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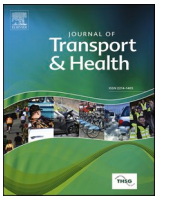

Parental perception of the neighborhood environment and health-related behaviors in Portuguese children: What has changed from 2009 vs. 2016

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ABSTRACT

Introduction: Physical activity (PA) is beneficial for health. However, most children do not achieve the daily recommended PA levels. This study assesses changes in parental perception of the neighborhood environment from 2009 to 2016 across three Portuguese districts, and explores the associations between parental perception of the neighborhood environment and children's time in multiple health-related behaviors.
Methods: We use two national cross-sectional surveys (2009 and 2016) on 3-10-year-old children. Parents reported children's time (min/day) in different activities (e.g., active transportation, indoor and outdoor play, sport participation, watching television, using computer, and using videogames) as well as perceptions of the neighborhood features. Analyses were stratified by year, and child's sex, age, family socioeconomic status, and district of residence were considered.
Results: Neighborhood features were better rated in 2016 vs. 2009. Major improvements were found related with facilities to ride a bicycle and more sense of security, although some geographical differences were noted. Major time-consuming behaviors differed: in 2009, playing indoor was the most common behavior (124 min/day); in 2016, outdoor play was the activity that consumed more time (125 min/day). The linear regression supports that walkability and safety perceptions potentiate children's PA, while PA features associate with screen-time.

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Conclusions: National policies and investments may have promoted healthier neighborhoods. Findings can point to environmental actions' priority (e.g., promote active transportation), but caution is needed since time devoted on health-related behaviors was poorly explained by the environment.

1. Introduction

Frequent physical activity (PA) is associated with better physical, social and psychological health. Lifestyle habits, such as PA participation, developed throughout childhood affect adolescence and adulthood (Downing et al., 2021; Granger et al., 2017; WHO, 2022). Childhood is a key developmental life stage during which regular PA is instrumental in the promotion of optimal health, including bone mineral density, healthy weight status, and improve social, emotional, cognitive aspects (Strong et al., 2005; Robinson et al., 2015; Timmons et al., 2012; Tandon et al., 2015). Globally, however, fewer than 25% of school-aged children engage in recommended levels of PA (i.e., at least 1 h of moderate-to-vigorous-intensity PA or MVPA per day) (Guthold et al., 2020), with worse scenarios in industrialized countries (Aubert et al., 2021). In Portugal, only 47% of boys and 22% of girls aged 6–10 years achieve 60 min of habitual physical activity (PA) each week day; prevalence is 32% (boys) and 29% (girls) on weekends (Machado-Rodrigues et al., 2023). Also, specific dimensions of PA such as active play, transportation and organized sport, may have experienced a decline over years (Pizarro et al., 2023).

Considerable research has been undertaken to understand factors associated with PA using a socio-ecological lens (Ferrari et al., 2019). Ecological models of health behaviors lead to predictions that children's PA is influenced by multiple nested layers of variables (Sallis and Owen, 2015). Although previous study suggested that children's PA levels may be influenced by genetic factors, evidence points for major contributions at the social level (e.g., parental modelling of PA, economic classification), neighborhood level (e.g., access to outdoor play space and playgrounds), as well as at the policy level (e.g., mandatory inclusion of bicycle paths alongside new road infrastructure) (Sallis et al., 2000; Heerman et al., 2016; Ikeda et al., 2018; Rodrigues et al., 2018).

Beyond the home and school environment where children spend much of their waking hours, the neighborhood is a pivotal setting for their PA due to its proximity to home and accessibility by active transport, such as walking and cycling (Carver et al., 2019). Consistent findings have been observed regarding the importance of walkability (e.g., street connectivity, diversity in land use) (Jia et al., 2021), infrastructure for walking and wheeling (Pan et al., 2021), and the availability/accessibility of dedicated sports facilities and destinations to be active (Lachowycz et al., 2012; Roemmich et al., 2006). Parks and playgrounds tend to be accessible free of charge and are, therefore, particularly important for promoting PA among all children (Veitch et al., 2018) however, the quality of facilities may vary with area-level socioeconomic status (SES). Inversely, barriers that hinder children's active lifestyle include parental perception of traffic, and stranger danger (Aranda-Balboa et al., 2020; Rodrigues et al., 2022). Overall, some neighborhoods are more supportive of PA than others, but recent works show that buildings, streets, and outdoor spaces are modifiable barriers to achieving recommended daily PA goals (CEH, 2009).

There is a need for broader research that investigates diverse aspects of the build environment that may impact overall PA. In the last decades, there has been much focus on environmental predictors of children's PA, including audits of streetscapes near schools (Oliver et al., 2016), playgrounds and recreational facilities (Crawford et al., 2008), as well as crime and safety (Carver et al., 2010). However, studies that examine a broad range of environmental characteristics that support diverse aspects of children's behaviors, including PA, and changes over time, are still lacking. Studies using similar methods and including sites that differ on sociodemographic characteristics can help to elucidate the association between neighborhood features, such as distance and crime safety, with children's lifestyle. The objectives of this study are twofold: 1) to assess changes in parental perception of the neighborhood environment from 2009 to 2016 across three Portuguese districts, and 2) to determine the associations between parental perception of the neighborhood environment and children's time in multiple health-related behaviors.

2. Methods

2.1. Data collection

Data were collected in two cross-sectional national projects. In 2009/10, the sample was based on a stratified random design that accounted for the number of children by age and sex living in each mainland Portuguese district, to provide a nationally representative survey of children aged 3-10-years. Schools were randomly selected in each district, with a total of 17,509 children assessed at that time. Participation rate was 57.4% (Jago et al., 2012). In 2016/17, the same public and private schools (n = 118) from the districts of Coimbra, Porto and Lisbon were selected. Information letters and written informed consent were disseminated to all parents. A total of 8472 children (mean age: 7.2 ± 1.9 years, 50.8% male) were recruited. Participation rates were 58% in Coimbra, 60% in Porto and 67% in Lisbon.

The 2009 study protocol was approved by Direcção Geral de Inovação e Desenvolvimento Curricular (DGIDC). In 2016, the study procedure was approved by Direção Geral da Educação (DGE) and Comissão Nacional de Proteção de Dados (CNPD, the Portuguese Data Protection Authority). Both studies were conducted following the principles of the Declaration of Helsinki. All participants' guardians gave written informed consent before enrollment in the study; all the children gave their oral consent to participate.

There were 15,320 eligible children for this study (8430 from 2016), which correspond to all children aged between 3 and 10-years-

old, from the three Portuguese districts studied in both projects. The analysis was restricted to the sample of children whose parents completed the IPAQ E-module, namely: 10,419 children (5796 from 2016).

2.2. Study places

Supplementary Fig. S1 shows the distribution map of the study places. Lisbon district is located along the western coast of Portugal. The district capital is the city of Lisbon, which is also the national capital and the country's largest city (~2.8 million people in its metropolitan area). Porto district is located on the north-west coast. Its capital is the city of Porto, the second largest city in Portugal (~1.8 million people in its metropolitan area). Coimbra district is located in the central region and its capital is the city of Coimbra, which is the smallest city of the three, with a population of 143,396 inhabitants (INE, 2011). The three sample cities account for nearly 50% of the Portuguese population and are in the top 10 places in Portugal with high road densities and population densities.

Coimbra, though the smallest of the three cities, is the largest and most important center in a vast region that has lost political and strategic significance as Lisbon and, later, Porto, expanded and increasingly concentrated population and services. Coimbra has the capacity to be strongly polarizing and balancing, thus contributing decisively to the increase in dynamics and competitiveness that are weak in Portugal, also as a result of its deeply two-headed and unbalanced urban network. In addition to having different degrees of urban development, the three cities have different characteristics in the structure of their green spaces. According to European data from the European Urban Atlas and the EUA/Grid Eurostat (Mendes, 2017), green spaces' total area (>2ha) in respect to the total population is: $8m^2$/inhabitant in both Porto and Coimbra, and $6m^2$/inhabitant in Lisbon. Availability of green spaces (>2ha) within 300 m is true for 12% of the population in Coimbra, 21% in Porto, and 22% in Lisbon. In terms of accessibility to those spaces (measured as a 10-min' walk), the number decreased to 5% in Coimbra, 10% in Lisbon, and 12% in Porto.

2.3. Variables

All the variables were collected using a standardized questionnaire. Supplementary Table S1 presents the definitions of each variable.

The Environmental Module of the International Physical Activity Prevalence Study questionnaire (IPAQ E-module) (Alexander et al., 2006) was used to assess parents' perceptions of the neighborhood environment. The module consisted of 15 questions regarding the local environment (defined as a 10- to 15-min walk from the home) that were shown to be associated with PA. The answers were dichotomized in "do not agree" and "agree". Similar procedures were used on other epidemiological studies (Rodrigues et al., 2022).

Children's health-related behaviors were measured using information from the parental survey. Information about the mode (car, public transport, walking, or cycling) and travel duration (minutes on each transport) were recorded for two travels: home-to-school and school-to-home. The mean time (min/day) devoted to active commuting (walking or cycling in one or both travels) was used. We also use sport participation time in a club/sport association outside school hours in a regular week. Sport participation time variable (min/day) indicates the children's time spent playing all kinds of sports throughout the 7-days of the week. Time (min/day) spent by the child playing indoors and outdoors (spontaneous PA) were also reported by the parents. Examples of indoor (more sedentary) play - reading, making puzzles, playing with cars and dolls - and outdoor (more active) play – running, jumping, playing with balls, riding a bicycle, and other plays that involve running – were provided; the time was aggregated for the entire week. For screen time assessment, we asked parents: "In a typical week, how much time per day does your child use a television/computer/electronic game?" Min/day were calculated for each device (and for total screen-time) in all days of the week (weekdays and weekend).

As a covariate, father's educational level was collected and categorized in low (9 years of school completed or less), medium (secondary school level; 10-to-12 years) and high (university degree). This variable is a proxy measure of SES, commonly used in Portuguese epidemiological studies since the country does not have an official measure of the SES. Parents also reported family car ownership (e.g., possible answers were no or yes) and main type of house (multiple response options were: detached single-family, two family residences or row houses, apartments or condos of 1–3 stories, apartments or condos of 4–12 stories, or apartments of more than 12 stories).

2.4. Statistical analyses

Counts and proportions, means and standard deviations were calculated to characterize the sample. Independent Samples Chi-square tests were used to: 1) test the differences of the answers to the IPAQ E-module between 2009 and 2016, and 2) compare the prevalence of difference (e.g., 2009–2016) of the agreement in the three districts. Independent Samples T-Tests were used to compare mean time of children's health-related behaviors between the two time periods for the three districts. Cohen's d ($=M_2\text{-}M_1)/SD_{pooled}$), as a measure of effect size of the mean differences was computed for each analysis.

A Pearson correlation was used to measure the strength of the linear relationship between the IPAQ E-module items. A principal component analysis (PCA) was performed to identify patterns on parental perceptions of the neighborhood environment. The Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO = .78) and the Bartlett Test of Sphericity (BTS<.001) were applied to evaluate whether the data were suitable for factor analysis. The orthogonal rotation (varimax option) was used to obtain independence of the factors. The factors having eigenvalues ≥1 were extracted and the items were retained in the pattern if the factor loading value was ≥.30. A total of four patterns were retained (Fig. S2), explaining 52.28% of the variance: pattern 1 related with the walk features (e.g., many places to go within easy walking distance; shops, stores, markets, or other places to buy things they need; well-maintained and unobstructed sidewalks; sidewalks on most of the streets), pattern 2 characterized by the existence of PA features (e.g., facilities to ride

a bicycle; many interesting things to look while walking; several free or low-cost recreation facilities; many people being physically active; well-maintained and unobstructed places to ride a bicycle), pattern 3 and 4 related with neighborhood safety, reflecting perceived crime (e.g., high crime rates that make them feel unsafe to go on walks at night or during the day; much traffic on the streets that makes it difficult or unpleasant to walk) and traffic rates (e.g., many 4-way intersection; much traffic on the streets that makes it difficult or unpleasant to ride a bicycle; public transport stops), respectively. Higher scores indicated better ratings of the perceived neighborhood environments.

Multiple linear regression models were performed using the following formula:

$$Y = \beta 0 + \beta 1x1 + \beta 2x2 + \cdots + \beta kxk + e$$

The dependent variables were the time in multiple health-related behaviors, including active commute, organized sport, outdoor and indoor play, television watching, computer and electronic games use. The four environmental scores from the PCA were the independent variables. We stratified the analyses by year and adjusted them for child's sex and age, family's SES, district of residence, and the PCA patterns. All the analyses were conducted using SPSS v.27. Significance level was set at 5%.

3. Results

Table 1 shows the sample characteristics. The sample was composed of 2252 (48.7%) boys and 2371 (51.3%) girls in 2009, and 2949 (50.9%) boys and 2847 (49.1%) girls in 2016. In 2009, 29.1% of children resided in Coimbra district, 33.9% in Lisbon and 37.0% in Porto. In 2016, 40.4% resided in Coimbra, 29.6% in Lisbon and 30.0% in Porto. A high-SES was the most prevalent in Coimbra (2009: 42.3%; 2016: 39.4%) and Lisbon (2009: 39.1%; 2016: 47.0%), independently of the year. Inversely, a low- (2009: 39.4%) or medium-SES (2016: 41.5%) were the most prevalent in Porto. Independently of the year, most children from Porto were living in apartments or condos of 1–3 stories, while in Lisbon, the most common type of house were apartments or condos of 4–12 stories. In Coimbra the majority of children were living in detached single-family houses or in apartments/condos of 1–3 stories. Overall, 90% of the families owned at least one car.

Fig. 1 shows the percentage of participants who agreed with each question of the IPAQ E-module. The existence of sidewalks, places to go within easy walking distance, including shops, stores and markets were the answers that gathered the higher percentage of agreement (i.e., response option "agree") in both 2009 and 2016. On the other hand, in 2009, 21% of parents reported lack of facilities to ride a bicycle and only 24.5% indicated that the places to ride a bicycle were well-maintained. However, those numbers were significantly better in 2016 (33% and 38%, respectively). Overall, all neighborhood features were better rated in 2016 compared to 2009. The major differences between 2009 and 2016 were a decrease in the perceived crime rates that made parents felt unsafe to walk at night (44.6% in 2009 to 26.3% in 2016; $\chi^2 = 483.3$, $p < .001$) and a perceived improvement in the maintenance of places to ride a bicycle (24.5% in 2009 compared to 38.3% in 2016; $\chi^2 = 257.9$, $p < .001$). Fig. 2 compares the distribution of the agreement with each E-module question considering the three districts. Most improvements in parental perception of the neighborhood characteristics (e.g., bike paths, special lanes, separated paths or trails) occurred in Lisbon ($p < .001$). A lower perception of "crime rates that make them feel unsafe to go on walks at night" was also the most significant difference between years in all districts ($p < .001$).

Fig. 3 shows the minutes per day spent by the children in multiple health-related behaviors in both 2009 and 2016; this information is complemented with statistical tests shown in Table 2. Overall, time spent engaged in healthier behaviors such as time devoted to organized sports and spontaneous activity (e.g., outdoor play) was higher in 2016 than in 2009. The biggest difference was in Coimbra for sport participation (+23 min/day) and Porto for outdoor play (+23 min/day). In 2016, outdoor play was the activity in which children reportedly spent more time in every district (approximately 124 min/day), while in 2009, the activity with more min/day was indoor play, independently of the districts (~125 min/day). Active commuting corresponded to only ~4 min/day in 2009 and the time significantly decreased in 2016, independently of the district ($p < .001$). Screen time was lower in 2016 than in 2009, particularly in Lisbon.

Table 3 presents the results from the adjusted linear regression models describing the relationship between the children's time in multiple health-related behaviors, and the parental perceived neighborhood environment. An association was found between the dependent and independent variables, similarly in both time periods. Walk features in the neighborhood were positively associated with more time in outdoor play in 2009 ($\beta = 3.88$ $p < .001$), but not in 2016. In 2016, walk features were inversely correlated with television time ($\beta = -1.77$, $p = .02$). PA features in the neighborhood were positively associated with more screen time, especially television, both in 2009 ($\beta = 1.91$, $p = .04$) and 2016 ($\beta = 2.12$, $p = .01$). Parental perceived crime rates were positively associated with more screen time and inversely related with sport participation in both 2009 and 2016. For each one-unit change in the crime rate score, there were less ~5–~6 min/day of sport participation in 2009 and 2016, respectively ($\beta = -5.22$, $p < .001$; $\beta = -6.16$, $p < .001$). In 2016, perceived crime rate was also inversely correlated with children's outdoor play ($\beta = -3.86$, $p < .001$). Perceived traffic rates were associated with more indoor play ($\beta = 1.77$, $p = .04$) and less television time ($\beta = -1.90$, $p = .01$) in 2016. In both 2009 and 2016, higher perception of traffic rates was positively related with active commuting, which may be related with the items included in the pattern, namely public transport stops and 4-way intersections. Overall, the R2 values were low (<.20), meaning that the variation in children's time in health-related behaviors is poorly explained by the parental perceptions of the environment.

4. Discussion

This study examined the associations between parent-perceived walk-, PA- and safety-related aspects of the neighborhood

Table 1
Sample description by year and district; number (percentage) and mean values (standard deviation).

		Coimbra			Lisbon			Porto			All districts		
		2009 (n = 1347)	2016 (n = 2343)	p-value	2009 (n = 1566)	2016 (n = 1713)	p-value	2009 (n = 1710)	2016 (n = 1740)	p-value	2009 (n = 4623)	2016 (n = 5796)	p-value
Child's													
Age (years)		7.4 (2.0)	7.3 (1.8)	<.001	7.6 (1.8)	7.4 (1.8)	.374	6.5 (2.2)	6.6 (2.0)	<.001	7.1 (2.0)	7.1 (1.9)	**<.001**
Sex	Boy	933 (49.5)	1531 (51.5)	.052	1157 (48.7)	1559 (51.4)	.430	1286 (48.9)	1190 (49.1)	.408	2252 (48.7)	2949 (50.9)	**.028**
	Girl	952 (50.5)	1440 (48.5)		1220 (51.3)	1476 (48.6)		1342 (51.1)	1234 (50.9)		2371 (51.3)	2847 (49.1)	
Family													
SES	Low	395 (30.6)	532 (23.5)	<.001	481 (33.4)	300 (18.4)	<.001	641 (39.4)	418 (25.3)	<.001	1517 (34.8)	1250 (22.6)	**<.001**
	Medium	350 (27.1)	838 (37.1)		397 (27.6)	563 (34.6)		526 (32.3)	684 (41.5)		1273 (29.2)	2085 (37.6)	
	High	546 (42.3)	890 (39.4)		563 (39.1)	766 (47.0)		461 (28.3)	547 (33.2)		1570 (36.0)	2203 (39.8)	
Car ownership	No	87 (6.7)	181 (8.0)	.133	180 (12.1)	154 (9.4)	.016	168 (10.2)	195 (11.9)	.130	435 (9.8)	530 (9.6)	.720
	Yes	1219 (93.3)	2070 (92.0)		1306 (87.9)	1478 (90.6)		1476 (89.8)	1447 (88.1)		4001 (90.2)	4995 (90.4)	
Neighborhood													
Main type of house[a]	1	422 (31.8)	820 (36.1)	.005	57 (3.8)	51 (3.1)	<.001	157 (9.5)	164 (9.9)	.010	636 (14.2)	1035 (18.6)	**<.001**
	2	162 (12.2)	314 (13.8)		282 (18.6)	241 (14.6)		253 (15.4)	278 (16.8)		697 (15.5)	833 (14.9)	
	3	440 (33.1)	621 (27.3)		298 (19.7)	260 (15.7)		757 (46.0)	654 (39.6)		1495 (33.3)	1535 (27.5)	
	4	292 (22.0)	502 (22.1)		818 (54.1)	1041 (62.9)		439 (26.7)	513 (31.1)		1549 (34.5)	2056 (36.9)	
	5	6 (.5)	7 (.3)		34 (2.2)	45 (2.7)		13 (.8)	11 (.7)		53 (1.2)	63 (1.1)	

[a] Response option: 1) detached single-family, 2) two family residences or row houses, 3) apartments or condos of 1–3 stories, 4) apartments or condos of 4–12 stories, or 5) apartments of more than 12 stories; p-value calculated by Independent Samples T-Test and Chi-Square Tests.

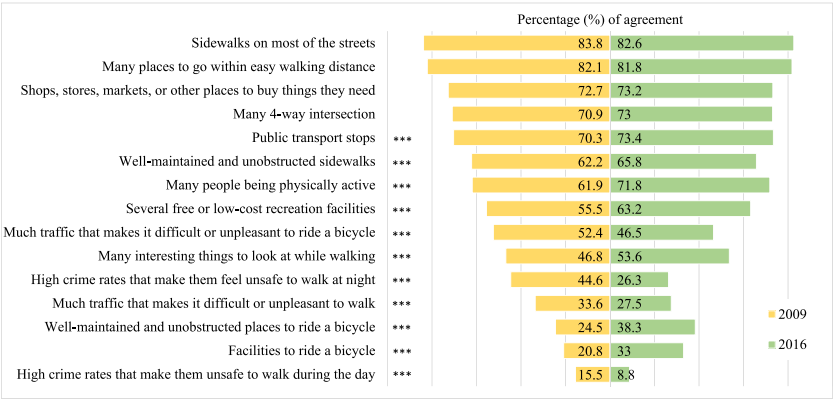

Fig. 1. Percentage of agreement (answer "agree") to the questions of the IPAQ E-module in 2009 and 2016; data for mainland Portugal (Chi-Square test: *p < .05, **p < .01, ***p < .001).

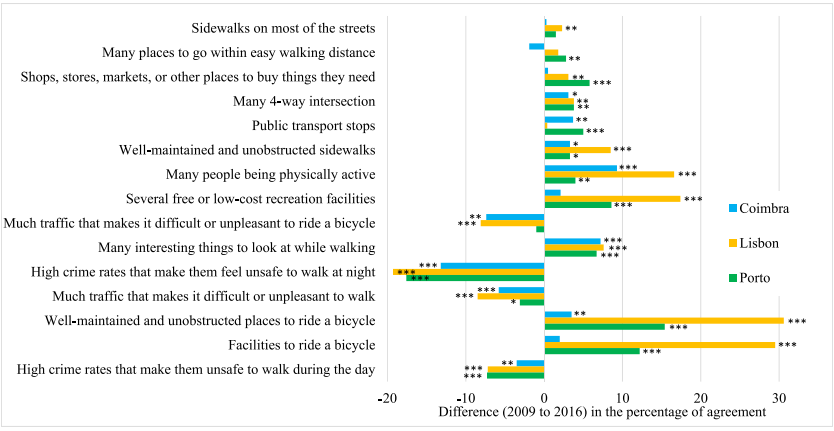

Fig. 2. Difference (2009–2016) in the prevalence of agreement (answer "agree") while answering to the IPAQ E-module regarding parental perception of the existence of neighborhood features within a 10- to 15-min walk from their residence; data from three Portuguese districts (Chi-Square test: *p < .05, **p < .01, ***p < .001).

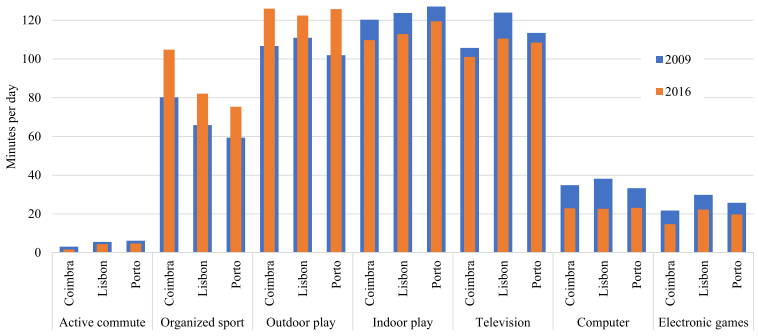

Fig. 3. Mean time (min/day) in different health-related behaviors; data from three Portuguese districts in 2009 and 2016 (see Table 2 for more information on th/e Independent Samples T-Test results).

environment and children's time in multiple health-related behaviors. By pooling and analyzing comparable data from three cities in two temporal periods, we were able to examine the extent to which the perception of the environment has changed in the last two decades, and if the physical and social environmental correlates of preschool-aged children's PA, sedentary and ST may be generalizable across geographical locations.

Overall, the environmental features were better rated by the parents in 2016 than in 2009. However, while a significant decrease in

Table 2
Children's mean time (min/day) in health-related behaviors in three Portuguese districts in 2009 and 2016; Independent Samples T-test and Cohen's d values.

		Coimbra		Lisbon		Porto		All districts	
		Mean min (SD)	t(df) = t statistics, p-value Cohen's d	Mean min (SD)	t(df) = t statistics, p-value Cohen's d	Mean min (SD)	t(df) = t statistics, p-value Cohen's d	Mean min (SD)	t(df) = t statistics, p-value Cohen's d
Active commute	2009	2.62 (7.12)	t(3479) = 6.02, p<.001	5.64 (9.99)	t(2628) = 4.31, p<.001	5.26 (10.48)	t(3087) = 2.84, p<.001	4.49 (9.45)	t(9198) = 8.09, p<.001
	2016	1.40 (4.69)	.22	4.03 (8.70)	.17	4.23 (9.65)	.10	3.02 (7.80)	.17
Organized sport	2009	87.59 (104.68)	t(3635) = −5.95,	73.25 (102.82)	t(3220) = −3.57,	59.77 (86.21)	t(3391) = −6.32,	72.44 (98.21)	t(10250) = −10.52,
	2016	110.14 (112.99)	p<.001 −.21	86.41 (105.93)	p<.001 −.13	81.58 (112.79)	p<.001 −.22	94.58 (111.63)	p<.001 −.21
Outdoor play	2009	106.44 (62.75)	t(3487) = −8.03,	111.15 (63.53)	t(3065) = −5.10,	100.86 (64.20)	t(3202) = −9.55,	105.99 (63.68)	t(9758) = −13.41,
	2016	125.83 (71.92)	p<.001 −.28	123.38 (68.88)	p<.001 −.18	123.86 (71.93)	p<.001 −.34	124.52 (71.04)	p<.001 −.27
Indoor play	2009	121.27 (64.06)	t(3555) = 4.87, p<.001	126.02 (64.25)	t(3143) = 5.11, p<.001	128.66 (67.51)	t(3301) = 3.73, p<.001	125.60 (65.47)	t(10003) = 8.50, p<.001
	2016	110.06 (67.03)	.17	114.06 (66.62)	.18	119.76 (69.41)	.11	114.16 (67.75)	.17
Television	2009	104.73 (57.11)	t(3532) = 2.09, p=.020	121.01 (61.26)	t(3078) = 6.12, p<.001	109.60 (61.07)	t(3212) = 1.82, p=.035	111.96 (60.33)	t(9826) = 6.41, p<.001
	2016	100.72 (53.56)	.07	108.03 (56.35)	.22	105.79 (57.81)	.06	104.41 (55.77)	.13
Computer	2009	34.49 (35.83)	t(3417) = 9.89, p<.001	36.17 (40.06)	t(3002) = 10.53,	29.57 (36.05)	t(3137) = 5.35, p<.001	33.26 (37.50)	t(9560) = 14.77, p<.001
	2016	22.35 (33.41)	.35	21.55 (36.07)	p<.001 .39	22.56 (37.33)	.19	22.18 (35.41)	.31
Electronic games	2009	22.23 (32.50)	t(3348) = 6.83, p<.001	29.01 (38.33)	t(2951) = 5.70, p<.001	22.22 (35.61)	t(3092) = 2.78, p<.001	24.55 (35.84)	t(9395) = 9.36, p<.001
	2016	14.74 (28.95)	.25	21.23 (35.77)	.21	18.65 (35.95)	.10	17.82 (33.35)	.20
Total screen time	2009	158.92 (91.30)	t(3179) = 7.52, p<.001	181.36 (101.29)	t(2733) = 9.30, p<.001	157.82 (98.38)	t(2848) = 3.95, p<.001	166.07 (97.90)	t(8764) = 12.45, p<.001
	2016	134.95 (81.64)	.28	147.19 (90.59)	.36	143.63 (93.05)	.15	141.15 (87.97)	.27

Results presented as mean minutes per day; Total screen time represents the added time for all three devices (e.g., television, computer, and electronic games); SD: standard deviation; interpreting Cohen's d as .2: small effect, .5: moderate effect, .8: large effect.

Table 3
Adjusted associations of the neighborhood features with children's time (min/day) engaged in health-related behaviors.

2009	Active commute	Organized sport	Outdoor play	Indoor play	Television	Computer	Electronic games	Total screen time
PCA Patterns[a]								
Walk features	.01 (−.31, .32), .978	1.33 (−1.58, 4.24), .369	3.88 (1.86, 5.90), <.001	.54 (−1.51, 2.58), .606	−.25 (−2.16, 1.67), .801	.18 (−.94, 1.29), .756	−.27 (−1.34, .80), .620	−.75 (−3.82, 2.32) .633
PA features	1.00 (.70, 1.30), <.001	.44 (−2.39, 3.26), .762	.99 (−.96, 2.94), .318	.81 (−1.17, 2.79), .421	1.91 (.07, 3.76), .042	1.26 (.18, 2.33), .022	.01 (−1.03, 1.05), .983	2.70 (−.25, 5.65) .073
Crime rates	.61 (.32, .90), <.001	−5.22 (−7.91, −2.53), <.001	−1.48 (−3.34, .38), .119	1.16 (−.73, 3.05), .229	4.07 (2.29, 5.85), <.001	2.10 (1.06, 3.14), <.001	2.05 (1.05, 3.05), <.001	7.18 (4.29, 10.07) <.001
Traffic rates	.58 (.28, .88), <.001	.51 (−2.24, 3.27), .715	.36 (−1.55, 2.27), .710	.64 (−1.31, 2.58), .521	1.08 (−.73, 2.89), .244	.47 (−.57, 1.52), .374	.64 (−.38, 1.66), .217	2.60 (−.30, 5.49) .079
R^2	.05	.13	.03	.07	.06	.19	.20	.20

2016	Active commute	Organized sport	Outdoor play	Indoor play	Television	Computer	Electronic games	Total screen time
PCA Patterns[a]								
Walk features	.38 (.19, .58), <.001	1.52 (−1.31, 4.36), .292	1.56 (−.37, 3.49), .113	.50 (−1.25, 2.24), .575	−1.77 (−3.24, −.30), .018	−.48 (−1.42, .45), .312	.24 (−.60, 1.09), .575	−1.39 (−3.70, .93) .240
PA features	.73 (.53, .93), <.001	−1.36 (−4.24, 1.51), .352	−1.49 (−3.44, .46), .135	−.08 (−1.84, 1.69), .931	2.12 (.63, 3.61), .005	.17 (−1.12, .78), .730	.91 (.05, 1.76), .038	2.55 (.20, 4.89) .033
Crime rates	.18 (−.04, .39), .101	−6.16 (−9.21, −3.11), <.001	−3.86 (−5.95, −1.76), <.001	.54 (−1.34, 2.41), .576	3.10 (1.51, 4.68), <.001	.98 (−.03, 1.99), .056	1.10 (.19, 2.02), .018	4.43 (1.92, 6.95) <.001
Traffic rates	.69 (.49, .88), <.001	2.33 (−.50, 5.15), .106	−.27 (−2.19, 1.65), .783	1.77 (.04, 3.50), .046	−1.90 (−3.37, −.44), .011	−.54 (−1.47, .39), .252	−1.20 (−2.04, −.36), .005	−3.77 (−6.08, −1.45) .001
R^2	.05	.13	.03	.10	.04	.08	.16	.13

Data presented as β (95% CI: confidence interval), p-value; PA: physical activity.

[a] Parental perception of the existence of neighborhood features within a 10- to 15-min walk from their residence; Total screen time represents the added time for all three devices (e.g., television, computer, and electronic games); models adjusted for children's sex and age, family SES, district of residence, and all the PCA patterns.

the perceived crime rates that "makes families feel unsafe to go on walks at night" was noticed between the two periods, this was still true for 26% of the families in 2016. We found that perception of negative features in the neighborhood (e.g., crime and traffic rates) were mostly associated with children's higher levels of screen time and indoor play, and less engagement in outdoor play and sports. The literature has shown that the environment can be a powerful factor to promote or hinder an active lifestyle. The negative influence of social environments on children's sport participation may result from mothers' decisions to keep their children indoors for safety reasons. A recent meta-analysis revealed that living in unsafe neighborhoods was associated with a reduction in children's PA by 13 h/week (An et al., 2017). Constrained parental behavior, mainly motivated by safety concerns about road traffic and stranger danger, was also a major barrier for active (outdoor) play (Veitch et al., 2006). Living in a neighborhood perceived as the least safe, was also found to be associated with more television time in the US, Australia and Portugal (Baldwin et al., 2022; Burdette and Whitaker, 2005; Rodrigues et al., 2022). Evidence points that outdoor play has been replaced by more time using electronic media indoors (Basset et al., 2015).

We also observed a significant increase in the perception of well-maintained and unobstructed places to ride a bicycle in 2016 vs. 2009. Over the last decade, Portugal has experienced several changes regarding urban cycling both in legislation and infrastructures (Léchaud, 2016). These improvements were mostly reported by parents living in Lisbon, a place that has experienced several changes in the built environment (e.g., bicycle parking facilities), together with the expansion of a cycling network and the implementation of a bike-sharing system (with a 70% e-bike fleet) (Félix et al., 2020). Through the principal component analysis, bike lanes were included in the PA features of the neighborhood, which was found to be inversely associated with children's active commute and positively associated with higher screen time.

Active commuting is still little prevalent in Portugal, with only 17% of 6-9-year-old children reporting walking or cycling to school (Whiting et al., 2021). This behavior still represents very little daily time among Portuguese children (i.e., less than 5 min/day), and was lower in 2016 than in 2009, which is worrying considering its important health benefits (Larouche et al., 2014). A nationwide project promoting cycling to school is currently being implemented, but ensuring adequate public transport service networks and providing security agents along the home-school path are essential when planning commuting options. Other factors influencing whether children walk or cycle to school may be the length of the school day and timetable, the location of elementary schools within communities, and weather conditions (Davison and Lawson, 2006). Moreover, more studies are needed to investigate if the existing bike lanes have adequate connections linking residential neighborhoods to school locations, or if they are primarily located in parks and recreational areas. In the second case, they may be a direct and indirect contributor of children's outdoor play (higher in 2016 than in 2009), and non-significant for active commuting.

Places with more PA features may attract "strangers" who are users of those facilities, which can increase the perception of danger and negatively influence children's outdoor play (Timperio et al., 2005), and consequently increase their screen time as seen in this study. Outdoor play is correlated with screen time in ways that the availability of household electronic media may "seduce" children away from the outdoors (Tandy, 1999; Woolley, 2006; Basset et al., 2015). Inversely, neighborhood's walk features were positively associated with children's outdoor play and inversely related with television time. The fact that positive associations between walk features, such as sidewalks, and outdoor play was found suggests that even for young children, "informal" play areas such as sidewalks provide a space suitable for outdoor play activities such as rope skipping, hopscotch or skating. These unstructured active plays may be encouraged by the parents due to convenience, proximity and opportunities for discreet surveillance by parents (if the play space is visible from home) or by neighbors.

Overall, we found that children's sport participation was significantly higher in 2016 than in 2009, and at the same time parents reported more people being physically active in the neighborhood. Magalhães et al. (2023) report an increase in the PA levels in some age groups, with the PA recommendations compliance being more prevalent in 2018 than in 2008 for youth females and adult males. Curiously, the two last Portuguese Report Cards on Physical Activity reported that sport participation decreased (Mota et al., 2018; Pizarro et al., 2023). However, this may reflect an effect of sample age since the Portuguese's Report Card on Physical Activity uses data for both children and adolescents, and it is known that the onset of puberty is a key time point where a decline in sport participation was observed (Brown et al., 2017). In the last decade, Portugal has implemented policies (i.e., the National Strategy for Promotion of Physical Activity from 2016) and made an investment in PA programs (e.g., the National Sports for All Program, the Sport Facilities Rehabilitation Program) (Eurostat, 2021). Other actions that may promote PA is include reinstating physical education as a subject that impacts a student's college application, and launching a mass media marketing campaign to disseminate the message that every move counts (Shinn et al., 2020).

Major strengths of this study are the large sample size of Portuguese children and the good response rate. Also, children were recruited from schools instead of neighborhoods with varying SES levels. Both projects included the same schools and used the same validated instruments. However, this investigation still has limitations. The cross-sectional design does not allow to measure improvements in parental perception between 2009 and 2016 nor drawing inferences on causality. Parental perceptions were purposefully explored; objectively measured built environment characteristics were not examined. Then, present findings do not represent the effects related to the objectively measurable physical environment of a neighborhood. Most respondents in this study were mothers, which limits the generalizability of findings to entire families, where fathers or other caregivers are responsible in some capacity for overseeing the child's PA. Also, our findings may not generalize to parents in different geographical locales since city- and geography-specific attributes are not uniform throughout the country. Nevertheless, the three regions have a similar landscape with the river and the hills, which can sometimes be challenging for active commuting. Future studies should explore changes in different types of suburban locations because suburban areas are expanding (Rocha, 2022).

The home environment also changed between the two time periods. Many children in our study live in apartments which can hinder outdoor time. Previous findings showed that outdoor space at home positively impacts children's PA (Neshteruk et al., 2018; Veitch

et al., 2006). Future studies may explore PA in a clearly defined environment (e.g., in the garden vs. in the public recreation spaces). Another limitation is the subjectively measured time in health-related behaviors, as parent-reported time may be biased. However, evidence suggests that social desirability accounts for only a small variance in PA (Motl et al., 2005). In addition, some aspects of screen time were not captured (e.g., tablet and smartphone). Besides, it needs to be acknowledged that it is very difficult to point out the exact relation between environmental factors and health-related behaviors, because of the strong interaction between environmental, social and individual factors. Therefore, future research may account for other moderating factors of the relation between neighborhood characteristics and children's time in physical and sedentary behaviors, such as family type and number of siblings.

5. Conclusion

This study examines changes in parental perceptions of the environment and highlights how neighborhood physical and social features are associated with children's active and sedentary behaviors. In general, between 2009 and 2016, parental perception of the neighborhood features improved, and their children spent more time per day engaging in healthy behaviors, such as sports and outdoor play. Neighborhood's walk features were positively related to children's active behaviors, and inversely associated with screen time. However, PA features showed an opposite effect, maybe associated with parental greater perception of "strangers" (i.e., people from outside the neighborhood/community) using that PA equipment. Overall, our findings indicate that the perception of neighborhood features did not account much for children's mean minutes per day in different behaviors; however, to develop a more healthy, active lifestyle, creating safely-friendly neighborhoods, with informal play areas such as well-maintained and unobstructed sidewalks, may be more effective than building formal spaces. More studies addressing these issues with larger representative samples and a longitudinal design, including both perceived and objective measures of neighborhood attributes, are needed. Future studies should also have a more balanced representation of fathers in the sample, since ours mostly reflect mothers' perception. Local actions are needed given that each neighborhood may present a specific urban and social context. Local policy makers from different sectors can use these research findings in creating more activity-friendly neighborhoods for children.

CRediT authorship contribution statement

Daniela Rodrigues: Writing – original draft, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization. **Aristides M. Machado-Rodrigues:** Writing – review & editing, Investigation. **Augusta Gama:** Writing – review & editing, Investigation. **Maria-Raquel G. Silva:** Writing – review & editing, Investigation. **Helena Nogueira:** Writing – review & editing, Investigation. **Gustavo Velasquez-Melendez:** Writing – review & editing. **Larissa Loures Mendes:** Writing – review & editing. **Cristina Padez:** Writing – review & editing, Investigation, Funding acquisition, Conceptualization.

Data availability

The data is available from the corresponding author upon reasonable request.

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Declaration of competing interest

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Appendix A. Supplementary data

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Data availability

Data will be made available on request.

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