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RESEARCH

Observing the neighborhood multidimensionality and overweight in children of different developmental stages—the emergence of an unusual association

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Abstract

The present study examines whether the association of the neighborhood environment and overweight in children is moderated by age. This was a cross-sectional study of 832 children aged 3 to 10 years living in the city of Oporto (Portugal). Children were recruited under the scope of the project "Inequalities in Childhood Obesity: The impact of the socioeconomic crisis in Portugal from 2009 to 2015." Overweight was defined according to the International Obesity Task Force criteria. Parents completed a self-administered questionnaire capturing sociodemographic characteristics and their perceptions of their neighborhood environment. Logistic regressions were used to examine the influence of parental perceived neighborhood characteristics (latent variables: attractiveness, traffic safety, crime safety, and walkability) on overweight in children. A stratified analysis by age category was conducted. Overall, 27.8% of the children were overweight, 17.4% were aged 3 to 5 years, and 31.8% were aged 6 to 10 years. Children aged 3 to 5 years were more sensitive to the neighborhood environment than children aged 6 to 10 years. For children aged 3 to 5 years, the risk of overweight was inversely associated with neighborhood crime safety (OR = 1.84; 95% CI 1.07–3.15; p = 0.030).

Conclusion: Our study suggests the existence of a sensitive age period in childhood at which exposure to a hostile neighborhood environment is most determining for weight gain. Until today, it was thought that the impact of the neighborhood environment on younger children would be less important as they are less autonomous. But it may not be true.

What is Known:

- *The neighborhood environment may adversely affect children's weight status. However, the moderating role of child age in the association between neighborhood environment and overweight is uncertain.*

What is New:

- *The study highlights that the association between the neighborhood environment and child overweight is attenuated by age. It is stronger for preschoolers than for early school-age children.*

Keywords Portugal · Childhood overweight · Neighborhood environment · Parental perceptions · Latent variables

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Abbreviations

OR Odds ratio
CI Confidence interval
Ref Reference

Introduction

Childhood overweight (including obesity) is a serious public health problem [1]. In 2016, 28.8% of children aged 5 to 9 years were overweight globally. This represents an increase of 23.5% since 1975 (from a prevalence of 5.3%) [2]. In Portugal, it was estimated that 22.6% of boys and 20.7% of girls aged 6 to 8 years were overweight by 2019, numbers that place the country in the group of countries with the highest rates of childhood overweight [3]. Overweight children are at significantly increased risk of short-term health problems, such as sleep apnea, asthma, insulin resistance, fatty liver disease, and high blood pressure [4]. In later life, they are more likely to experience some types of cancer (e.g., renal, breast, and endometrial), reproductive disorders, cardiovascular disease, type 2 diabetes mellitus, obstructive respiratory disease, and adult overweight [5].

The principal cause of overweight is an imbalance between the calories consumed and the calories expended [6]. The neighborhood environment can directly increase the risk of overweight in children through more or less automatic responses to environmental stimuli [7]. Children who are more exposed to fast-food restaurants in their neighborhood are more likely to eat at these restaurants two or more times per week [8, 9], and this behavior is associated with a higher probability of having poor diet quality (e.g., consuming fewer fruits and nonstarchy vegetables, less milk, and more sugar-sweetened beverages) [10, 11]. In turn, children with less access to destinations have been reported to be less physically active [12, 13]. The neighborhood environment may also influence children's risk of overweight via parental practices. The literature shows that parents' concerns about road safety and "stranger danger" are the main causes of restricted outdoor activities for children [14, 15].

Understanding the aspects of the neighborhood environment that can contribute to overweight among preschoolers (aged 3–5 years) and early school-age (aged 6–10 years) children is vital for the development of effective public policies to combat the overweight epidemic. In Portugal, this may be particularly pertinent, as the country has recently faced severe budgetary constraints that have led to cuts in public investment and spending on the National Health Service [16]. Hence, this paper answers the following research question: What are the neighborhood environmental attributes associated with overweight in Portuguese preschoolers and early school-age children? We built up a conceptual model based on the Environmental Research framework for weight Gain prevention (EnRG) to support our research hypothesis and conduct the statistical analyses (Fig. 1). According to EnRG framework, body weight is influenced by unconscious and conscious processes which result from different types of environmental factors, cognitive mediators, and behavior and person moderators [17]. In our conceptual model, the perceived neighborhood environment is stratified into perceived physical and perceived social attributes, which influence body

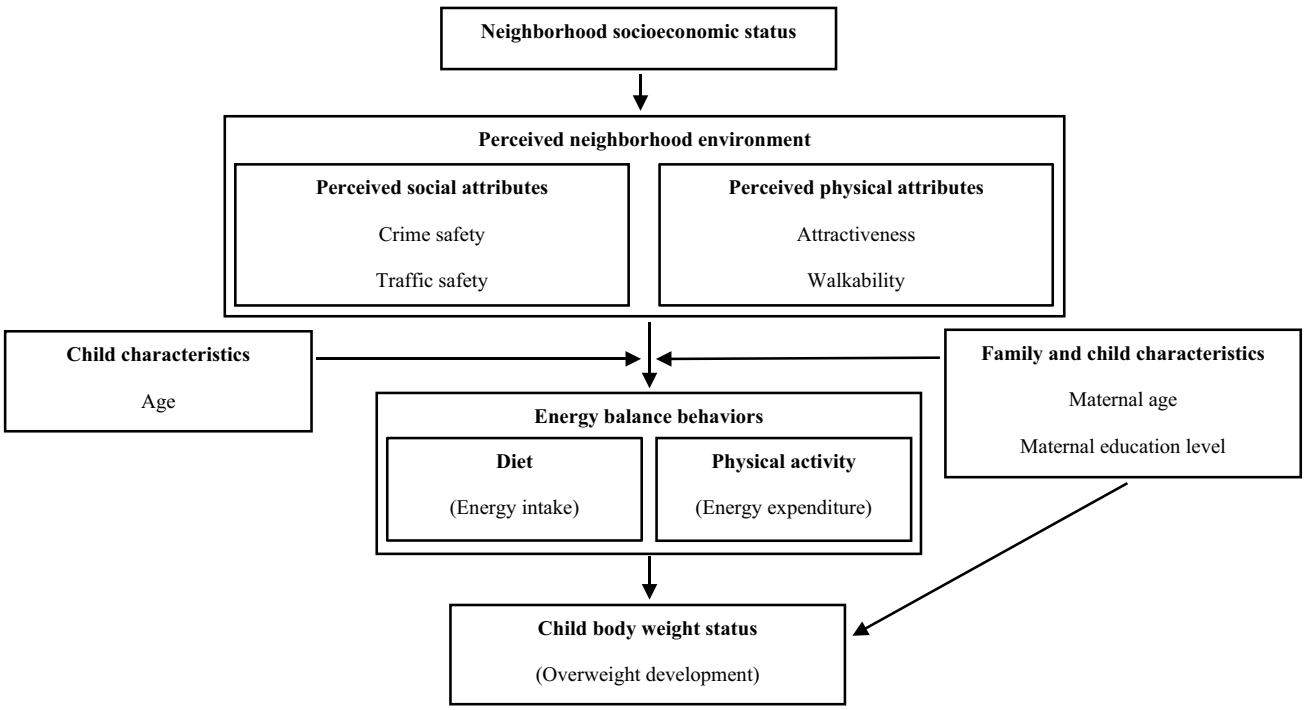

Fig. 1 Conceptual model for the association between perceived neighborhood environment and childhood overweight

weight through energy balance behaviors that are moderated by child's age. Confounding covariates related to child (e.g., sex and birth order), family (e.g., maternal age and education), and neighborhood (e.g., neighborhood socioeconomic status) also affect the association between the perceived neighborhood environmental attributes and body weight. Based on our conceptual model, we hypothesize that perceived neighborhood environmental attributes are associated with Portuguese children overweight, and such relationship is moderated by age.

Methods

Study population

The data used for the present cross-sectional study were extracted from the project "Inequalities in Childhood Obesity: The impact of the socioeconomic crisis in Portugal from 2009 to 2015" (ObesInCrisis). Details about the project can be found elsewhere [18, 19]. Briefly, the sample for the project was recruited between November 2016 and April 2017 from 118 preschools and primary schools of the districts of Coimbra, Oporto, and Lisbon. Project participants were selected by proportional stratified random sampling based on the number of boys and girls aged 3 to 10 years in each district. A total of 8472 children (age range: 3.5–11.5 years; 50.8% male) participated in the project; this corresponds to a participation rate of 58% in Coimbra, 61% in Oporto, and 67% in Lisbon. Ethical approval for the ObesInCrisis was obtained from the Portuguese Commission for Data Protection (Authorization number 745/2017) and the Directorate General for Innovation and Curriculum Development (Registration number 0565500003). Written informed consent was obtained from the parents or legal guardians of all children prior to data collection. Given that our study focused on children between 3 and 10 years of age from the municipality of Oporto (the capital of the Oporto metropolitan area), 950 children were considered for analysis. One hundred and eighteen children did not provide their home postal code, so only 832 children could be included. The municipality of Oporto is in the northwest region of Portugal, covers an area of 39.74 km^2, and is divided into seven parishes as a result of the administrative and territorial reform initiated in 2013. In 2019, its population was estimated at approximately 216,606 people (97,378 men and 119,228 women), of which only 28.5% were aged 65 years and over, and 7.7% were beneficiaries of the social insertion income [20].

Measures

Body mass index

The children's weight and height were measured by trained researchers during school visits. Measurements were made with the children wearing light clothing and no shoes following a standardized protocol. Weight was recorded to an accuracy of 100 g using a calibrated electronic scale (SECA 220, Birmingham, UK), and height was recorded to an accuracy of 1 mm using a portable stadiometer (SECA 213, Birmingham, UK). Body mass index (BMI) was calculated with measured weight and height (BMI = kg/m^2), and a BMI *z* score was assigned to each child. We used the sex- and age-specific BMI reference values of the International Obesity Task Force to determine whether a child had normal weight or was overweight. In our study, overweight included both overweight and obesity.

Parental perceptions about the neighborhood environment

The environmental module of the International Physical Activity Prevalence Study was used to assess parents' perceptions of their neighborhood environment. Parents were asked to reflect on the area within a 15-min walk from their home and to indicate whether the following existed: (1) many shops, stores, markets, or other places to buy things they need; (2) public transport stops; (3) sidewalks on most streets; (4) facilities to ride a bicycle; (5) several free or low-cost recreation facilities; (6) high crime rates that make them feel that it is unsafe to go on walks at night; (7) much traffic on the streets that makes it difficult or unpleasant to walk; (8) many people being physically active; (9) many interesting things to look at while walking; (10) many four-way intersections; (11) well-maintained and unobstructed sidewalks; (12) well-maintained and unobstructed places to ride a bicycle; (13) much traffic on the streets that makes it difficult or unpleasant to ride a bicycle; (14) high crime rates that make them feel that it is unsafe to go on walks during the day; and (15) many places to go within a short walking distance. Responses were given on a 4-point Likert scale ranging from 1 (completely disagree) to 4 (completely agree). For analysis purposes, the scores of the negative items (items 6, 7, 10, 13, and 14) were reversed so that a higher score represented a more favorable condition of the neighborhood environment.

Confounding factors

Parents completed a series of demographic questions. Among other demographic information, parents were asked to report the child's sex, number of siblings, birth order, maternal age and level of education (years of education completed), and current residential postal code. Birth order was coded into three groups: only child, firstborn, and not firstborn. Maternal age was included as a continuous variable.

Maternal education level was classified as low (9 years of schooling completed or less), middle (10 to 12 years of schooling completed), and high (university/tertiary qualification). Each postal code was geocoded using QGIS 3.10 and linked to a statistical section. The median selling price of homes per square meter (m^2) at the statistical level was established as a measure of neighborhood socioeconomic status. For analytical purposes, the median residential property price per m^2 was converted into tertiles. Information on house prices per m2 was provided by the National Statistics Institute and included all residential properties with gross private areas between 35 and 600 m^2 sold between 1 January 2022 and 31 December 2022. These confounding variables were selected based on a priori knowledge about their relationship with children's overweight [21].

Statistical analyses

To reduce the number of parents' perceptions of their neighborhood environment to a smaller number without losing relevant information, a categorical principal component analysis was performed. The Kaiser−Meyer−Olkin (KMO) test and the Bartlett test of sphericity were used to assess the factorability of the data. Varimax rotation was applied to make the factors more interpretable. Factors with eigenvalues greater than 1 were extracted. Only items with absolute factor loadings equal to or greater than 0.5 were retained in the factor structure. Descriptive statistics were calculated and expressed as count (%) or mean (standard deviation). The chi-square test and Student's *t* test for independent samples were used to assess age differences. Logistic regression was used to measure the association between the latent variables of perceived neighborhood environment and overweight. We first performed unadjusted models and subsequently models adjusted for child sex and birth order, maternal age and level of education, and the median residential property price per m^2 within the neighborhood. Logistic regression analyses were run separately for preschoolers and early school-age children to evaluate the role of age as an effect modifier. To account for the possible clustering of children in schools, robust standard errors were calculated using the Huber-White Sandwich estimator. *P* values < 0.05 were considered statistically significant. All statistical analyses were performed using SPSS 21.0 for Microsoft Windows (SPSS Inc., Chicago, IL, USA).

Results

A description of the analytical sample is presented in Table 1. Of the 832 children who participated in the study, 597 (71.8%) were aged between 6 and 10 years. Half of the children were female (52.2%) and were not firstborn (49.6%). Stratification by age category revealed that children aged between 6 and 10 years were more likely to be

Table 1 Participant characteristics by age category

	Overall (*n* = 832)	**3–5 years (*n* = 235)**	**6–10 years (*n* = 597)**	***P* value[a]**
Sex, % (*n*)				
Female	52.2 (434)	49.4 (116)	53.3 (318)	0.310
Male	47.8 (398)	50.6 (119)	46.7 (279)	
Birth order, % (*n*)				
Only child	27.5 (219)	32.6 (75)	25.4 (144)	0.109
First-born	23.0 (183)	20.4 (47)	24.0 (136)	
Non-firstborn	49.6 (395)	47.0 (108)	50.6 (287)	
BMI status, % (*n*)				
Normal	72.2 (601)	82.6 (194)	68.2 (407)	< 0.001
Overweight/obese	27.8 (231)	17.4 (41)	31.8 (190)	
Maternal age (years), mean (SD)	36.8 (6.2)	35.7 (5.9)	37.3 (6.4)	0.001
Maternal education, % (*n*)				
Low	23.6 (192)	17.2 (40)	26.2 (152)	0.001
Medium	35.2 (286)	31.5 (73)	36.7 (213)	
High	41.2 (335)	51.3 (119)	37.2 (216)	
Residential property values per m^2, % (*n*)				
Low (283€–1951€)	33.2 (276)	33.2 (78)	33.2 (198)	0.011
Medium (1952€–2492€)	32.8 (273)	39.6 (93)	30.2 (180)	
High (2493€–4583€)	34.0 (283)	27.2 (64)	36.7 (219)	

[a]Chi-square and Student's t-test for independent samples analysis

overweight ($p < 0.001$), have older and less educated mothers ($p = 0.001$), and live in neighborhoods where the median residential property price per m^2 was in the 2493 to 4583 euro range ($p = 0.011$).

The KMO general measure and Bartlett's sphericity test indicated that the perceived environment data were suitable for factor analysis (KMO = 0.75; $X^2 = 2021.37$; $p < 0.001$). Principal component analysis with varimax rotation identified four factors with eigenvalues greater than 1 and factor loadings ≥ 0.5. These four factors accounted for 59.42% of the total variance. The first factor, designated "attractiveness," consisted of five items that assessed the availability of physical activity opportunities and the aesthetic quality of the neighborhood (23.90% of the total variance explained; Cronbach's alpha = 0.77); the second factor, called "crime safety," comprised two items that measured the presence of criminal activity in the neighborhood (15.12% of the total variance explained; Cronbach's alpha = 0.64); the third factor, called "traffic safety," comprised 3 items that evaluated traffic volume in the local streets (12.14 of the total variance explained; Cronbach's alpha = 0.56); and the fourth factor, entitled "walkability," included 3 items that evaluated access to useful destinations and the presence of infrastructures that facilitate pedestrian mobility in the neighborhood (8.27% of the total variance explained; Cronbach's alpha = 0.60) (see the Supplementary Table 1).

Table 2 shows the odds ratio for overweight for each neighborhood environment latent variable, stratified by child age category. In the unadjusted analyses, regardless of the age category, the characteristics of the neighborhood environment were not associated with overweight. After adjusting for relevant confounding factors such as child sex and birth order, maternal age and education, and the median residential property price per m^2 in the neighborhood, a significant association was identified for children aged 3 to 5 years. For these children, the odds ratio for overweight increased approximately twofold when parents reported a negative perception about crime safety (OR = 1.84; 95% CI 1.07–3.15; $p = 0.030$).

Table 2 Associations between overweight and perceived neighborhood attributes stratified by age category

	3–5 years ($n = 235$)			6–10 years ($n = 597$)		
	OR	**95% CI**	***P* value**	**OR**	**95% CI**	***P* value**
Unadjusted						
Attractiveness						
Negative perception	0.93	0.47–1.85	0.903	1.28	0.89–1.85	0.140
Positive perception	Ref			Ref		
Traffic safety						
Negative perception	0.57	0.29–1.16	0.635	0.898	0.62–1.30	0.834
Positive perception	Ref			Ref		
Crime safety						
Negative perception	1.64	0.82–3.28	0.091	0.96	0.67–1.39	0.303
Positive perception	Ref			Ref		
Walkability						
Negative perception	0.98	0.49–1.94	0.955	1.08	0.75–1.56	0.228
Positive perception	Ref			Ref		
Adjusted[a]						
Attractiveness						
Negative perception	0.99	0.42–2.32	0.980	1.27	0.69–2.34	0.426
Positive perception	Ref			Ref		
Traffic safety						
Negative perception	0.69	0.27–1.76	0.407	0.95	0.66–1.38	0.408
Positive perception	Ref			Ref		
Crime safety						
Negative perception	1.84	1.07–3.15	0.030	0.85	0.56–1.29	0.773
Positive perception	Ref			Ref		
Walkability						
Negative perception	0.87	0.42–1.83	0.692	1.04	0.70–1.54	0.826
Positive perception	Ref			Ref		

[a]Adjusted for sex, birth order, maternal education, maternal age, and neighborhood median residential property price per m^2

Discussion

We examined the perceived neighborhood environment correlates of overweight among children aged 3 to 5 years and 6 to 10 years. Crime safety was the unique neighborhood environment latent variable associated with overweight in children aged 3 to 5 years. None of the neighborhood environment latent variables were independently related to overweight among children aged 6 to 10 years.

Our finding that children aged 3 to 5 years had a higher risk of being overweight when their parents perceived their neighborhood as unsafe due to high crime rates is consistent with previous findings. In New York, for example, Lovasi et al. concluded that the neighborhood homicide rate was significantly associated with both higher BMI *z* scores and obesity prevalence among preschool-aged children from low-income families [22]. In a group of 883 Ukrainian children aged 3 years, an association between "unfriendly" neighborhoods (which could be a proxy measure of neighborhood crime) and higher BMI *z* scores was found [23]. A potential explanation for our finding is that parents who are concerned about crime in their neighborhood may prevent their younger children from going outside and being involved in physical activities [24, 25]. Younger children are commonly perceived as "innocent" and less capable of defending themselves against assailants and, consequently, are more spatially restricted by their parents than older children [26]. Children who spend more time inside the home spend more time watching television and videos/DVDs [27]. According to the literature, the number of hours of television viewing is a significant predictor of overweight [28]. The positive association between television viewing and overweight is possibly mediated through shorter sleep duration, reduced time spent performing physical activity, exposure to higher-calorie food advertisements, and higher consumption of ultra-processed foods [29, 30]. Future studies should seek to deeply understand the processes and pathways that make the body weight of younger children so sensitive to exposure to unsafe environments. These studies would be of great importance for scientific and public health policy [31].

It is important to note that although children aged 3 to 5 years seem more sensitive to their neighborhood attributes, we found a higher prevalence of overweight in the 6 to 10 age group. Weight gain is a gradual process that begins in early childhood. At about 6 years of age, the adiposity rebound occurs and the total body fat increases rapidly into adolescence [32]. For example, after adjusting for sex, ethnicity, and baseline age, Huang et al. found an average increase of 2.0 ± 0.9 kg per year in total body fat between ages 8 and 13 [33]. Thus, it is natural that overweight is greater in the older children of our sample. We also hypothesize that the higher prevalence of overweight among the older children may reflect a temporal gap between exposure to inappropriate neighborhood conditions and overweight. This temporal gap has not been deeply studied, and therefore, it is not known how long it takes for a child's body weight to respond to their neighborhood effects.

Our results suggest that future interventions to reduce overweight in children aged 3 to 5 years should take into account relevant area-level factors. Efforts must be made to reduce local crime rates and increase parents' perceptions of safety. Strategies such as demolishing derelict buildings, improving public lighting, cleaning vacant lots, increasing police presence, and adding video surveillance to streets could help achieve both these goals [34–36]. In neighborhoods where it is difficult or impossible to rapidly alleviate crime, recreational physical activity programs should be implemented in schools. Partnerships through formal shared-use agreements between schools and other community agencies can create new opportunities for recreational physical activity [37]. Shared-use agreements, also termed joint-use agreements, allow local agencies or community groups not associated with schools to use school buildings and grounds for before- or after-school programs [38].

The results of this study should be interpreted with the limitations in mind. Due to its transversal nature, no causal relationships can be inferred. The children in this study came from a large city, and the proportion belonging to a minority ethnic group or of a low socioeconomic status was small; therefore, the generalization of our results to other populations must be done with caution. Most participants were mothers, who may rate their neighborhoods differently from fathers. It should be noted that some previous studies concluded that women are more likely to report unfavorable views of their neighborhood compared to men (e.g., limited access to transit stops, sidewalks, and facilities to bicycle and more disorder) [39–41]. Despite these limitations, this study has some strengths. The study setting in Portugal adds geographic and cultural diversity to previous studies that assessed whether the effects of neighborhood environments on child weight status vary by age. The use of composite measures of neighborhood environments allowed a more direct exploration of the environmental drivers of overweight in children. Other strengths are the use of a validated and reliable questionnaire to assess parents' perceptions of their neighborhood environment and the inclusion of individual-, family-, and neighborhood-level confounding variables in our models.

Conclusion

The present study contributes to a growing body of evidence on the role of the neighborhood environment on overweight. Our study suggests that approaches based on neighborhoods could be a strategy to prevent excessive weight gain during the first years of life. This includes increasing access to safe places for physical

activity. As 3- to 5-year-old children experience a greater impact from the local environment than 6- to 10-year-old children, these interventions become more relevant. Notably, rapid weight gain in early childhood is associated with higher body fat mass and overweight in adulthood. Future interventions to reduce childhood overweight may benefit from including families, schools, municipalities, and private community organizations and from targeting a specific age category.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s00431-023-05326-0.

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Authors' contributions All the authors contributed to the conception and design of the study. Data collection was performed by D.R., A.G., M.R.G.S., A.M.M.R., and C.P. Data analysis was carried out by A.C.L. The first draft of the manuscript was written by A.C.L., and H.G.N. commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Data availability The datasets generated during and/ or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval The study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Portuguese Ministry of Education (registration number 0565500003) and the Portuguese Data Protection Authority (authorization number 745/2017).

Consent to participate Written informed consent was obtained from parents or legal guardians of all children.

Consent for publication Not applicable.

Competing interests The authors declare no competing interests.

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