International Journal of Obesity (2012) 36, 914–919

www.nature.com/ijo

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PEDIATRIC ORIGINAL ARTICLE

Spatial accessibility to physical activity facilities and to food outlets and overweight in French youth

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OBJECTIVE: Some characteristics of the built environment have been associated with obesity in youth. Our aim was to determine whether individual and environmental socio-economic characteristics modulate the relation between youth overweight and spatial accessibility to physical activity (PA) facilities and to food outlets.
DESIGN: Cross-sectional study.
SUBJECTS: 3293 students, aged 12 ± 0.6 years, randomly selected from eastern France middle schools.
MEASUREMENTS AND METHODS: Using geographical information systems (GIS), spatial accessibility to PA facilities (urban and nature) was assessed using the distance to PA facilities at the municipality level; spatial accessibility to food outlets (general food outlets, bakeries and fast-food outlets) was calculated at individual level using the student home address and the food outlets addresses. Relations of weight status with spatial accessibility to PA facilities and to food outlets were analysed using mixed logistic models, testing potential direct and interaction effects of individual and environmental socio-economic characteristics.
RESULTS: Individual socio-economic status modulated the relation between spatial accessibility to PA facilities and to general food outlets and overweight. The likelihood of being overweight was higher when spatial accessibility to urban PA facilities and to general food outlets was low, but in children of blue-collar-workers only. The odds ratio (OR) (95% confidence interval) for being overweight of blue-collar-workers children compared with non-blue-collar-workers children was 1.76 (1.25–2.49) when spatial accessibility to urban PA facilities was low. This OR was 1.86 (1.20–2.86) when spatial accessibility to general food outlets was low. There was no significant relationship of overweight with either nature PA facilities or other food outlets (bakeries and fast-food outlets).
CONCLUSION: These results indicate that disparities in spatial accessibility to PA facilities and to general food outlets may amplify the risk of overweight in socio-economically disadvantaged youth. These data should be relevant for influencing health policies and urban planning at both a national and local level.

International Journal of Obesity (2012) **36,** 914–919; doi:10.1038/ijo.2012.10; published online 7 February 2012

Keywords: overweight; built environment; physical activity; youth; geographic information system

INTRODUCTION

The prevalence of childhood obesity has dramatically increased worldwide over the last few decades.[1] Although obesity is a complex health issue related to genetic and lifestyle factors, there is growing evidence linking overweight to 'obesogenic' environments.[2,3] One environmental dimension that is receiving increased attention is the built environment, and more specifically, spatial accessibility to build and service structures that may influence physical activity (PA) patterns or dietary behaviour, such as parks, playgrounds, sports clubs, land-use types, transportation systems and food outlets.[4,5]

Several studies have demonstrated that some characteristics of the built environment are associated with healthy/unhealthy dietary behaviours[6] and PA.[7] However, the relationships with weight status, in particular that of youth, are less consistent.[8-12] In some studies,[13-16] but not in others,[17] youth overweight was inversely related to indices of high walkability and spatial accessibility to PA facilities.[8,10] Similarly, the studies that investigated the relationships between access to food outlets or fast-food outlets and youth overweight have given mixed results.[18-20]

Individual characteristics may be correlated with those of the place of residence, indicating that individual and environmental characteristics probably interact to jointly affect weight status in various ways. First, an inverse relationship between individual or environmental socio-economic status (SES) and health-related behaviour or body mass index (BMI) has been found in numerous studies.[21,22] Second, data indicate that neighbourhoods in which low-income children live often have lower accessibility to healthy food or PA facilities than do wealthier neighbourhoods.[23] Third, in line with what has been called 'deprivation amplification',[24] environmental factors may have greater effects on disadvantaged children than on their more favoured counterparts.[25] Thus, it has been suggested that eco-epidemiological models of obesity should consider both individual and environmental demographic and SES

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Received 28 April 2011; revised 4 January 2012; accepted 10 January 2012; published online 7 February 2012

characteristics, at least as confounders or modifiers of built environment effects.[26] Despite this, most available studies have focused on direct or independent contributions of specific built environmental factors.

The aim of this study was to assess the risk of overweight in a representative sample of French 12-year-old students according to their spatial accessibility to PA facilities and to food outlets, taking into account various individual and environmental characteristics. We hypothesised that individual and environmental SES characteristics can moderate the association of built environment variables with overweight and with obesity-related behaviours (supervised PA and dietary habits). Using geographical information system (GIS) methods, we analysed spatial accessibility to different PA facilities and to food outlets in relation to the risk of youth overweight, testing potential direct and interaction effects of individual and environmental SES characteristics.

MATERIALS AND METHODS

Study population

Participants included a representative sample of middle-school first-level students (aged 12.0 ± 0.6 years) residing in the Bas-Rhin department (eastern France). Briefly, as previously described,[21,27] one-third of first-level classes from the 88 schools in the department were randomly selected. Written informed parental consent was obtained for volunteer participants (77% of the 4421 eligible students). Anthropometric and lifestyle data were collected in 2001 by trained research assistants. Students' home addresses and occupational status of both parents were obtained from the school administration. The study was approved by the French National Committee for Informatics and Liberties. The study sample broadly matched the family socio-occupational background of the targeted population. A total of 77 students were excluded from analyses because of missing data. Thus, 3327 students constituted the final study population sample.

Individual anthropometric and behavioural variables

Measured weight and height were used to define overweight according to International Obesity Task Force age and gender BMI cutoffs.[28] Students were asked to complete a food frequency questionnaire, as previously described.[27] Four variables were considered here, as dichotomous indicators of unhealthy/healthy diet: consumption of fruits/vegetables/fruit juice, consumption of French fries/potatoes chips and nibbling while watching television the day before the survey, and soft drinks versus water as the most frequent beverage. PA was assessed using the Modifiable Activity Questionnaire for Adolescents.[29] Regular (at least once per week) participation in supervised PA (i.e., PA performed by adolescents under supervision by adults) outside of school was reported (dichotomous indicator yes/no). The highest occupational category of either parent, as determined by French socio-occupational nomenclature,[30] was used to group individual SES into two categories: children of blue-collar-workers or children of higher socio-occupational categories (non-blue-collar-workers). Student home address was geocoded using the Google Map API.[31]

Built and social environment variables

Spatial accessibility to PA facilities. Spatial accessibility to PA facilities was assessed using the distance to PA facilities at the municipality level using the 1998 French National Institute of Statistics and Economic Studies inventory database.[30] This database includes 11 PA facilities (6 urban facilities: athletic tracks, open-space playgrounds, large collective playgrounds, indoor PA facilities, tennis courts and swimming pools; 5 nature facilities: hiking trails, outdoor recreational parks, boating centres, ski resorts and beaches). For each facility, the distance was set at 0 if the facility was located within the municipality. If there was no facility within the municipality, we used the Euclidian distance to the nearest municipality, which owned that facility. Two variables were defined, one for the urban facilities, the other for the nature facilities, using the mean standardized distance. Each variable was categorized in tertiles (low, medium and high).

Spatial accessibility to food outlets. Spatial accessibility to food outlets was calculated at individual level using the student home address and the food outlets addresses obtained from Dun and Bradstreet business lists for year 2000. All food outlets were geocoded[22] and categorized in three groups using their French activity codes:[30] bakeries ($n = 1053$), general food retail (groceries, fresh fruit/vegetable stores, supermarkets and hypermarkets; $n = 1024$) and fast-food outlets ($n = 371$).

Spatial accessibility to each of these three food outlet groups was calculated using an interaction potential model.[32] One advantage of GIS-based methods is that they overcome arbitrary limits associated with administrative boundaries.[33] The model used here attempted to represent a potential accessibility at any one home address by combining the number of facilities and their proximity, discounting the potential with increasing distance; food outlets within a 1000 m radius were considered. Each variable was divided into three categories: absence of food outlet in the 1000 m radius (low-spatial accessibility), spatial accessibility below the median (medium-spatial accessibility) and spatial accessibility over the median (high-spatial accessibility).

Environment socio-economic characteristics and urbanisation. Median tax income and educational level were obtained at IRIS level from 1999 and 2001 French census data. French IRIS[23] represent neighbourhoods of a scale comparable to a census block group in the United States. Degree of urbanisation was obtained from a regional land use database.[34] Values for each student home address was estimated by means of kernel density method using the Spatial Analyst extension of ArcGIS, version 9.2 (ESRI, Inc., Redlands, CA, USA) with a radius of 1000 m for median tax income and educational level and 2000 m for urbanisation. Urbanisation estimates were subsequently aggregated into three classes.

Statistical analyses

Baseline descriptive statistics were expressed as means (s.d.) or percentages.

Analyses examined the relations of (1) adolescent weight status with spatial accessibility to urban PA facilities, nature PA facilities and the three categories of food outlets (general food outlets, bakeries and fast-food outlets), (2) regular supervised PA with spatial accessibility to urban and nature PA facilities and (3) the four dietary behaviours with each of the three types of food outlets. We used logistic mixed models (multilevel models) taking into account the hierarchical structure (students nested within schools), with adjustment for individual variables (gender, age and SES) and environmental variables (urbanisation, tax income, educational level and county). In these models, the random effect defined at the school level allowed taking into account the residual correlation in the outcomes within school persisting after adjustment for the covariates. For regular supervised PA and dietary behaviours as outcome, analyses were also run with overweight as additional fixed effect. Interactions between measures of spatial accessibility and fixed effects were tested. Only significant interactions are presented. Results are presented with odds ratios (OR) with 95% confidence interval. Statistical analyses were conducted using SAS software (SAS, version 9.2, SAS Institute Inc., Cary, NC, USA). Significance was set at a P-value of 0.05.

RESULTS

Characteristics of subjects

Characteristics of the 3327 students aged 12.0 ± 0.6 years, with a sex ratio of about 1, are presented in Table 1. One-fifth was classified as blue-collar-workers children, one-fifth were overweight (19.7%) and one-third reported no regular supervised PA. Concerning dietary behaviour, one-third had consumed fruits, vegetables or juice more than four times during the preceding 24 h, nearly one-third had eaten French fries or potatoes chips, and one-third had nibbled while watching TV. Soft drinks were the most frequently consumed beverages for 43.0% of the students.

Relationships between overweight and spatial accessibility to PA facilities

The associations of overweight with spatial accessibility to urban (Model 1a) and nature (Model 1b) PA facilities are presented in Table 2. In the two models, the OR of overweight was negatively associated with the median income tax ($P = 0.02$) and with the educational level ($P < 0.01$) of the place of residence but there was no significant relationship with age, gender, county or urbanisation of the place of residence (data not shown). An interaction was found between individual SES and spatial accessibility to urban PA facilities ($P = 0.02$). The likelihood of being overweight was inversely associated with spatial accessibility to urban PA facilities, but in blue-collar-workers children only. The OR of overweight was 1.76 (1.25–2.49) in blue-collar-workers children having low-spatial accessibility to urban PA facilities compared with non-blue-collar-workers children with similar low-spatial accessibility to urban PA facilities as referent category. Overweight was not related to nature PA facilities.

Table 1. Characteristics of students ($n = 3327$)

Characteristics	N *(%)*
Boys	1650 (49.6)
Overweight	654 (19.7)
Regular supervised PA[a]	2172 (66.3)
Fruits/vegetables/fruit juice consumption >4 times per day[a,b]	963 (30.2)
Consumption of French fries[a,b]	1039 (32.0)
Nibbling while watching TV[a,b]	948 (29.6)
Soft drinks as the most frequent beverage[a]	1394 (43.0)
Individual SES	
Blue-collar-workers children	727 (21.9)
Non-blue-collar-workers children	2583 (78.4)
Urbanization of place of residence	
Low	1370 (41.2)
Medium	863 (26.0)
High	1094 (32.9)
Spatial accessibility to food outlets	
Low-spatial accessibility to bakeries	516 (15.5)
Low-spatial accessibility to general food outlets	705 (21.2)
Low-spatial accessibility to fast-food outlets	1687 (50.7)

Abbreviation: PA, physical activity. [a]Data available for 3275 subjects. [b]The day preceding the survey.

Relationships between overweight and spatial accessibility to food outlets

The associations of overweight with spatial accessibility to each type of food outlet (Models 2a, 2b and 2c) are presented in Table 2. In the three models, the OR of overweight was negatively associated with the median income tax ($P < 0.02$) and with the educational level of the place of residence ($P < 0.01$), but there was no significant relationship with age, gender, county or urbanisation of the place of residence (data not shown). There was an interaction between spatial accessibility to general food outlets and individual SES ($P = 0.05$). The likelihood of being overweight was inversely associated with spatial accessibility to general food outlets in blue-collar-workers children only. The OR of overweight was 1.86 (1.21–2.86) for blue-collar-workers children having a low-spatial accessibility to general food outlets compared with non-blue-collar-workers children with similar low-spatial accessibility to general food outlets as referent category. Overweight was not significantly related to the accessibility to bakeries or fast-food outlets.

Relationships between obesity-related behaviours and spatial accessibility to PA facilities and food outlets

The associations of regular supervised PA with spatial accessibility to urban and nature PA facilities are presented in Table 3 (Models 3a and 3b). Regular supervised PA was negatively associated with the educational level of the place of residence ($P < 0.05$), but not with either the median tax income or urbanisation of the place of residence (data not shown). There was no significant interaction between individual SES and spatial accessibility to PA facilities. Regular supervised PA was higher in non-blue-collar-workers than in blue-collar-workers children ($P < 0.001$) and was positively associated to spatial accessibility to urban PA facilities ($P < 0.01$) but not to spatial accessibility to nature PA facilities. The OR of regular supervised PA was 1.61 (1.05–2.45) for children having high-spatial accessibility to urban PA facilities compared with children with low-spatial accessibility to urban PA facilities. Further adjustment on overweight did not alter these relationships. Dietary behaviours were not associated with any of the three measures of spatial accessibility to food outlets (data shown in Supplementary Table 1; models 4a, 4b and 4c).

DISCUSSION

In the present study, we examined the relationship of 12-year-old student overweight and obesity-related behaviour with spatial accessibility to PA facilities and to food outlets, estimated by GIS methods. We specifically explored the hypothesis that such relationships are modulated by individual and environmental

Table 2. Odds of being overweight according to spatial accessibility to PA facilities and to food outlets ($n = 3327$)[a]

Independent variable		*Urban PA facilities (model 1a) OR (95% CI)*	P[b]	*Nature PA facilities (model 1b) OR (95% CI)*	P[b]	*General food outlets (model 2a) OR (95% CI)*	P[b]	*Bakeries (model 2b) OR (95% CI)*	P[b]	*Fast-food outlets (model 2c) OR (95% CI)*	P[b]
Individual SES	Spatial accessibility										
Non-blue-collar-workers children	Low	1		1		1		1		1	
	Medium	0.97 (0.69 - 1.35)		0.87 (0.58 - 1.31)		1.10 (0.81 - 1.50)		0.99 (0.72 - 1.37)		0.97 (0.71 - 1.31)	
	High	1.08 (0.62 - 1.88)		0.64 (0.40 - 1.02)		1.20 (0.84 - 1.73)		1.18 (0.82 - 1.70)		1.06 (0.76 - 1.50)	
Blue-collar-workers children	Low	1.76 (1.25 - 2.49)		1.05 (0.73 - 1.52)		1.86 (1.20 - 2.86)		1.33 (0.80 - 2.21)		1.35 (1.00 - 1.81)	
	Medium	0.83 (0.53 - 1.30)		0.99 (0.60 - 1.63)		1.15 (0.77 - 1.72)		1.17 (0.78 - 1.77)		1.03 (0.67 - 1.58)	
	High	1.13 (0.62 - 2.04)		0.88 (0.53 - 1.48)		1.26 (0.82 - 1.92)		1.22 (0.80 - 1.86)		1.11 (0.72 - 1.71)	
			0.02		0.53		0.05		0.66		0.48

Abbreviations: PA, physical activity; SES, socio-economic status. [a]Odds ratios (OR) and 95% confidence interval (CI) were estimated using logistic mixed models taking into account the hierarchical structure (students nested within schools). Fixed effects were gender, age, and county, urbanization, tax income and educational level of the place of residence. [b]P of interaction between individual SES and spatial accessibility.

Table 3. Odds of supervised PA according to spatial accessibility to PA facilities ($n = 3275$)[a]

Independent variable	*Urban PA facilities (model 3a) OR (95% CI)*	P	P[b]	*Nature PA facilities (model 3b) OR (95% CI)*	P	P[b]
Spatial accessibility						
Low	1			1		
Medium	1.54 (1.18–2.00)			0.85 (0.67–1.07)		
High	1.61 (1.05–2.45)	<0.01	<0.01	0.93 (0.64–1.33)	0.36	0.40

Abbreviation: PA, physical activity. [a]Odds ratios (OR) and 95% confidence interval (CI) were estimated using logistic mixed models taking into account the hierarchical structure (students nested within schools). Fixed effects were gender, age, individual SES, and county, urbanization, tax income and educational level of the place of residence. [b]Additional adjustment on overweight.

SES characteristics. Our main findings provide support for an individual/environment interaction. When spatial accessibility to urban PA facilities or to general food outlets was low, there was an increased likelihood of being overweight in blue-collar-workers children but not in children from higher socio-occupational categories. Consistent with existing evidence,[9,35] the association of spatial accessibility to PA facilities with regular supervised PA, independently of individual and environmental SES characteristics, indicates that PA level might partly mediate the effects of environmental SES on youth overweight.

The strengths of our study lie in the high-participation rate and the only one age group, which limited variability related to age-related behavioural changes observed during adolescence, along with measured BMI and assessment of both PA and food environments. Moreover, we measured environmental characteristics and spatial accessibility to food outlets across continuous space using sophisticated geographical methods to estimate spatial accessibility, without relying on arbitrary administrative boundaries. Some limitations to the study should be mentioned. First, we used cross-sectional data and could not make direct causal inferences. Second, regular supervised PA and dietary measures were self-reported, with relatively crude and non-exhaustive questions concerning diet. Third, this study is based on secondary analysis of pre-existing data. Therefore, information on spatial accessibility to PA facilities was limited and was only available at the municipality level. Although the food outlets variables were more detailed, they were subject to measurement error because of potential inaccuracies in the commercial database used. Moreover, we had no information on other components of accessibility (organisational, economic and qualitative), nor on other PA-related elements, including security and walkability indices.

Numerous physical and built environment features have been associated with PA in a growing body of literature.[13,36] Few studies have examined the impact of the built environment on youth obesity, and the possible relationship between the built environment and weight status remains subject to debate.[5,8,10–12] In a recent review,[9] we found that the inverse relationship between youth weight and indices indicating higher walkability was the most consistent. Contrary to observations in adults, but consistent with our results showing no association between overweight and spatial accessibility to nature PA facilities, parks and ‘green areas’ were generally not strongly associated with youth BMI. Recent data showing that park users are primarily very young children and adults suggest that this type of setting may be less important for PA in older children.[37]

A beneficial relationship between weight and spatial accessibility to PA facilities has been reported in only four out of nine papers.[9] However, we should emphasise that about half of the negative papers did not control for environmental or individual SES. Only one study[15] adjusted for both, and it found that the number of schools (as potential sites of PA practice) inaccessible on weekends was higher in neighbourhoods with lower SES and was independently associated with significantly higher BMI. Yet, as emphasised by socio-ecological models of behaviour, spatial accessibility is only one of multiple determinants of a healthy lifestyle and health itself. On the other hand, a more favourable socio-economic context and denser social networks might influence the built environment.[23] Previous studies[38,39] have found a higher number of PA facilities in more affluent places of residence. However, such relationships are not clear-cut and may be context specific. In two European studies,[24,40] associations between environmental SES and the presence of PA facilities, or comfort-specific characteristics of such facilities, were found to vary from positive to negative depending on the facility. Nevertheless, inter-relationships between built and socio-economic characteristics may result in confounding the association between differing environmental exposures,[41] and, as such, both categories of environmental determinants should be included in the analyses.

The current study extends previous research on the effects upon health of spatial accessibility to different facilities by specifically examining cross-level interactions among built environmental characteristics and environmental or individual SES. To our knowledge, no previous study had specifically addressed this issue in relation to PA facilities and youth overweight. Although more research is needed to delineate the exact mechanisms underlying the interactions observed here and to better identify policy-relevant target populations and determinants, our results suggest that disadvantaged children may be more dependent on local environmental determinants than their more favoured counterparts.

Interestingly, we found an analogous interaction between individual SES and spatial accessibility to general food outlets. These results are consistent with existing data indicating that an inverse relationship between overweight and the density of supermarkets, thought to offer a higher variety of healthy food choices, depends on individual characteristics that might reflect SES, such as ethnic origin and mothers employment conditions.[42] Similarly, a positive relationship with convenience stores in low-income towns was found in one study,[20] whereas in another study, a positive relationship with fast-food outlets availability was found for a low SES population living in East Harlem, New York.[19] In contrast to data on the association between spatial accessibility to PA facilities and regular supervised PA, we found no relationship between spatial accessibility to general food outlets and dietary behaviours. Our crude measurement of dietary behaviour may explain, at least in part, this negative result. It may also reflect the fact that the food environment is complex. Organisational characteristics, such as store opening hours, food quality, prices and parental choices, may be as important as spatial accessibility to food outlets and should be taken into account in future research. These characteristics vary according to country and culture, indicating that future studies should be carried out in various geographical and socio-economic settings. Moreover, we cannot exclude the possibility that the relationship of PA and food environment variables with weight is indirect and may reflect other contextual obesity determinants, such as higher walkability or more dense social networks in commercially attractive neighbourhoods.[43]

In conclusion, our data add to the growing body of evidence documenting relationships between the built environment and health outcomes, including youth overweight, by demonstrating specific interactions between individual and environmental factors in shaping health and health-related inequalities. Although more research is necessary to determine whether these interactions are context-specific, present results may be relevant for influencing health policies and urban planning at both a national and local level.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

ACKNOWLEDGEMENTS

This work is part of the ELIANE (Environmental LInks to physical Activity, Nutrition and hEalth) study. ELIANE is a supported by the French National Research Agency (Agence Nationale de la Recherche, ANR-07- PNRA-004). We thank the schools' medical staffs for their technical assistance.

AUTHOR CONTRIBUTIONS

CS is the principal investigator and coordinated the cross-sectional survey. CS and RC performed the analyses and drafted the manuscript. J-MO, BC, BS, HC, PS, AB, DB and CW assisted with the literature search and writing of the manuscript. J-MO is the coordinator of the ELIANE study; CS, BC and CW are the principal investigators in the ELIANE study.

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Supplementary Information accompanies the paper on International Journal of Obesity website (http://www.nature.com/ijo)