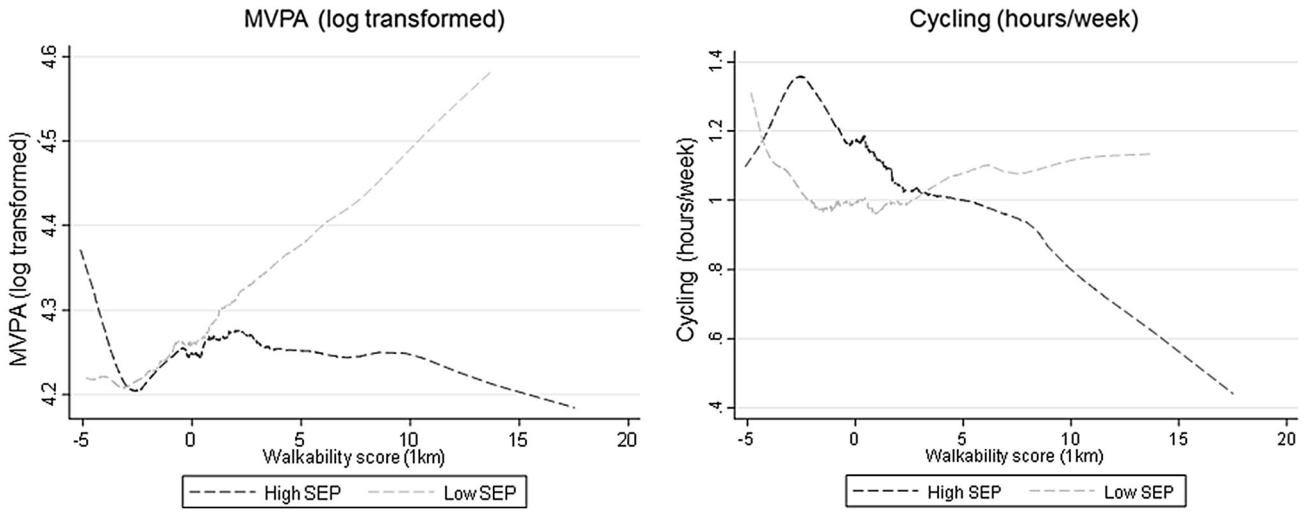

Fig. 2 Association between moderate-to-vigorous physical activity and cycling and the walkability index by socio-economic neighbourhood. Swiss children's objectively assessed PHYsical Activity 2014, Switzerland. *SEP* socio-economic neighbourhood position

language regions. This is consistent with previous findings, where French-speaking children were less physically active and more sedentary (Bringolf-Isler et al. 2018a) than German-speaking children (Bringolf-Isler et al. 2015). The difference could not be explained by the objectively assessed environment (Bringolf-Isler et al. 2015). In this sample, German-speaking parents perceived their neighbourhood more favourable than French- and Italian-speaking parents. It thus might be that parental perception and respective conclusions differ by culture and impact on the children's restrictions. Such patterns should be investigated more thoroughly in an international context. Accelerometer-based MVPA was significantly higher in Swiss adolescents than in other European countries (Verloigne et al. 2012) and compared to the Australian CLAN study, Swiss parents were less concerned about their neighbourhood safety, yet the association between personal safety and MVPA was stronger than that in the Australian sample (Carver et al. 2008).

In contrast to the objectively assessed green spaces, the perceived access was also positively associated with MVPA. This might reflect that not only the quantity of green spaces promotes youth to be active but also the quality of green spaces is important. Interestingly, in a previous analyses of the same data set, a contrary finding was found when testing such associations with sedentary behaviour, where a significant negative association was found with the objectively assessed green spaces but not with respective parental perceptions (Bringolf-Isler et al. 2018a). Probably the mechanisms are not the same for MVPA and sedentary behaviour. While a high quality of green spaces seems to increase MVPA, a low quantity may cause barriers to play outdoors, resulting in spending more time being sedentary.

Although cycling is part of MVPA, their correlates differed considerably. For example, overall MVPA decreased by age but cycling was more common in adolescents. This highlights the need to assess any barriers for an active lifestyle separately for different domains of PA. In contrast to children, adolescents showed a significant negative association between cycling and objectively assessed traffic safety. This might be surprising, as cycling skills are less developed in children. The reason could be that for adolescents the target-oriented transport, especially commuting to school (correlation between total time cycling and time spent cycling for school: $r = 0.7$), becomes important. Primary school children in Switzerland tend to walk to school (Bundesamt für Statistik 2017) as distances are short and the use of bicycles is often not allowed.

Among factors representing parent's perceptions, the positive direction of the association between traffic in local streets and cycling was surprising. However, it is consistent with an Australian study (Timperio et al. 2004) which concluded that this positive association reflects greater awareness of traffic conditions among parents whose children are engaging in these behaviours. Moreover, there was a negative association between stranger danger and cycling which might not be direct but an indicator of generally more cautious parents.

It could be that a good public transport network is a competitor to cycling, potentially explaining the negative association between cycling and the proximity to public transport. A Swiss pilot study found that if youth have the choice, they prefer public transports because they can use

Table 4 Mediation effects of the parents' perceived environment on the associations between the objectively assessed environment and youth's square root transformed time spent cycling time

		Total effect	Direct effect:		Indirect effect		Mediation effect %[a]
		c-path Coefficient (95% CI[c]) All values for * 1000	*c*′-path Coefficient (95% CI[c]) All values for * 1000	*a*-path Coefficient (95% CI[c]) All values for * 1000	*b*-path Coefficient (95% CI[c])	*ab*-path All values for *1000 Coefficient (SE[d])	
Road safety							
Main street density	(*m*/200 m buffer)	− 0.1 (− 0.2; 0.1)	− 0.1 (− 0.2; 0.0)	2.4 (1.8; 2.9)***	0.008 (− 0.005; 0.02)	0.02 (0.02)	
Aesthetics and incivilities							
Crime rate	*n*/100 000 inhabitants	− 0.3 (− 1.4; 0.09)	− 0.2 (− 1.4; 1.0)	0.10 (7.1; 14.8)***	− 2.8 (− 19.5; 13.9)	− 0.03 (0.1)	12.2
Personal safety							
Walkability	*z* score (1000 m)	− 1.1 (14.5; 12.3)	− 0.9 (14.4; 12.6)	− 46.1 (− 111.5; 19.3)	0.005 (− 0.007; 0.02)	− 0.2 (0.3)	19.6
Dead ends	*n*/200 m buffer	− 23.4 (− 57.9; 11.2)	− 24.1 (− 58.8; 10.4)	161.0 (− 7.1; 32.9)	0.005 (− 0.006; 0.02)	0.8 (1.0)	
Number of school children	*n*/200 m buffer	− 0.6 (− 0.1; 0.0)	− 0.1 (− 1.2; 0.0)	2.4 (− 0.5; 5)	0.005(− 0.006; 0.02)	0.01 (0.02)	
Distance to the next bus stop	In *m*	− 0.1 (− 0.2; − 0.0)*	− 0.1 (− 0.3; − 0.0)*	0.3 (0.2; 0.8)	0.005 (− 0.006; 0.02)	0.002 (0.002)	
Access to playgrounds							
Green space (NDVI[b])	Score/1000 m Buffer	79.1 (− 327.5; 485.7)	67.3 (− 339.5; 474.2)	454.2 (− 141.7; 1050.0)	0.03 (− 0.01; 0.06)	0.01 (0.01)	

Swiss children's objectively assessed PHYsical Activity 2014, Switzerland

All analyses adjusted for age, sex, household income, socio-economic neighbourhood index (SEP), language region, urbanicity, season

c-coefficient: estimates of the associations between each parameter of the objective environment (e.g. mains street density) and children's square root transformed cycling time

c′-coefficient: estimates of the association between the parameter of the objective environment (e.g. main street density) and children's square root transformed cycling time, adjusted for the scores of the perceived environment as a potential mediator (e.g. the road safety score as perceived by parents). *a*-coefficient: estimates of the association between parameter of the objective environment (e.g. main street dentistry) and the scores of the perceived environment (e.g. the road safety score as perceived by parents)

b-coefficient: estimates of the association between the scores of the perceived environment (e.g. the road safety score as perceived by parents) and children's square root transformed cycling time, adjusted for the objectively assessed road safety (e.g. main street density)

The *c*-path describes the direct effect of the objective environment on children's square root transformed cycling time, while the product of *a*- and *b*-path coefficients provides an estimate of the possible indirect effect. The total effect equals the sum of the direct and the indirect effect

*p value ≤ 0.05

**p value ≤ 0.01

***p value ≤ 0.001

[a]The significance of the mediation was only tested if the total effect was statistically significant

[b]*NDVI* normalised difference vegetation index

[c]*CI* confidence interval

[d]*SE* standard error

their mobile phones to be on social networks and also because they perceive cycling as less "cool" (Sauter and Wyss 2014). In addition, parents often support the use of public transport because they perceive it as safer.

For both MVPA and cycling, a positive association with walkability was observed in low SES neighbourhoods. Consistent with previous findings (Bringolf-Isler et al. 2014; De Meester et al. 2012), a high walkability tended to be associated with more MVPA and cycling in youth from

low SEP areas, whereas the opposite direction of the association was seen in high SEP areas. Considering these findings, interventions in low SES areas should focus on structural changes.

There are some limitations regarding this study which must be acknowledged. First, the study was of cross-sectional design making it impossible to draw conclusions about causality. Second, objective environmental parameters linked to children's and adolescent's residence are only surrogate measures of young peoples true environmental exposure, both tending to lead to an underestimation of associations. Third, questionnaires can be a source of bias because of social desirability. The bias may be aggravated by parents reporting on children's behaviour. This may also apply to self-reported information on cycling. The strengths of the study are the relatively large sample size based on national registry data, thus avoiding clustering, the inclusion of both objective and perceived neighbourhood characteristics, the use of accelerometers to assess MVPA and the approach to analyse associations considering multiple levels of influence across the ecological model in the analyses.

Conclusion

This study shows that the correlations of MVPA and cycling are not the same and that they differ by subgroup. Such differences should be considered when introducing interventions. For spatial planning, a high walkability in low SEP areas and safe routes to school for cyclists are recommended. As parental perceptions were independently associated with MVPA and to a lesser degree also with cycling, additional efforts should be aimed at objectifying parental sense of security.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all parents of participants included in the study. In addition also adolescents filled in a consent form.

References

Bringolf-Isler B, Grize L, Mader U, Ruch N, Sennhauser FH, Braun-Fahrlander C (2008) Personal and environmental factors associated with active commuting to school in Switzerland. Prev Med 46:67–73

Bringolf-Isler B, Kriemler S, Mader U, Dossegger A, Hofmann H, Puder JJ, Braun-Fahrlander C (2014) Relationship between the objectively-assessed neighborhood area and activity behavior in Swiss youth. Prev Med Rep 1:14–20. https://doi.org/10.1016/j.pmedr.2014.09.001

Bringolf-Isler B, Mader U, Dossegger A, Hofmann H, Puder JJ, Braun-Fahrlander C, Kriemler S (2015) Regional differences of physical activity and sedentary behaviour in Swiss children are not explained by socio-demographics or the built environment. Int J Public Health 60:291–300. https://doi.org/10.1007/s00038-014-0645-8

Bringolf-Isler B, Probst-Hensch N, Kayser B, Suggs S (2016) Schlussbericht zur SOPHYA-Studie. Swiss TPH, Basel

Bringolf-Isler B, de Hoogh K, Schindler C, Kayser B, Suggs LS, Dossegger A, Probst-Hensch N, Group SS (2018a) Sedentary behaviour in swiss children and adolescents: disentangling associations with the perceived and objectively measured environment. Int J Environ Res Public Health. https://doi.org/10.3390/ijerph15050918

Bringolf-Isler B, Schindler C, Kayser B, Suggs LS, Probst Hensch NM (2018b) Objectively measured physical activity in population-representative parent–child pairs: parental modelling matters and is context-specific. BMC Public Health 18(1):1024. https://doi.org/10.1186/s12889-018-5949-9

Brockman R, Jago R, Fox KR, Thompson JL, Cartwright K, Page AS (2009) "Get off the sofa and go and play": family and socioeconomic influences on the physical activity of 10–11 year old children. BMC Public Health 9:253. https://doi.org/10.1186/1471-2458-9-253

Bundesamt für Landestopographie der Schweiz (2000) Landestopographie Bf. VECTOR25–Das digitale Landschaftsmodell der Schweiz, Wabern

Bundesamt für Statistik (2012) Bundeamt für Statistik: Raumgliederung der Schweiz. https://www.bfs.admin.ch/bfs/de/home/grundlagen/raumgliederungen.assetdetail.2118452.html. Accessed 2 Oktober 2017

Bundesamt für Statistik (2014) Volkszählung, Neuenburg, Schweiz. https://www.bfs.admin.ch/bfs/de/home/statistiken/bevoelkerung/erhebungen/volkszaehlung.html. Accessed 21 Nov 2018

Bundesamt für Statistik (2017) Verkehrsverhalten der Bevölkerung. Ergebnisse des Mikrozensus Mobilität und Verkehr 2015. Neuchatel

Burgi R, Tomatis L, Murer K, de Bruin ED (2016) Spatial physical activity patterns among primary school children living in neighbourhoods of varying socioeconomic status: a cross-sectional study using accelerometry and Global Positioning

System. BMC Public Health 16:282. https://doi.org/10.1186/s12889-016-2954-8
Carver A, Timperio A, Crawford D (2008) Perceptions of neighborhood safety and physical activity among youth: the CLAN study. J Phys Act Health 5:430–444
De Meester F, Van Dyck D, De Bourdeaudhuij I, Deforche B, Sallis JF, Cardon G (2012) Active living neighborhoods: is neighborhood walkability a key element for Belgian adolescents? BMC Public Health 12:7. https://doi.org/10.1186/1471-2458-12-7
D'Haese S, Cardon G, Deforche B (2015) The environment and physical activity. In: Freulut ML (ed) The ECOG's Book on child and adolescent obesity, European Childooh Obesity Group (ECOG), Brussels
Ding D, Sallis JF, Kerr J, Lee S, Rosenberg DE (2011) Neighborhood environment and physical activity among youth a review. Am J Prev Med 41:442–455. https://doi.org/10.1016/j.amepre.2011.06.036
European Environment Agency (2006) Digital land cover (CORINE CLC-2006 Version 13.02-2010)
Frank LD, Sallis JF, Saelens BE, Leary L, Cain K, Conway TL, Hess PM (2009) The development of a walkability index: application to the Neighborhood Quality of Life Study. Br J Sports Med 44:924–933
Freedson P, Pober D, Janz KF (2005) Calibration of accelerometer output for children. Med Sci Sports Exerc 37:S523–S530
Giles-Corti B, Donovan RJ (2003) Relative influences of individual, social environmental, and physical environmental correlates of walking. Am J Public Health 93:1583–1589
Giles-Corti B, Timperio A, Bull F, Pikora T (2005) Understanding physical activity environmental correlates: increased specificity for ecological models. Exerc Sport Sci Rev 33:175–181
Gubelmann C, Marques-Vidal P, Bringolf-Isler B, Suggs LS, Vollenweider P, Kayser B (2018) Correlates of weekday compliance to physical activity recommendations in Swiss youth non-compliant in weekend days. Prev Med Rep 9:86–91. https://doi.org/10.1016/j.pmedr.2017.12.004
Kamphuis CB, van Lenthe FJ, Giskes K, Brug J, Mackenbach JP (2007) Perceived environmental determinants of physical activity and fruit and vegetable consumption among high and low socioeconomic groups in the Netherlands. Health Place 13:493–503. https://doi.org/10.1016/j.healthplace.2006.05.008
Kremers SP, de Bruijn GJ, Visscher TL, van Mechelen W, de Vries NK, Brug J (2006) Environmental influences on energy balance-related behaviors: a dual-process view. Int J Behav Nutr Phys Act 3:9. https://doi.org/10.1186/1479-5868-3-9
Lamprecht M, Fischer A, Wiegand D, Stamm H (2015) Sport Schweiz 2014. Kinder- und Jugenbericht. Bundesamt für Sport BASPO, Magglingen
Larouche R (2015) Built environment features that promote cycling in school-aged children. Curr Obes Rep 4:494–503. https://doi.org/10.1007/s13679-015-0181-8
McGrath LJ, Hopkins WG, Hinckson EA (2015) Associations of objectively measured built-environment attributes with youth moderate-vigorous physical activity: a systematic review and meta-analysis. Sports Med 45:841–865. https://doi.org/10.1007/s40279-015-0301-3
Panczak R, Galobardes B, Voorpostel M, Spoerri A, Zwahlen M, Egger M (2012) A Swiss neighbourhood index of socioeconomic position: development and association with mortality. J Epidemiol Community Health 1:2. https://doi.org/10.1136/jech-2011-200699
Prins RG, Oenema A, van der Horst K, Brug J (2009) Objective and perceived availability of physical activity opportunities: differences in associations with physical activity behavior among urban adolescents. Int J Behav Nutr Phys Act 6:70
Rowlands AV, Eston RG (2007) The measurement and interpretation of children's physical activity. J Sports Sci Med 6:270–276
Sallis JF, Cervero RB, Ascher W, Henderson KA, Kraft MK, Kerr J (2006) An ecological approach to creating active living communities. Annu Rev Public Health 27:297–322. https://doi.org/10.1146/annurev.publhealth.27.021405.102100
Sauter D, Wyss K (2014) Pilotstudie: Velonutzung von Jugendlichen im Kanton Basel-Stadt. Schlussbericht, Zürich
Sobel M (1982) Asymptotic confidence intervals for indirect effects in structural equation models. In: Leinhart S (ed) Sociological methodology. Jossey-Bass, San Francisco, pp 290–312
Timperio A, Crawford D, Telford A, Salmon J (2004) Perceptions about the local neighborhood and walking and cycling among children. Prev Med 38:39–47
Troiano RP, Berrigan D, Dodd KW, Masse LC, Tilert T, McDowell M (2008) Physical activity in the United States measured by accelerometer. Med Sci Sports Exerc 40:181–188
Van Dyck D, Cardon G, Deforche B, Sallis JF, Owen N, De Bourdeaudhuij I (2010) Neighborhood SES and walkability are related to physical activity behavior in Belgian adults. Prev Med 50(Suppl 1):S74–S79. https://doi.org/10.1016/j.ypmed.2009.07.027
Verloigne M, Van Lippevelde W, Maes L, Yildirim M, Chinapaw M, Manios Y, Androutsos O, Kovacs E, Bringolf-Isler B, Brug J, De Bourdeaudhuij I (2012) Levels of physical activity and sedentary time among 10- to 12-year-old boys and girls across 5 European countries using accelerometers: an observational study within the ENERGY-project. Int J Behav Nutr Phys Act 9:34. https://doi.org/10.1186/1479-5868-9-34
Weier J, Herring DH (2000) Measuring vegetation (NDVI & EVI). http://earthobservatory.nasa.gov/Features/MeasuringVegetation/. Accessed 21 Nov 2018
WHO (2011) Global strategy on diet, physical activity and health