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Environmental and Psychosocial Correlates of Accelerometer-Assessed and Self-Reported Physical Activity in Belgian Adults

Delfien Van Dyck · Greet Cardon · Benedicte Deforche · Billie Giles-Corti · James F. Sallis · Neville Owen · Ilse De Bourdeaudhuij

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Abstract
Background Despite the well-known benefits of physical activity (PA) on overall health, the majority of the adult population does not engage in sufficient PA. To develop effective interventions to increase PA, it is necessary to understand the most important PA correlates and to investigate whether correlates are similar in different population subgroups.
Purpose This study examined associations between physical environmental perceptions and self-reported and objectively assessed PA in Belgian adults. Moreover, associations between psychosocial factors and PA, and the moderating effects of sociodemographic factors were investigated.
Method A sample of 1,200 Belgian adults (20–65 years; 47.9% males) completed a survey measuring sociodemographic variables and psychosocial correlates, the Neighborhood Environmental Walkability Scale and the long-version International Physical Activity Questionnaire. They wore an accelerometer for 7 days.
Results Perceiving neighborhoods to be high walkable (high residential density, high land use mix access, and high land use mix diversity) and recreation facilities to be convenient, and the availability of home PA equipment were the most consistent physical environmental correlates of PA. The strongest psychosocial correlates were social support from friends and family and self-efficacy. The psychosocial associations were most consistent for self-reported leisure-time PA and less clear for self-reported active transportation and accelerometer-assessed PA. Few significant sociodemographic moderators were found.
Conclusion Both physical environmental and psychosocial factors were associated with PA in adults, with psychosocial factors being important especially for leisure-time PA. Correlates of PA were similar regardless of gender, age, or socio-economic status, so interventions to change these factors could have population-wide effects.

Keywords Transportation · Socio-economic status · Accelerometers · Ecological models

D. Van Dyck · B. Deforche
Fund for Scientific Research Flanders (FWO),
Ghent, Belgium

D. Van Dyck (✉) · G. Cardon · B. Deforche ·
I. De Bourdeaudhuij
Faculty of Medicine and Health Sciences,
Department of Movement and Sports Sciences, Ghent University,
Watersportlaan 2,
9000 Ghent, Belgium
e-mail: Delfien.VanDyck@UGent.be

B. Deforche
Department of Human Biometrics and Biomechanics,
Vrije Universiteit Brussel,
Brussels, Belgium

B. Giles-Corti
Centre for the Built Environment and Health,
The University of Western Australia,
Perth, Australia

J. F. Sallis
Department of Psychology, San Diego State University,
San Diego, CA, USA

N. Owen
School of Population Health, The University of Queensland,
Brisbane, Australia

Introduction

In the past, studies of physical activity (PA) correlates in adults focused on the contribution of psychosocial factors, including self-efficacy, social support, and perceived benefits and barriers. More recently, research has examined relationships between physical environmental factors and PA [1]. Numerous studies have found positive associations between physical environmental attributes (particularly residential density, street connectivity, land use mix, neighborhood safety, and aesthetics) and PA behaviors [1–3].

Associations between environmental attributes and PA need to be understood in relation to both objectively assessed and self-reported PA. Objective measurement methods (e.g., accelerometers) measure PA more accurately, but lack domain-specific information (e.g., when activity is done for leisure or transport purposes) [4]. Self-report methods (e.g., questionnaires) allow domain-specific PA information to be gathered, but suffer from several sources of bias, including social desirability and over-reporting [5]. For example, a study of relationships between objectively assessed neighborhood walkability [measured using Geographic Information Systems (GIS) databases] and PA in Belgian adults found that living in a high-walkable neighborhood was positively associated with both objective and self-reported PA [6].

Studies focusing only on the physical environmental correlates of PA have thus far explained modest proportions of the variance in PA behavior. For example, an Australian study showed that approximately 4.2% of the variation in walking for transport was explained by neighborhood walkability [7]. Ecological models of health behavior posit that PA behaviors are influenced by combinations of factors at multiple levels of influence, including sociodemographic, psychosocial, and physical environmental variables [8–10].

Some recent ecological studies examined the relative contribution of sociodemographic, psychosocial, and physical environmental factors on various self-reported PA behaviors [11–14]. A study in Australian adults found that individual as well as social environmental and observed physical environmental factors were related to self-reported walking [12]. However, for self-reported overall PA (defined as meeting current PA recommendations by any type of PA), the associations were stronger for individual and social environmental parameters than physical environmental variables [11]. In a European study, a clear differentiation in correlates was observed between different types of PA. Perceived environmental factors (neighborhood walkability, availability and quality of walking facilities) were found to be important for self-reported active transportation, while self-reported recreational PA was explained best by psychosocial variables like social support, self-efficacy, and perceived benefits and barriers [13]. In a Japanese study, separate analyses for men and women showed gender-specific associations between perceived environmental and psychosocial factors and attaining recommended levels of PA [14].

From these studies, it appears that associations between physical environmental and psychosocial factors and PA are behavior-specific, which underlines the importance of developing specific models for different PA behaviors (e.g., cycling and walking for transport and leisure, leisure-time PA) [2]. Until now, most studies examining the possible physical-environment and psychosocial correlates of PA have used only self-report PA measures. When using self-report measures, domain-specific information can be obtained, but adults tend to over-report their PA levels [5, 15]. Therefore, it is important in this emerging field of research to examine both self-reported and objectively assessed PA.

Furthermore, the direction and strength of associations can depend on sociodemographic characteristics like gender and age. With some exceptions [14, 16, 17], few studies have investigated the possible moderating effects of sociodemographic factors, so no definite conclusions can be drawn at this stage. To develop effective interventions for different population subgroups, further examinations of the correlates of PA in different subgroups are needed.

The present study had three main aims and focused on the factors associated with both objectively assessed and self-reported PA behaviors. The first aim was to examine associations between environmental perceptions and PA behaviors. The second aim was to examine the associations of psychosocial factors, additional to the contribution of physical environmental factors, to explaining PA behaviors. The third aim was to examine potential moderating effects of sociodemographic attributes on the relationship of physical environmental and psychosocial factors with multiple PA behaviors.

Method

For the present study, cross-sectional data from the Belgian Environmental Physical Activity Study (BEPAS) in Ghent, Belgium, were used. BEPAS was based on the methods of the USA Neighborhood Quality of Life Study [18] and the Australian Physical Activity in Localities and Community Environments study [7]. These studies were primarily designed to investigate associations between neighborhood walkability, neighborhood SES, and adults' PA.

Procedures

The design and procedures have been described elsewhere [6]. In brief, 1,200 participants were recruited from 24 selected neighborhoods in Ghent. These neighborhoods were stratified on GIS-based walkability (high versus low) and matched on neighborhood SES (high versus low). This selection procedure resulted in six high-walkable/high-SES, six high-walkable/low-SES, six low-walkable/high-SES, and six low-walkable/low-SES neighborhoods. In each selected neighborhood, 250 randomly selected adults (20–65 years) received an information letter and were visited at home 2 to 6 days after posting the letter. Recruitment continued until 50 participants per neighborhood were measured (response rate=58.0%). Participants completed a written informed consent, a questionnaire on sociodemographics and psychosocial factors, the Dutch version of the Neighborhood Environmental Walkability Scale (NEWS), and the long International Physical Activity Questionnaire (IPAQ—interview version). They also wore an accelerometer for seven consecutive days. BEPAS was approved by the ethics committee of the Ghent University Hospital.

Measures

Physical Activity Self-reported PA was measured with the Dutch IPAQ (last 7 days interview version). The IPAQ has good reliability (intra-class correlation range from 0.46 to 0.96) and fair-to-moderate criterion validity (median ρ= 0.30) in a 12-country study [19]. The questionnaire assesses frequency (number of days in the last 7 days) and duration (hours and minutes per day) of PA in different domains (work, transportation, recreation, and household).

Accelerometers (model 7164; Computer Science Application, Inc., Shalimar, FL, USA) were used to objectively measure PA. Accelerometers are valid and reliable tools to measure PA in adults [20]. The accelerometers were set to measure in epochs of 1 min. Minutes of 1,952 to 5,724 counts and minutes of more than 5,724 counts corresponded to PA of moderate and high intensity, respectively [21]. Participants were asked to wear the accelerometer above the right hipbone throughout the day and to remove it only for water activities like swimming and bathing. Accelerometer data were reduced with MAHUffe Analyzer 1.9.0.3 (www.mrc.epid.cam.ac.uk). Data from participants with at least 10 h of wearing time for at least 4 days (including 1 weekend day) were included in the analyses. Non-wearing time was defined as 60 min or more of consecutive zero counts. Due to insufficient wearing time and technical problems, data of 34 participants (2.8%) were excluded from all analyses.

Demographic Variables Self-reported demographic variables included gender, age, education (primary school, secondary school, college/university), living situation (alone, with parents, with partner, with children, with partner and children), working status (employed, unemployed, student, retired, on a career break, doing the housekeeping), working situation (employee, education, profession, executive staff, workman, self-employed), height, and weight.

Psychosocial Variables All questions on psychosocial correlates were derived from previous studies in adults and adolescents [22–24]. The construction and content of the items, as well as descriptive results, are presented in Table 1. Four categories of psychosocial variables were included: social influences, self-efficacy, perceived benefits, and perceived barriers. For the social influences, scales were constructed for modeling [sum of two items, Cronbach's alpha (α)=0.58], social norm (sum of two items, α=0.85), and social support from family (sum of four items, α=0.77) and friends (sum of four items, α=0.84). Scales were constructed for perceived benefits (e.g., losing weight, enjoying PA; sum of 21 items, α=0.92) and perceived barriers (e.g., lack of time, health problems; sum of 22 items, α=0.90). All these items were scored on a five-point Likert scale. Factor analysis identified two self-efficacy scales, one for self-efficacy towards internal barriers (e.g., if you are stressed; sum of seven items, α=0.80) and the other towards external barriers (e.g., if the weather is bad; sum of seven items, α= 0.90). All self-efficacy items were scored on a three-point scale (I know I can, I think I can, I know I cannot).

Perceived Physical Environmental Factors To measure perceived physical environmental factors, the Dutch version of the NEWS questionnaire was used [25]. The construction and content of the items, as well as descriptive results, are presented in Table 1. Physical environmental factors included were residential density, land use mix diversity, land use mix access, street network connectivity, availability and quality of walking and cycling infrastructures, safety for cycling, aesthetics, perceived safety from crime and traffic, PA equipment in the home environment, convenience of recreation facilities, satisfaction with neighborhood services, and emotional satisfaction with the neighborhood. The Dutch NEWS has acceptable to good reliability (intraclass correlation coefficients between 0.40 and 0.97) and acceptable validity (coefficients between 0.21 and 0.91) [26]. All environmental factors were rated on a four-point scale, except for residential density (three-point scale), land use mix diversity (five-point scale), satisfaction with neighborhood services, and emotional satisfaction with neighborhood (both seven-point scales). PA equipment in the home environment was assessed using a list of 13 items (available/not available). Because of the multicollinearity ($r\geq 0.60$) between residential density, land use mix diversity, and land use mix access, a "walkability Z-score" was calculated based on the Z-scores of these three scales and used in all analyses.

Analyses

Descriptive statistics were obtained using SPSS 15.0. Multivariate regression analyses were conducted using

Table 1 PA behavior, environmental perceptions, and psychosocial factors of the total sample

	Content of the item	Response category	Mean±SD
PA behavior			
Activity monitor (min/day)			
Light intensity PA			332.8±93.8
MVPA			35.2±23.7
Self-reported PA (min/week)			
Walking for transport			77.5±141.3
Walking for recreation			76.4±133.1
Cycling for transport			63.1±113.6
Leisure-time moderate PA			36.1±95.9
Leisure-time vigorous PA			58.1±123.6
Environmental perceptions			
Residential density (5 items)	Presence of different types of residences (e.g., detached single family residences, row houses, apartments)	3-point scale[a]	1.91±0.52
Land use mix diversity (20 items)	Distance to local facilities (e.g., supermarket, post office, park, primary school, café)	5-point scale[b]	3.07±0.88
Land use mix access (5 items)	Access to neighborhood services (e.g., ease to walk to public transport, possibilities to do shopping in local area)	4-point scale[c]	3.04±0.52
Street connectivity (3 items)	Connectedness of street network (e.g., presence of intersections, dead-end streets, alternate routes)	4-point scale[c]	2.86±0.53
Walking infrastructure (5 items)	Availability and quality of walking infrastructure (e.g., footpaths on most streets, maintenance of footpaths, footpaths separated from streets)	4 point-scale[c]	2.62±0.57
Cycling infrastructure (6 items)	Availability and quality of cycling infrastructure (e.g., cycling lanes in most streets, maintenance of cycling lanes, cycling lanes separated from streets)	4-point scale[c]	2.15±0.52
Safety for cycling (2 items)	Prevalence of bicycle theft and precautionary measures against bicycle theft	4-point scale[c]	2.41±0.70
Aesthetics (4 items)[c]	Presence of aesthetic features (e.g., green spaces, attractive buildings, streets free from litter and graffiti)	4-point scale[c]	2.60±0.57
Safety from traffic (7 items)	Perceived safety from traffic problems (e.g., speed of traffic in neighborhood, availability of pedestrian crossings and traffic signals, exhaust fumes from cars)	4-point scale[c]	2.51±0.44
Safety from crime (6 items)	Perceived safety from crime (e.g., crime prevalence in the neighborhood, perceived safety for walking and cycling during the day and at night)	4-point scale[c]	3.08±0.48
Home PA equipment (13 items)	Availability of 13 items in the home environment (e.g., running shoes, bicycle, trampoline)	Total number of items	3.37±1.82
Convenience of recreation facilities (19 items)	Distance to PA facilities (e.g., soccer field, squash court, running track, swimming pool)	5-point scale[b]	3.18±0.79
Satisfaction with neighborhood services (5 items)	Degree of satisfaction with neighborhood services (e.g., access to highway, distance to work)	7-point scale[d]	5.76±0.91
Emotional satisfaction with neighborhood (3 items)	Degree of emotional satisfaction with neighborhood (e.g., number of friends in neighborhood, neighborhood is a good place to live)	7-point scale[d]	5.08±1.21
Psychosocial factors			
Social influences			
Modeling (2 items)	How frequently are family and friends physically active?	5-point scale[e]	2.97±0.93
Social norm (2 items)	Do family and friends think that you should be physically active?	5-point scale[f]	3.36±1.07
Social support from family (4 items)	Social support from family towards PA (e.g., encourage you to do PA, invite you to do PA together)	5-point scale[g]	2.17±0.84
Social support from friends (4 items)	Social support from friends towards PA (e.g., encourage you to do PA, invite you to do PA together)	5-point scale[g]	2.12±0.85
Self-efficacy			
Towards internal barriers(7 items)	Confidence to be physically active under potentially difficult situations (internal; e.g., feeling tired, being in a depressive mood)	3-point scale[h]	2.05±0.51
Towards external barriers(7 items)	Confidence to be physically active under potentially difficult situations (external; e.g., bad weather, early in the morning)	3-point scale[h]	1.79±0.58

Table 1 (continued)

	Content of the item	Response category	Mean±SD
Perceived benefits (21 items)	Agreement with possible positive effects of PA (e.g., losing weight, having fun)	5-point scale[f]	3.52±0.63
Perceived barriers (22 items)	Agreement with possible barriers, preventing you to do PA (e.g., lack of time, lack of support)	5-point scale[f]	2.30±0.59

PA physical activity, *MVPA* moderate-to-vigorous physical activity, *SD* standard deviation

[a] No, some, a lot

[b] 1–5 min, 6–10 min, 11–20 min, 21–30 min, >30 min

[c] Strongly disagree, somewhat disagree, somewhat agree, strongly agree

[d] From strongly disagree to strongly agree

[e] From never to daily

[f] From strongly disagree to strongly agree

[g] From never to very often

[h] I know I can, I think I can, I know I can not

MLwiN 2.02. Because all PA indices were positively skewed, logarithmic transformations were used to improve normality. All explanatory variables were centered on their means. Raw data were used to calculate mean PA scores of the sample (Table 1). Multilevel modeling (two-level—participant-neighborhood) was applied to take clustering of participants in neighborhoods into account. These models were used to examine independent associations between the dependent variables (PA) and the environmental and psychosocial factors. Gender, age, and educational attainment were included as a first block of variables in all analyses. Then, environmental variables were added as a second block, followed by the psychosocial variables. Using this method, the contribution of psychosocial variables was estimated beyond the sociodemographic and physical environmental variables. Also, the moderating effects of sociodemographics [dichotomous variables—gender (male=0; female=1), individual SES (based on educational attainment—low SES=0; high SES=1), age (≤42 years=0; >42 years=1)] on the associations of PA with physical environmental and psychosocial factors were investigated by entering the cross-product terms in the model. In case of significant interactions, separate models were run to interpret the direction of the interactions. For all analyses, statistical significance was set at 0.05.

Results

Demographic Characteristics and Physical Activity

The final sample consisted of 1,166 participants (47.9% male, 52.1% female). Mean age was 42.7 (12.6) years, mean body mass index (BMI) was 24.3 (3.9) kg/m^2. Of all participants, 60.9% had a college/university degree, 76.1% were employed, and 75.1% reported having a white-collar job. Compared with Belgian census data [27], the sample was more likely to be highly educated and employed, and participating women were more likely to have a lower BMI. PA data of the total sample are shown in Table 1. More extensive data on sociodemographics and PA have been reported elsewhere [6].

Associations of Physical Environmental and Psychosocial Variables with Accelerometer-Assessed and Self-Reported PA

Associations with Accelerometer-Assessed MVPA (Table 2) More accelerometer-based MVPA was associated with a higher walkability score (CI=0.011, 0.027), perceiving the neighborhood to be less aesthetically pleasing (CI=−0.079, −0.009) and having more PA equipment in the home environment (CI=0.011, 0.035). More self-efficacy towards internal barriers (CI=0.051, 0.141) and fewer perceived barriers (CI=−0.095, −0.017) were also related to more accelerometer-assessed MVPA.

The moderating effects of gender, age and SES on the associations of physical environmental and psychosocial factors with objectively assessed MVPA were investigated. For gender, positive associations of PA equipment in the home environment and internal self-efficacy with accelerometer-assessed MVPA were stronger in men than women. The positive relation between social support from family and accelerometer-based MVPA was only significant in women. For SES, the positive association between home PA equipment and accelerometer-assessed MVPA was only significant in low-SES adults. The association between perceived barriers and accelerometer-based MVPA was stronger for low-SES rather than high-SES adults. Detailed results of these moderating effects are shown in Table 3.

Table 2 Multivariate regression analyses on the contribution of physical environmental and psychosocial variables to different types of PA

Dependent variables	Significant associations	β (SE)	95% CI
Activity monitor			
Moderate-to-vigorous PA	Environmental variables		
	Walkability score	0.019 (0.004)	0.011, 0.027
	Aesthetics	−0.044 (0.018)	−0.079, −0.009
	Home equipment	0.023 (0.006)	0.011, 0.035
	Psychosocial variables		
	Self-efficacy (internal)	0.096 (0.023)	0.051, 0.141
	Perceived barriers	−0.056 (0.020)	−0.095, −0.017
Self-reported PA			
Walking for transport	Environmental variables		
	Walkability score	0.110 (0.018)	0.075, 0.145
	Satisfaction with neighborhood services	−0.106 (0.034)	−0.173, −0.039
	Psychosocial variables		
	Modeling	−0.073 (0.032)	−0.136, −0.010
	Social support from family	0.085 (0.035)	0.016, 0.154
	Self-efficacy (internal)	0.158 (0.059)	0.042, 0.274
Cycling for transport	Environmental variables		
	Walkability score	0.047 (0.016)	0.016, 0.078
	Street connectivity	0.127 (0.064)	0.002, 0.252
	Convenience of physical activity facilities	−0.091 (0.043)	−0.175, −0.007
	Safety from crime	0.181 (0.065)	0.054, 0.308
	Psychosocial variables		
	Modeling	0.059 (0.033)	0.006, 0.124
	Self-efficacy (external)	0.429 (0.085)	0.262, 0.596
	Perceived benefits	−0.108 (0.051)	−0.208, −0.008
Walking for recreation	Environmental variables		
	Walkability score	0.058 (0.016)	0.027, 0.089
	Street connectivity	−0.145 (0.068)	−0.278, −0.012
	Psychosocial variables		
	Social support from family	0.104 (0.040)	0.028, 0.182
	Self-efficacy (internal)	0.155 (0.064)	0.030, 0.280
Leisure-time moderate PA	Psychosocial variables		
	Social support from family	0.078 (0.032)	0.015, 0.141
	Social support from friends	0.105 (0.033)	0.040, 0.170
	Self-efficacy (internal)	0.130 (0.046)	0.040, 0.220
Leisure-time vigorous PA	Environmental variables		
	Convenience of physical activity facilities	−0.084 (0.040)	−0.162, −0.006
	Home equipment	0.086 (0.015)	0.057, 0.115
	Psychosocial variables		
	Social support from friends	0.172 (0.033)	0.107, 0.237
	Self-efficacy (external)	0.308 (0.065)	0.181, 0.435
	Self-efficacy (internal)	0.367 (0.077)	0.216, 0.518

Walkability score=Z-score residential density+Z-score land use mix diversity+Z-score land use mix access

CI confidence interval, *PA* physical activity

Associations with Self-Reported Walking for Transport and Recreation, Cycling for Transport, and Moderate and Vigorous Leisure-Time PA (Table 2) A higher walkability score (CI=0.110, 0.018) and less satisfaction with neighborhood services (CI=−0.173, −0.039) were associated with more walking for transport. However, walking for transport was also associated with less modeling (CI=−0.136, −0.010), more social support from family (0.016, 0.154), and more self-efficacy towards internal barriers (0.042, 0.274).

A higher walkability score (CI=0.016, 0.078), perceiving neighborhoods to have connected street networks (CI=0.002, 0.252), convenient recreation facilities (CI=−0.175, −0.007), and to be safe from crime (CI=0.054, 0.308) were positively related to cycling for transportation. More modeling (CI=0.006, 0.124), more self-efficacy towards external barriers (CI=0.262, 0.596), and fewer perceived benefits (CI=−0.208, −0.008) were also associated with more cycling for transport.

A higher walkability score (CI=0.027, 0.089) and less perceived street connectivity (CI=−0.278, −0.012) were associated with more recreational walking. Moreover, more social support from family (CI=0.028, 0.182) and more self-efficacy towards internal barriers (CI=0.030, 0.280) were related to more recreational walking.

For other self-reported moderate-intensity leisure-time PA, no significant associations were found with physical environmental factors. Social support from family (CI=0.015, 0.141) and friends (CI=0.040, 0.170) and self-efficacy towards internal barriers (CI=0.040, 0.220) were positively related to other moderate-intensity leisure-time PA.

Perceiving recreation facilities to be convenient (CI=−0.162, −0.006) and reporting more PA equipment in the home environment (CI=0.057, 0.115) were associated with more vigorous leisure-time PA. Additionally, social support from friends (CI=0.107, 0.237) and self-efficacy towards external (CI=0.181, 0.435) and internal barriers (CI=0.216, 0.518) were positively related to vigorous leisure-time PA.

Analysis of the moderating effects of gender, age, and SES showed that gender did not significantly moderate any association of physical environmental and psychosocial factors with self-reported PA. For SES, the positive association between self-reported walkability and cycling for transport was only significant in high-SES adults. Age moderated four associations between psychosocial factors and self-reported PA behaviors, but the direction of these interactions was inconsistent (shown in Table 3).

Discussion

The first aim of the present study was to examine the associations between environmental perceptions and PA behaviors. Based on the findings in relation to this research question, the most consistent physical environmental correlates of the various PA behaviors were perceptions of high walkability, convenience of recreation facilities, and availability of PA equipment in the home. More specifically, the perception of high walkability was positively associated with self-reported active transportation (walking and cycling), recreational walking, and accelerometer-assessed MVPA. When comparing these findings to a previous report describing the associations of objectively measured neighborhood walkability with different PA behaviors in the same study sample [6], results were very similar. It appears that in Belgium, both objectively measured and perceived walkability are important correlates of different types of PA, not only of active transportation. Many other studies, mainly conducted in non-European countries, have found strong associations between walkability and active transportation, but associations with recreational walking and total PA have been less consistent [27, 28]. A possible explanation for the association between walkability and total PA found in this study could be that in Belgian adults, active transportation (which is usually found to be a correlate of walkability) is a large proportion of total PA. In other countries, and mainly in non-European countries, levels of active transportation (especially cycling) are much lower than in Belgium [29]; in circumstances where active transport accounts for a higher proportion of total PA, it is thus more likely to be associated with walkability.

Having PA equipment in the home environment was related to more self-reported vigorous leisure-time PA, confirmed by an association with accelerometer-assessed MVPA. This finding is in line with many other studies, showing that the availability of home equipment is a consistent environmental correlate of vigorous PA [1, 9, 14, 30].

Perceiving convenient recreation facilities in the neighborhood was associated with self-reported vigorous leisure-time PA and cycling for transport. In other studies [31, 32], this factor also emerged as a consistent environmental correlate of multiple PA behaviors. Physical environmental factors were most strongly associated with cycling for transport, which is promising for future interventions that aim to increase cycling rates through changes in environments [33]. Because correlates of cycling are rarely studied, these findings could be country-specific, as cycling rates are generally high in Belgium [29].

Surprisingly, perceived aesthetics was negatively associated with accelerometer-based PA, and satisfaction with neighborhood services was negatively related to self-reported walking for transport. These negative associations are in contrast with results from other studies [34–36]. However, because the present study was cross-sectional, the negative associations might be due to inverse causality. Physically active adults, who spend a lot of time walking or cycling in their neighborhood, might be more aware of the environmental problems in their neighborhood compared with their non-active counterparts [37–39]. Moreover, it might be that high neighborhood walkability usually is accompanied by poorer aesthetics and that walkability is more important in the decision to be physically active than aesthetics. Another possible explanation for these negative associations could be that people who perceive their

Table 3 Significant moderating effects of sociodemographics on the associations of physical environmental and psychosocial factors with PA behaviors

Interaction	Dependent variable	β (SE)	95% CI	Regression model for separate groups		
				Groups	β (SE)	95% CI
Gender×home equipment	Accelerometer-based MVPA	−0.020 (0.011)	−0.042, −0.002	Male	0.042 (0.009)	0.024, 0.060
				Female	0.021 (0.008)	0.005, 0.037
Gender×social support from family	Accelerometer-based MVPA	0.043 (0.024)	0.004, 0.090	Male	−0.024 (0.019)	−0.061, 0.013
				Female	0.033 (0.016)	0.002, 0.064
Gender×self-efficacy (internal)	Accelerometer-based MVPA	−0.100 (0.040)	−0.178, −0.022	Male	0.211 (0.030)	0.152, 0.270
				Female	0.096 (0.028)	0.041, 0.151
SES×home equipment	Accelerometer-based MVPA	−0.036 (0.011)	−0.058, −0.014	High SES	0.005 (0.007)	−0.009, 0.019
				Low SES	0.052 (0.009)	0.034, 0.070
SES×walkability score	Self-reported cycling for transport	0.073 (0.024)	0.026, 0.120	High SES	0.094 (0.016)	0.063, 0.125
				Low SES	0.030 (0.023)	−0.015, 0.075
SES×perceived barriers	Accelerometer-based MVPA	0.081 (0.034)	0.014, 0.148	High SES	−0.070 (0.022)	−0.113, −0.027
				Low SES	−0.148 (0.029)	−0.205, −0.091
Age×social support from friends	Self-reported leisure-time vigorous PA	−0.144 (0.062)	−0.266, −0.022	20–42 years	0.383 (0.051)	0.283, 0.483
				43–65 years	0.242 (0.042)	0.160, 0.324
Age×self-efficacy (internal)	Self-reported leisure-time moderate PA	0.191 (0.101)	0.007, 0.389	20–42 years	0.004 (0.070)	−0.133, 0.141
				43–65 years	0.207 (0.074)	0.061, 0.166
	Self-reported leisure-time vigorous PA	−0.353 (0.102)	−0.553, −0.153	20–42 years	0.904 (0.081)	0.745, 1.063
				43–65 years	0.617 (0.068)	0.484, 0.750
Age×self-efficacy (external)	Self-reported leisure-time vigorous PA	−0.278 (0.090)	−0.454, −0.102	20–42 years	0.793 (0.074)	0.648, 0.938
				43–65 years	0.495 (0.058)	0.381, 0.609

Walkability score=Z-score residential density+Z-score land use mix diversity+Z-score land use mix access

CI confidence interval, *PA* physical activity, *MVPA* moderate-to-vigorous physical activity

neighborhood to be less aesthetically pleasing or are less satisfied with neighborhood services are mainly active outside their neighborhood. Nonetheless, we are unable to draw definite conclusions since the PA measures used in this study did not differentiate between PA that took place within or outside the neighborhood. Yet another possibility is that people who are not satisfied with their most local shops walk farther to other services.

A negative relationship of street connectivity with self-reported recreational walking was found. This could be due to the fact that high connectivity was defined as perceiving few dead-end streets and many intersections. Less connected neighborhoods with many dead-end streets do not enhance active transportation, but may be more appealing for recreational walking due to less automobile traffic.

No environmental factors were associated with self-reported moderate-intensity leisure-time PA. Moderate-intensity leisure-time PA covers a broad range of behaviors including cycling, swimming, and jogging undertaken in a variety of settings, and some of these behaviors might be associated with environmental factors while others are not. If more detailed measures of leisure-time PA were used, more specific associations might be able to be identified.

The second aim was to study associations of psychosocial factors with objectively assessed and self-reported PA additional to the associations of environmental factors. Consistent associations with psychosocial factors were found for self-reported leisure-time PA (moderate intensity, vigorous intensity, recreational walking). The strongest psychosocial correlates appeared to be social support (from friends and family) and self-efficacy (both towards internal and external barriers). Many other studies reported the importance of these factors to explain variance in leisure-time PA [13, 32, 40]. Stronger associations with leisure-time than transport PA were expected because the psychosocial measures were developed to explain leisure-time PA, which is also expected to be more governed by choice than necessity. The strongest β values were found for self-efficacy. So, even beyond the contribution of environmental factors, self-efficacy remained one of the most important correlates of PA in adults, suggesting promise for interventions targeting both individuals and their environment [41].

The associations of psychosocial factors with accelerometer-assessed PA and self-reported active transportation beyond the physical environmental associations were less clear. In line with previous studies, perceived barriers were negatively related to accelerometer-based PA [32, 42], but for modeling, social norms, perceived benefits, and self-efficacy, the associations were inconsistent or negative. There are some possible explanations for the mixed findings. First, because the questions on psychosocial correlates did not specify a type or domain of PA, it appears that adults tended to consider mainly leisure-time PA when responding. In the future, more specific psychosocial scales (also targeting active transportation) might be more able to find significant associations [9]. Second, because performing leisure-time PA is a conscious individual choice, psychosocial constructs might play an especially important role. Therefore, the availability of a supportive environment alone may be insufficient to increase leisure-time PA in adults, so both people and places may need to be targeted in interventions [11, 13, 41, 43]. Conversely, active transportation can be seen as a relatively automatic reaction to environmental cues, and less as a conscious choice, based upon psychosocial constructs [44]. Nevertheless, this reaction can only occur when the environment itself is supportive for active transportation (e.g., distances to destinations are feasible for active transport). There are substantial differences in the supportiveness of environments between countries and between continents (due to topography, culture, transportation infrastructure, and built environments) [45], so differences in the strength of associations between environmental factors, psychosocial constructs, and active transport can be expected when conducting studies in multiple countries. Third, a possible methodological explanation is that self-reported PA and psychosocial variables share method variance, which could explain the lower associations with accelerometer-measured PA. This pattern has been documented in a few studies [46, 47].

The third study aim was to examine the moderating effects of sociodemographic factors (gender, age, individual SES) on the associations of physical environmental and psychosocial factors with PA. In general, few significant moderating effects were found. For gender, the associations of home PA equipment and internal self-efficacy with accelerometer-assessed MVPA were stronger for men, while the relation of social support from family to accelerometer-based MVPA was stronger for women. For SES, the associations of home equipment and perceived barriers with accelerometer-assessed MVPA were stronger for low-SES adults, while the association of walkability with cycling for transport was only significant for high-SES adults. For age, inconsistent interactions were found. Few other studies have investigated these moderating effects of sociodemographics, showing mixed results and some dissimilarities to the results found in the present study [14, 16, 17]. Concerning gender, Sallis and colleagues [48] found comparable results that social support was only associated with PA in women and environmental factors were only important for men. Nevertheless, because of the inconsistencies across studies and since few studies have examined moderators, no conclusive explanation can be given for the moderating effects identified. Additional research is needed to confirm our findings, as it is important to know whether the same PA interventions could be expected to produce similar effects for men and women, younger and older adults, or for those of higher and lower SES.

An important strength of this study was the use of both objective and self-reported measures of PA, partially compensating for the weaknesses of both measurement types. To our knowledge, this was one of the first studies using both types of measures when investigating physical environmental and psychosocial correlates of adult PA. Another strength was the large study sample, with approximately 1,200 adults.

One limitation was the cross-sectional design, which precluded determination of causality. Second, the study sample was more likely to be employed and more highly educated compared with the general Belgian population. In addition, Belgium has high cycling rates relative to many other countries inside and outside Europe. These issues may limit the generalizability of our findings to other European countries with similar characteristics. Third, because of the mixed models statistical approach, it is not possible to compare the variance explained for environmental versus psychosocial variables. Fourth, many associations were tested in this study, so some significant associations might have been found by chance.

In summary, the present study confirmed that environmental perceptions were associated with a range of PA behaviors in adults, and that the additional explanatory power of psychosocial factors remained important, especially for leisure-time PA. It is important to develop and refine behavior-specific models when investigating correlates of PA behaviors, so evidence-based intervention strategies can be developed for the multiple domains and settings of PA. Moreover, including both objective and self-report/perceived measures of the physical environmental attributes is necessary to investigate domain-specific correlates of PA. Correlates of PA were similar regardless of gender, age, or socio-economic status, so interventions to change these factors could have population-wide effects.

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We confirm that we have no conflict of interest. We have full control of all primary data and we agree to allow the journal to review are data if requested. All personal identifiers have been removed or disguised so the person(s) described are not identifiable and cannot be identified through the details of the story.

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