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Physical Activity in Older Adults: An Ecological Approach

Christina M. Thornton, J.D., M.A.[1], **Jacqueline Kerr, Ph.D.**[2], **Terry L. Conway, Ph.D.**[3], **Brian E. Saelens, Ph.D.**[4], **James F. Sallis, Ph.D.**[3], **David K. Ahn, Ph.D.**[5], **Lawrence D. Frank, Ph.D.**[6,7], **Kelli L. Cain, M.A.**[3], and **Abby C. King, Ph.D.**[5,8]

[1]University of California, San Diego/San Diego State University, Joint Doctoral Program in Public Health, Health Behavior; 3900 Fifth Avenue, Suite 310, San Diego, CA 92103, USA

[2]Department of Family Medicine and Public Health, University of California-San Diego, 9500 Gilman Drive # 0811, La Jolla, CA 92093, USA

[3]Department of Family Medicine and Public Health, University of California-San Diego, 3900 Fifth Avenue, Suite 310, San Diego, CA 92103, USA

[4]Department of Pediatrics, University of Washington & Seattle Children's Research Institute, 2001 Eighth Ave, Suite 400, Seattle, WA 98121, USA

[5]Stanford Prevention Research Center, Department of Medicine, Stanford University School of Medicine, 1070 Arastradero Road, Suite 100, Palo Alto, CA, USA

[6]School of Community and Regional Planning, University of British Columbia, Vancouver BC, #433-6333 Memorial Road Vancouver, BC, Canada V6T 1Z2

[7]Urban Design 4 Health, Inc., Seattle, WA, USA

[8]Division of Epidemiology, Department of Health Research & Policy, and Stanford Prevention Research Center, Department of Medicine, Stanford University School of Medicine, 259 Campus Drive, HRP Redwood Building, T221, Stanford, CA 94305-5405, USA

Abstract

Background—Studies identifying correlates of physical activity (PA) at all levels of the ecological model can provide an empirical basis for designing interventions to increase older adults' PA.

Purpose—Applying ecological model principles, this study concurrently examined individual, psychosocial, and environmental correlates of older adults' PA to determine whether built environment factors contribute to PA over and above individual/demographic and psychosocial variables.

Statement of Conflict of Interest

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

Compliance with Ethical Standards

Informed consent: Informed consent was obtained from all individual participants included in the study.

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

Methods—Using a cross-sectional observational design, 726 adults, aged ≥ 66 years, were recruited from two US regions. Explanatory variables included demographics, self-efficacy, social support, barriers, and environmental variables measured using geographic information systems (GIS) and self-report. Outcomes included reported walking for errands and leisure/exercise, and accelerometer-measured daily moderate to vigorous PA (MVPA). Analyses employed mixed-model regressions with backward elimination.

Results—For daily MVPA, the only significant environmental variable was GIS-based proximity to a park ($p < .001$) after controlling for individual/demographic and psychosocial factors. Walking for errands was positively related to four environmental variables: reported walking/cycling facilities ($p < .05$), GIS-based intersection density ($p < .01$), mixed land use ($p < .01$), and private recreation facilities ($p < .01$). Walking for leisure/exercise was negatively related to GIS-based mixed land use ($p < .05$). Non-Hispanic White race/ethnicity, self-efficacy, and social support positively related to all three PA outcomes ($p < .05$).

Conclusions—Correlates of older adults' PA were found at all ecological levels, supporting multiple levels of influence and need for multilevel interventions. Environmental correlates varied by PA outcome. Walking for errands exhibited the most environmental associations.

Keywords

built environment; exercise; accelerometer; health promotion; public health; aging

Introduction

Older adults comprise the least physically active segment of the U.S. population (1), and could arguably benefit the most, in terms of health and function, from increases in regular physical activity (2, 3). To help older adults meet national physical activity guidelines (4), authorities recommend that interventions follow an ecological approach (5) and target factors at the individual, psychosocial, and environmental levels (6). Studies identifying correlates of physical activity at all levels of the ecological model can provide an empirical basis for intervention design (7). Yet few studies have concurrently examined factors at all ecological levels to evaluate the contribution of neighborhood built environments, over and above individual/demographic and psychosocial correlates, in understanding physical activity among older adults (8, 9).

Ecological models focus on the relationship between people and their physical and sociocultural environments, and posit that environmental contexts are a significant predictor of health behavior (6). The inclusion of environmental and policy level determinants distinguishes ecological models from most health behavior theories, which emphasize individual and social influences (6). Ecological models are most useful for informing research and practice when applied to a specific behavior, since unique environmental and policy factors may influence each behavior (10). For instance, the factors affecting older adults' leisure walking may differ from factors affecting walking for transport, and require distinct intervention strategies.

The “built environment” is the physical design of a community, including its buildings, land uses (commercial, residential, etc.), transportation system, and recreational features (11). Studies have shown mixed results regarding how older adults’ physical activity relates to built environment features (9, 11). For example, there have been discrepant findings as to whether older adults walk more if they live close to a park (11, 12, 13) and whether they are more physically active in residential-only or mixed use neighborhoods (14, 15). Methodological limitations may help explain inconsistent findings. Studies tend to rely on self-report or objective measures of environmental factors; few have reported both (9, 16). Many studies focused on total physical activity and did not assess correlates of specific physical activity domains, such as walking for transportation or walking for leisure/exercise (9, 11). Ecological models suggest that we can enhance our ability to predict physical activity by developing separate models for different physical activity domains and testing environmental variables thought to influence those specific types of activity (10).

Previous analysis of the Senior Neighborhood Quality of Life Study (SNQLS) data showed that older adults living in high-walkable neighborhoods engaged in more accelerometer-measured moderate-to-vigorous physical activity (MVPA) and self-reported active transport than older adults living in less walkable areas (17). The present analysis provided a more comprehensive assessment of physical activity correlates by applying an ecological approach and concurrently assessing individual/demographic, psychosocial, and environmental factors to determine which factors provided significant independent explanatory value. The study aim was to examine whether built environment variables contributed to the explanation of older adults’ physical activity beyond that of individual/demographic and psychosocial variables.

The present study adds to the literature by assessing both objective and reported environmental factors as potential correlates of older adults’ physical activity. We advance the literature by using multiple measures of physical activity including objective accelerometry, self-reported walking for errands, and self-reported leisure walking (18). Based on ecological models and studies of younger adults, we hypothesized that built environment features would be differentially associated with physical activity by physical activity outcome (10, 19). For example, we expected walking for errands to relate to mixed land use, because residents of neighborhoods with a mixture of residential and retail land uses may have more walkable destinations.

Method

Study Design and Neighborhood Selection

SNQLS study design and neighborhood selection methods have been reported previously (17). Briefly, SNQLS employed a cross-sectional, observational design to assess the relationship between physical activity and the built environment in older adults. The study took place from 2005 to 2008 in two US regions: King County, Washington, and four counties in the Baltimore, MD-Washington, DC region. The regions were selected based on the availability of parcel-level land use data and variability of built environment characteristics believed to relate to walkability (20). Within each region, Census block groups were categorized as either high-income or low-income using 2000 US Census data.

Walkability of each block group was assessed using geographic information system (GIS) measurements of four components: residential density, land use mix, intersection density, and retail floor area ratio (17, 21). Block groups were categorized into one of four quadrants: high-walkability/high-income, high-walkability/low-income, low-walkability/high-income, and low-walkability/low-income. Participants were sampled from block groups in each quadrant to balance variability in income and walkability. The study received approval from Institutional Review Boards at participating institutions.

Participants and Procedures

Within selected block groups, participants were recruited using introductory letters and follow-up telephone calls. Eligibility criteria included being 66 years of age or older, able to complete surveys in English, and the self-reported ability to walk further than 10 feet at a time. After providing written consent, participants were mailed an accelerometer along with directions for use and return. Participants were directed to wear the accelerometer for seven days and complete a survey either in writing, online, or via telephone interview. A second round of accelerometer and survey data was collected six months later using the same procedures. Participants received $25 compensation each time they completed the survey and accelerometer protocol.

Measures

Physical activity outcomes—Three outcomes were measured to assess older adults' physical activity: 1) accelerometer-measured MVPA, 2) self-reported walking for errands, and 3) self-reported walking for leisure/exercise.

Accelerometer-measured moderate to vigorous physical activity: Participants were instructed to wear accelerometers (Actigraph, LLC; Fort Walton Beach, FL, model 7164 or 71256) for seven days at two time points, approximately six months apart (1). Participants wore the accelerometers on an elastic belt with the device positioned over their right hip. The accelerometers collected data in one-minute epochs. 53 participants were asked to re-wear the accelerometer because they did not meet minimum wear-time requirements (five valid days or 66 valid hours over each seven-day period) or their accelerometer malfunctioned. Data were then screened for valid hours (defined as no more than 45 consecutive zero intensity counts) and valid days (defined as at least 8 valid hours). MVPA was scored based on commonly used cut points (>1952 counts/minute) (22), and calculated as minutes of MVPA per valid wearing day.

Reported walking for errands and walking for leisure/exercise: Physical activity in two domains (walking for errands and walking for leisure/exercise) was assessed using the CHAMPS physical activity questionnaire, which has been validated in older populations (23) and has shown good test-retest reliability ($r = .76$) (24). For each domain, participants were asked to report duration (total time spent "during an average week") on a six-category scale ranging from "less than one hour a week" to "9 or more hours a week." Walking for errands was assessed with one item addressing weekly duration of walking "to do errands (such as to/from a store)." Walking for leisure/exercise was assessed by the mean of two CHAMPS items: weekly duration of walking "leisurely for exercise or pleasure" and weekly duration of walking “fast or briskly for exercise.” CHAMPS items are translated into minutes per week by taking the midpoint of the selected duration range (e.g., 1 – 2.5 hours = 105 minutes) (23).

Individual variables—Individual level variables included demographics, BMI, health conditions, and self-rated mobility impairment.

Demographics: Participants reported age, gender, race/ethnicity, education (seven levels, from less than seventh grade to graduate degree), marital status (four categories: never married, married or living with partner, divorced/separated, and widowed), years at current address, possession of a valid driver’s license, number of people in household, number of drivable vehicles in household, caretaking duties (yes/no), height, and weight. Census data, including median age, median household income, and percentage non-White, were collected for each participant’s block group.

Body mass index (BMI): Self-reported height and weight was used to calculate participants’ BMI (kg/m^2).

Health conditions: Participants also reported medical issues including whether they had ever received treatment for a heart condition, diabetes, high blood pressure or osteoarthritis.

Self-rated mobility impairment: To assess lower body functioning at each time point, participants completed the 11-item advanced lower extremity subscale of the Late-Life Function and Disability Instrument (LLFDI). The LLFDI has been validated in older populations (25) and has shown test-retest intraclass correlation coefficients ranging from .68–.82 (26).

Psychosocial variables—Psychosocial variables included self-efficacy for walking, physical activity barriers, and social support.

Self-efficacy for walking: Participants reported their level of confidence on a 10-point scale (from “not confident at all” to “absolutely confident”) to walk ½ block, 4 blocks, and 10 blocks. Responses were averaged across the three items. The items have shown good internal consistency (α = .90) and test-retest reliability (r = .67) among older adults (27).

Barriers to regular physical activity: Participants reported barriers to physical activity with four items (α = 0.53) asking participants to rate the importance on a five-point scale (1 = “not important,” 2 = “slightly important,” 3 = “moderately important,” 4 = “very important,” 5 = “extremely important) of 4 potential barriers to physical activity, including taking too much time, feeling self-conscious, feeling physically uncomfortable during exercise, and having less time for friends and family. Responses to the four items were averaged (28).

Social support: Family support for physical activity was measured with a four-item scale from a validated measure (29). The scale asked participants to rate on a 5-point scale (“never” to “very often”) how often during the past six months their family: (1) walked or exercised with them, (2) gave them encouragement to do physical activity, (3) made positive comments about the participant’s physical appearance, and (4) criticized or made fun of them for walking or exercising. The same four items were repeated to assess social support participants receive from friends, acquaintances, or coworkers. The social support scale was computed as the average of responses to the eight items.

Environmental variables—The present study assessed objective and perceived built environment measures.

Objective built environment: GIS was used to integrate data from county-level tax assessors, land use at the parcel level, and street networks to measure walkability based on a one-kilometer street network buffer around each participant’s home. A one-kilometer buffer has been shown to detect environmental associations with older adults' physical activity (30). Four components of walkability were assessed: residential density, land use mix (relative diversity and evenness of residential, entertainment, retail, and office land uses), intersection density, and retail floor area ratio (21). Lists from local park agencies and parcel-level land use data were used to calculate the number of parks within a one-kilometer buffer of each participant’s home, and the distance in meters to the closest park. Private recreation facilities (e.g., gyms and dance studios) were identified and geocoded (31). For each participant, the number of recreation centers within a one-kilometer buffer of their home and the distance in meters to the closest recreation center were calculated.

Self-reported neighborhood environment: Participants reported perceived neighborhood characteristics using five slightly modified subscales from the Neighborhood Environment Walkability Scale (NEWS) (32). The NEWS subscales included: neighborhood aesthetics (four items), traffic safety (three items), walking/cycling facilities (four items), personal safety (six items), and pedestrian safety (eight items). Participants rated items using a four-point scale (“strongly disagree” to “strongly agree”), and subscale scores were computed as the mean of item responses. All subscales showed moderate to high test-retest reliability, with alpha coefficients ranging from .58 to .80 (32). Participants also completed a 12-item checklist of physical activity equipment (e.g., treadmills, sports equipment, and exercise videos) in their home, yard, or housing complex. A home equipment index was created by summing the “yes” responses from the checklist.

Statistical Analysis

For each primary outcome (accelerometer-measured MVPA, walking for errands, and walking for leisure/exercise), mixed effects regression models were fitted to account for the multi-level data structure. All models were adjusted for repeated measures over time (accelerometry and self-reported walking measured initially and 6 months later), site (Seattle and Baltimore regions), and participants nested within census block groups (random effect). An initial model was built using a hierarchical approach by first adding individual-level demographic variables, then adding census-level demographic variables, and finally adding psychosocial variables. With each addition of a new group of variables, a backward stepwise regression was used to eliminate variables that failed to be significantly associated with the outcome at $p < 0.05$. One variable was removed at a time until all variables in the model were significant. After creating the initial model, the eliminated variables were reintroduced to assess whether any non-significant variable dropped became significant when reintroduced. Several variables, however, were kept in the model despite non-significant p values due to their importance to study design (e.g., study site). Also, the LLFDI measure of lower body functioning was excluded from the stepwise analysis to avoid collinearity due to its strong correlation (r =.72) with self-efficacy for walking.

We then analyzed each environmental variable individually, controlling for the individual/demographic and psychosocial variables that remained in the model. Finally, backwards stepwise regression were used to eliminate nonsignificant variables, applying the same process described above for the individual/demographic and psychosocial variables. For ease of interpreting the final models, we reported the regression coefficient for remaining categorical variables or the regression coefficient multiplied by the standard deviation for remaining continuous variables. Since units vary considerably for the continuous variables, using a multiple of the standard deviation provides a uniform interpretation of predictor effects – i.e., the change in outcome units (e.g., minutes of MVPA or walking for errands) for every one standard deviation increase in the continuous variable. Consequently, the modified betas are comparable for continuous variables. For categorical variables the meaning of the unmodified betas still represents an average difference between the comparison and reference levels.

The above analysis steps were conducted separately for accelerometer-measured MVPA, self-reported transportation walking, and self-reported leisure walking. All analyses were carried out using SAS 9.1.3 software and the PROC MIXED procedure.

Results

Participant Characteristics

Descriptive statistics for the study sample are presented in Table 1. Of the 3359 eligible older adults contacted, 726 were enrolled (21.6% enrollment rate) including 368 participants from Seattle and 358 from Baltimore. The retention rate at 6 months was 89%, after eliminating ineligible movers. Reasons for attrition included dropping out after completing Survey 1 (n = 8); not responding to Survey 2 contacts (n = 16), or refusing to complete Survey 2 after being contacted (n = 21). The participants had a mean age of 74.4 years (SD = 6.3, range 66–97 years), were balanced by gender (53% female), and were well educated (15.9% completed high school, and 48.9% completed college). The majority of participants (70.7%) identified themselves as non-Hispanic White. The study sample was generally comparable with 2000 Census block group data with respect to age, education, and race/ethnicity, except that the sample from the Seattle/King County area had a greater proportion of Caucasians (87.7% in the sample, versus 75.7% Census). A full comparison of the study sample with 2000 Census block group data, stratified by study region and income/walkability quadrant, has been previously published (17). Participants wore the accelerometers an average of 14.5 hours/day for 6.9 days. Participants reported walking an average of 41.4 minutes/week (SD = 83.0) for errands and 100.6 minutes/week (SD = 126.2) for leisure/exercise. Participants' accelerometer-measured MVPA averaged 13.4 minutes/day (SD = 16.5).

Correlates of Older Adults' Physical Activity

The final stepwise models of individual/demographic, psychosocial, and environmental correlates of the three physical activity outcomes are provided in Tables 2–4. The *B*SD* provides an effect size indicator that can be used to assess the relative contributions of individual/demographic, psychosocial, and environmental variables within each model. For example, when explaining older adults' accelerometer-measured MVPA, the effect size of distance to the closest park ($B*SD = -1.81$) was comparable in magnitude (although opposite in direction) to that of social support ($B*SD = 1.61$). In contrast, demographic variables of age and gender showed over twice the effect size ($B*SD = -4.60$ and −4.31, respectively). Using the *B*SD* as an effect size indicator, the final models for each physical activity outcome show the relative contributions of individual/demographic, psychosocial, and environmental variables to older adults' physical activity.

Accelerometer-measured moderate to vigorous physical activity

After controlling for individual/demographic and psychosocial variables, one environmental variable remained in the model as a significant correlate of accelerometer-measured MVPA: GIS-measured distance in meters of the closest park (negative association; $p = .001$) (Table 2). Two psychosocial variables remained in the model (self-efficacy, $p < .0001$; social support, $p = .0002$). Demographic variables remaining in the model included age, gender, non-Hispanic White race/ethnicity, BMI, number of people in household, Census block percentage non-White, and treatment for osteoarthritis or high blood pressure.

Walking for errands

Four environmental variables remained in the model as significant correlates of reported walking for errands after controlling for individual/demographic and psychosocial variables (all positive associations; Table 3). Three of the four environmental variables retained in the model were objective GIS variables: intersection density ($p =.009$), mixed land use ($p = .01$), and number of private recreation centers within a one-kilometer buffer of the participant's home ($p = .005$). One self-reported environmental measure, walking/cycling facilities ($p = .04$), was also retained in the model. Two psychosocial variables remained in the model: self-efficacy ($p < .0001$) and social support ($p = .002$). Demographic variables remaining in the model included non-Hispanic White race/ethnicity, length of time at current address, having a driver's license, and treatment for high blood pressure.

Walking for leisure or exercise

After controlling for individual/demographic and psychosocial variables, one environmental variable remained in the model as a significant correlate of walking for leisure or exercise: mixed land use (negative association, $p = .047$) (Table 4). Two psychosocial variables remained in the model (self-efficacy, $p < .0001$, and social support, $p < .0001$). Individual/demographic variables remaining in the model included age, non-Hispanic White race/ethnicity, Census block median age, and treatment for osteoarthritis.

Discussion

Consistent with the ecological model principle of multiple levels of influence on behavior, the present study found correlates of older adults' physical activity at the individual/demographic, psychosocial, and environmental levels. The relative importance of factors at each level, in terms of explaining older adults' physical activity, varied based on physical activity outcome (accelerometer-measured MVPA, walking for errands, or walking for leisure/exercise). As hypothesized, and in accordance with studies of younger adults (33, 34), the environmental variables retained in the final models were generally conceptually matched with the physical activity outcome (e.g., walking for errands related to having a mix of residential and retail land uses that provide local destinations). These findings suggest that to increase older adults' physical activity, interventions that are matched to physical activity domains and target influences at multiple levels may prove most effective.

The final model for walking for errands retained the largest number of environmental variables (four variables, compared to one variable in each of the other models). This finding is consistent with previous findings from the United States and international studies, which show more consistent associations between multiple built environment factors and walking for transportation (20, 33, 35, 36). In this study, like models for younger adults (34), objectively measured walkability factors and seniors' perceptions of walking/cycling facilities were associated with more walking for errands. The number of private recreation centers within one kilometer of the participant's residence was also associated with walking for errands, indicating that recreation centers may be important destinations for older adults.

For walking for errands, the explanatory value of the environmental variables retained in the model (with effect sizes ranging from $B*SD$ 4.11 to 8.24) was similar to, or greater than, that of social support ($B*SD = 5.16$). Self-efficacy, in comparison, explained a larger portion of the variability ($B*SD = 10.80$). Interestingly, two demographic variables provided the greatest explanatory value for walking for errands: non-Hispanic White race/ethnicity ($B*SD = 19.51$) and having a driver's license ($B*SD = -28.14$; negative correlate). Studies of younger populations have also shown that those without a driver's license walk more for errands (37).

The final model for leisure/exercise walking retained fewer environmental variables than the model for walking for errands. For older adults' leisure/exercise walking, the effect sizes for the two psychosocial factors in the model (self-efficacy, $B*SD = 27.40$ and social support, $B*SD = 25.44$) were three times larger than the effect size for the single significant environmental variable (mixed land use $B*SD = -8.01$). This comports with previous findings that self-efficacy and social support are important correlates of walking for exercise among older adults (27). The only environmental variable retained in the model for leisure walking was mixed land use, which had a negative association. Greater mixed land use was associated with more walking for errands, but less walking for leisure/exercise. At least one other study of older adults found that older adults engage in more leisure walking in suburban neighborhoods with fewer land uses (14). Perhaps mixed use areas have attributes that can act as barriers to older adults' leisure activity, such as heavy traffic or more street crossings. Four demographic variables remained in the model for leisure walking: non-

Hispanic White race/ethnicity ($B*SD$ = 29.89, positive association), treatment for osteoarthritis ($B*SD$ = −19.34, negative association), Census block median age ($B*SD$ = −10.57, negative association), and individual participant age ($B*SD$ = −9.22, negative association). It is notable that for leisure/exercise walking, the effect sizes of self-efficacy and social support ($B*SD$ = 27.40 and $B*SD$ = 25.44, respectively) were similar to race/ethnicity ($B*SD$ = 29.89), the strongest demographic correlate.

The final model for accelerometer-measured MVPA only retained one environmental variable: proximity to a park ($B*SD$ = −1.81). This finding is similar to findings in two other studies which found significant relationships between older adults' physical activity and park proximity (38) and park density relative to home residence (39). This comports with a study of 6–12 year-old children which found only one environmental variable significantly related to children's accelerometer-measured MVPA: parents' perceived proximity of play areas to their home (40). However, this finding differs from a similar analysis conducted in adults (n = 2199, aged 20–65), which found relationships between accelerometer-measured MVPA and walkability-related factors, but not park proximity variables (34). In contrast to younger adults, perhaps children and older adults spend a greater proportion of their time participating in leisure activity (as compared to active transport), making environmental factors such as parks and recreational facilities, and their proximity, more important for overall physical activity.

The demographic variables remaining in the model for MVPA had effect sizes ranging from $B*SD$ = −4.60 (age) to $B*SD$ = −1.11 (number of people in household). The inverse relation between number of people in the household and MVPA suggests the possible influence of social factors (e.g., household members directly or inadvertently discouraging seniors from being active) or physical health factors (i.e., older adults living with others due to poor health or function). Psychosocial variables remaining in the model (self-efficacy, $B*SD$ = 2.91, and social support, $B*SD$ = 1.61) explained a small amount of variability in MVPA, with effect sizes in the same range as demographic and environmental variables.

Several patterns appeared across models. In each model, objectively assessed environmental variables provided greater explanatory value as compared to self-reported environmental variables. Only the final model for "walking for errands" included a self-reported NEWS variable (walking/cycling facilities). This finding comports with another study that found objective environmental variables were stronger correlates of older adults' MVPA (18). Objective measures may provide particularly useful information for research and city planning addressing older adults' physical activity.

In addition, two psychosocial variables, self-efficacy and social support, were consistently related to all three physical activity outcomes. Strong correlations between psychosocial variables and physical activity have also been found in adults (33, 41), providing support for psychosocial models such as Social Cognitive Theory (42) and the role of psychosocial strategies in multilevel interventions. In contrast, perceived physical activity barriers were not retained in any model. This is surprising considering the relatively consistent findings associating perceived barriers with less physical activity among younger adults (43), and that most older adults report having at least one physical activity barrier (44). Evidence shows that physical health is the most common barrier to physical activity reported by older adults (45). Perhaps the perceived physical barrier assessed in this study (“feeling physically uncomfortable during exercise”) did not capture the types of physical health conditions associated with decreased physical activity in older adults. At least one other study has shown that chronic health conditions may be stronger correlates of older adults’ physical activity than perceived barriers (46). Our results showed that variables relating to chronic physical health conditions (i.e., treatment for osteoarthritis and high blood pressure) correlated with decreased physical activity.

The only demographic variable associated (positively) with physical activity in all three final models was being non-Hispanic White. This differed from a previous study of older adults with racial/ethnic demographics similar to the current study (47), which found that Hispanics and "other" racial/ethnic groups engaged in the most accelerometer-measured MVPA, followed by non-Hispanic Whites and non-Hispanic Blacks. Moreover, in the present study age was inversely associated with physical activity in two models (walking for leisure or exercise and accelerometer-measured MVPA), supporting the importance of identifying behavioral and contextual factors that promote physical activity into advanced age. Finally, two prevalent age-associated chronic health conditions (osteoarthritis, hypertension) were each associated with less physical activity in two of the three final models. Regular physical activity can help mitigate or control both of these chronic health conditions into older ages (4).

Study strengths included the large sample from two diverse US regions, good sample retention, the use of objective and reported measures of physical activity, measurement of multiple physical activity domains, and use of an ecological approach to concurrently examine multiple levels of physical activity determinants. A limitation of the present study is the inability to determine whether study participants differed in some meaningful way from people who declined to participate or did not answer the phone. It is possible that people who didn’t participate were busy, and perhaps more physically active, than study participants. Alternatively, non-participation (or not answering the phone) might reflect greater physical and cognitive impairments, and lower levels of physical activity than study participants. Overall, study participants were similar to 2000 Census block group data with respect to age, education, and, for the Baltimore region, percentage of Caucasians.

This study did not test for mediation or analyze interactions among the individual, psychosocial, and environmental variables. Future research might examine how relationships between environmental factors and older adults’ physical activity vary by demographic factors such as race/ethnicity, income, or gender. Previous research exploring such interactions and mediation in younger adult populations found differing results based on physical activity outcome (e.g. walking for leisure versus walking for errands) and environmental factor (e.g., walkability versus access to parks) (33, 41); future research might replicate these analyses in older adults.

In conclusion, the ecological principle of multiple levels of influence on behavior was supported by individual/demographic, psychosocial, and environmental correlates of all three physical activity outcomes. The results justify prospective research to improve understanding of the causal pathways underlying such associations. Consistent with behavioral specificity of ecological models (10), the relative contributions of psychosocial and environmental variables differed across physical activity outcomes. Environmental variables were particularly strong correlates of walking for errands, though psychosocial correlates were also strong. Psychosocial variables were the dominant correlates of walking for leisure/exercise. Both psychosocial and environmental correlates were weak in explaining accelerometer-measured MVPA, which was best predicted by demographic variables (age and gender). For all three physical activity outcomes, aspects of the neighborhood built environment significantly explained variation in older adults' physical activity, over and above individual/demographic and psychosocial factors. The results justify further exploration of environmental and policy changes that can support physical activity, function, and vitality in older adults. If the present results are confirmed, they provide an empirical rationale for multi-level interventions to promote physical activity among older adults.

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Table 1

Participant Characteristics: Individual/Demographic, Psychosocial, Environmental, and Physical Activity Variables (N = 726)

Individual/Demographic	**Mean (SD) or %**
Age (years)	74.4 (6.3)
Gender (% women)	53.1%
Non-Hispanic white	70.7%
With college degree	48.9%
Married or living with partner	56.8%
Residing in the Baltimore region (versus Seattle region)	49.3%
Have driver's license	91.9%
Employed part time or full time	18.1%
Treatment for heart condition	20.7%
Treatment for diabetes	16.4%
Treatment for high blood pressure	54.5%
Treatment for osteoarthritis	17.8%
Caretaking duties	9.6%
Late-Life Function and Disability Instrument, lower extremity (Time 1, range: 0–100)	57.2 (17.8)
Number of people in household (range: 1–5)	1.8 (0.8)
Number of drivable vehicles in household (range: 0–5)	1.6 (0.9)
Ratio of drivable vehicles per adults in household (range: 0–3)	0.9 (0.5)
Time at current address, years (range: <1–73)	24.7 (15.5)
Body Mass Index (kg/m2)	26.4 (4.7)
Median Age (Census block group) (range: 23–78)	32.8 (5.8)
Percent non-White (Census block group; range: 3–100)	43.8%
Median Household Income (Census block group; range: $8.7K–$133.2K)	56.4K (20.6K)
Psychosocial	Mean (SD)
Self-efficacy for walking (range: 1–10)	8.3 (2.6)
Social support (range: 0–4)	2.2 (0.7)
Barriers to physical activity (range: 1–5)	1.6 (0.6)
Environmental	Mean (SD)
Residential density, ratio of residential units to residential land area (determined using geographic information system [GIS]; range: 0.34–189.9)	8.5 (14.2)
Mixed land use, normalized scores for diversity of land use types per buffer area (GIS-determined; range: 0.0–.88)	0.24 (0.25)
Intersection density, counts per 1 km buffer (GIS-determined; range: 6–185)	64.3 (24.9)
Retail floor area to land area, ratio (GIS-determined; range: 0–2.4)	0.24 (0.27)
Number of parks within 1 km buffer, counts (GIS-determined; range: 0–15)	3.2 (3.0)
Distance to closest park, meters (GIS-determined; range: 0.15–2994.5)	574.6 (511.9)

Individual/Demographic	**Mean (SD) or %**
Number of recreation centers within 1 km buffer, counts (GIS-determined; range: 0–77)	5.7 (10.0)
Distance to closest recreation center, meters (GIS-determined; range: 0.1–3303.2)	712.1 (565.6)
Neighborhood aesthetics (NEWS; range: 1–4)	3.1 (0.7)
Traffic safety (NEWS; range: 1–3)	2.7 (0.7)
Walking/cycling facilities (NEWS; range: 1–4)	2.8 (0.8)
Personal safety (NEWS; range: 1–6)	3.4 (0.6)
Pedestrian safety (NEWS; range: 1–8)	2.6 (0.5)
Home equipment index (range: 0–12)	3.5 (2.3)
Physical Activity: accelerometer-measured and reported	Mean (SD)
Accelerometer measured MVPA (min/valid day; Time 1; range: 0–117.8)	13.4 (16.5)
Walking for errands (CHAMPS; min/week; Time 1, range: 0–585)	41.4 (83.0)
Walking for leisure/exercise (CHAMPS; min/week; Time 1; range: 0–585)	100.6 (126.2)

Table 2

Final Stepwise Model Including Individual/Demographic, Psychosocial, and Environment Variables for Accelerometer-measured MVPA per Day

Predictor Variable	Std Dev of PredVar	B*SD[a] or B	95% CI	P-value
Individual/Demographic Variables remaining in model				
Age (years)	6.26	−4.60	−5.47, −3.73	< .0001
Gender (male = ref)		−4.31	−6.05, −2.57	< .0001
Non-Hispanic White (non-White = ref)		2.30	0.09, 4.51	.044
BMI (kg/m^2)	4.74	−1.31	−2.18, −0.44	.003
Number of people in household (range: 1–5)	0.76	−1.11	−1.94, −0.28	.01
Treatment for osteoarthritis (no = ref)		−2.61	−4.76, −0.46	.02
Treatment for high blood pressure (no = ref)		−2.74	−4.38, −1.10	.001
Census Demographic Variables remaining in model				
Percent non-White	29.1	−1.73	−3.17, −.29	.02
Psychosocial Variables remaining in model				
Self-efficacy for walking (range: 1–10)	2.64	2.91	1.92, 3.90	< .0001
Social support (range: 0–4)	0.69	1.61	0.78, 2.44	.0002
Environmental Variables remaining in model				
Distance of closest park (meters, GIS-determined)	511.9	−1.81	−2.85, −0.77	.001

Note. Model adjusted for repeated measures over time, site (Seattle, Baltimore), and subjects' nesting within census blocks.

[a] For a continuous predictor, the regression coefficient is multiplied by its standard deviation. The quantity represents the change in the dependent variable for a 1 *SD* increase in the predictor. For categorical variables, the regression coefficient is shown. The *B*SD* effect sizes can be compared within (but not between) models.

Table 3

Final Stepwise Model Including Individual/Demographic, Psychosocial, and Environment Variables for Walking for Errands Minutes per Week

Predictor Variable	Std Dev of PredVar	B*SD[a] or B	95% CI	P-value
Individual/Demographic Variables remaining in model				
Non-Hispanic White (non-White = ref)		19.51	10.93, 28.09	< .0001
Time at current address (months)	185.9	−6.21	−2.54, −9.88	.0009
Have a driver’s license (no = ref)		−28.14	−15.41, −40.87	< .0001
Treatment for high blood pressure (no = ref)		−7.98	−1.32, −14.64	.02
Psychosocial Variables remaining in model				
Self-efficacy for walking (range: 1–10)	2.64	10.80	7.18, 14.42	< .0001
Social support (range: 0–4)	.69	5.16	1.84, 8.48	.002
Environmental Variables remaining in model				
Walking/cycling facilities (NEWS; range: 1–4)	0.84	4.11	.18, 8.04	.04
Intersection density (count per buffer area, GIS-determined)	24.86	6.04	1.56, 10.52	.009
Mixed land use: residential, entertainment, retail, office (GIS-determined; range: 0–.88)	0.25	6.54	1.49, 11.59	.01
Number of recreation centers in 1km buffer (counts, GIS-determined)	9.99	8.24	2.47, 14.01	.005

Note. Model adjusted for repeated measures over time, site (Seattle, Baltimore), and subjects’ nesting within census blocks.

[a] For a continuous predictor, the regression coefficient is multiplied by its standard deviation. The quantity represents the change in the dependent variable for a 1 *SD* increase in the predictor. For categorical variables, the regression coefficient is shown. The *B*SD* effect sizes can be compared within (but not between) models.

Table 4

Final Stepwise Model Including Individual/Demographic, Psychosocial, and Environment Variables for Walking Leisurely or Fast for Exercise, Minutes per Week

Predictor Variable	**Std Dev of PredVar**	**B*SD[a] or B**	**95% CI**	**P-value**
Individual/Demographic Variables remaining in model				
Age (years)	6.26	−9.22	−2.03, −16.41	.01
Non-Hispanic White (non-White = ref)		29.89	13.35, 46.43	.0004
Treatment for osteoarthritis (no = ref)		−19.34	−1.51, −38.17	.03
Census Demographic Variables remaining in model				
Median age (years)	5.82	−10.57	−2.79, −18.35	.008
Psychosocial Variables remaining in model				
Self-efficacy (range: 1–10)	2.64	27.40	19.77, 35.03	< .0001
Social support (range: 0–4)	0.69	25.44	18.80, 32.28	< .0001
Environmental Variables remaining in model				
Mixed land use: residential, entertainment, retail, office (GIS-determined; range: 0–.88)	0.25	−8.01	−0.04, −15.98	.047

Note. Model adjusted for repeated measures over time, site (Seattle, Baltimore), and subjects' nesting within census blocks.

[a] For a continuous predictor, the regression coefficient is multiplied by its standard deviation. The quantity represents the change in the dependent variable for a 1 *SD* increase in the predictor. For categorical variables, the regression coefficient is shown. The *B*SD* effect sizes can be compared within (but not between) models.