### Title

Longitudinal associations of physical activity patterns and the environment: the Multi-Ethnic Study of Atherosclerosis (MESA)




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# Longitudinal associations of physical activity patterns and the environment: the Multi-Ethnic Study of Atherosclerosis (MESA)

A dissertation submitted in partial satisfaction of the requirements for the Master's degree

in

Public Health

by

Maíra Tristão Parra

Committee in charge:

Professor Paul Joseph Mills, Chair
Professor Sarah Linke
Professor Michael Pratt

2021

The thesis of Maíra Tristão Parra is approved, and it is acceptable in quality and form for publication on microfilm and electronically

University of California San Diego

2021

## Dedication

To God, who always provides me the courage, health, and dedication to achieve my career goals. To my parents, who are the source of love and support that I need. To my siblings, for all the motivation and belief in my abilities. To my husband, who had been by my side every step of the way. To all great mentors at UC San Diego throughout my post-doctoral and MPH journey.

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## List of Abbreviations

| | |
|---|---|
| ADA | American Diabetes Association |
| BMI | Body Mass Index |
| CHD | Coronary Heart Disease |
| IMR | Individuals meeting recommendations |
| IQR | Interquartile Range |
| GED | Graduate Equivalence Degree |
| HDL | High-density Lipoprotein |
| JNC | Joint National Committee |
| LDL | Low-density Lipoprotein |
| MESA | Multi-Ethnic Study of Atherosclerosis |
| MET | Metabolic Equivalent of a Task |
| MVPA | Moderate to Vigorous Physical Activity |
| NCEP | National Cholesterol Education Program |
| PA | Physical Activity |
| RR | Risk Ratio |
| SD | Standard Deviation |
| SES | Socioeconomic Status |

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I would also like to acknowledge Professor Augusto Cesar Ferreira De Moraes, a friend, and co-author of this work. Through the past year, he has been supportive and motivating me to move forward. Also, I would like to acknowledge Dr. Erin Delker for the methodological discussions related to this work and for her friendship.

The work presented in the Introduction, Methods, Results, Discussion, and Conclusion is co-authored by Professor Augusto Cesar Ferreira De Moraes, Dr. Marcus Vinícius Nascimento Ferreira, Professor Paul J Mills, and Professor Matthew Allison. The data analyzed in this work is from the Multi-Ethnic Study of Atherosclerosis (MESA) cohort. A manuscript proposal has been previously submitted to the MESA Steering Committee and approved. The present work is currently being prepared for a manuscript submission.

I thank the funding of the National Institutes of Health (NIH), the National Heart, Lung and Blood Institute (NHLBI) for the support through the T32 Post-doctoral fellowship in Cardiovascular Epidemiology and Prevention [5T32hl079891-13].

ABSTRACT OF THE THESIS

Longitudinal associations of physical activity patterns and the environment: the Multi-Ethnic Study of Atherosclerosis (MESA)

by

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Master of Public Health

University of California San Diego, 2021

Professor Paul J Mills, Chair

Insufficient physical activity (PA) contributes to morbidity and premature mortality, while the perception of the environment may play a role in PA engagement. We analyzed longitudinal data from participants of the Multi-Ethnic Study of Atherosclerosis to evaluate the potential relationship between perceived environment and PA patterns over time. Exposure variables were the perceived aspects of the neighborhood environment and the perception of safety. MET-minutes/week were calculated from self-reported intentional PA, and participants were categorized

into meeting (≥ 500 MET-minutes/week) versus not meeting PA guidelines. Based on data obtained at visits 1 and 6, we created categories of participants regarding meeting or not PA guidelines (adopters, relapsers, maintainers, and insufficiently active). Multinomial Poisson regression models were used to assess the association between environmental perceptions and outcome. Model 1 was adjusted for study site and contextual markers of SES; Model 2 was further adjusted for age, sex, race/ethnicity, educational level, marital status, and occupation; Model 3 was further adjusted for waist circumference, LDL cholesterol, HDL cholesterol, and triglycerides levels, hypertension diagnosis, diabetes diagnosis, smoking status, alcohol consumption, emphysema, asthma, arthritis, pain in the lower limbs and swelling of the feet and ankles. Perception of "lack of parks and playgrounds" as "not problematic" increased the risk of being a relapser, compared to be in the "maintainers" group. Perception of "poor sidewalks" as "somewhat a serious problem" was associated with a lower risk of becoming an adopter of PA. The perception of "unsafe neighborhood" was associated with the adopter and the insufficiently active group.

## Introduction

Insufficient physical activity (PA) can contribute to premature morbidity and mortality, especially the development of chronic diseases such as coronary heart disease (CHD), type 2 diabetes, and breast and colon cancers (2), and thereby cost billions for healthcare systems worldwide (1). The association of the built environment (home, workplace, neighborhood) and physical activity has been demonstrated previously (3), indicating the importance of objectively measured neighborhood characteristics such as walkability, safety, connectivity of streets, as well as one's perception of the environment. Psychosocial factors, such as perceived enjoyment of PA, perceived social support, and self-efficacy, were shown as moderators of the relationship between perceived environmental attributes and walking and recreational moderate to vigorous PA levels. In this regard, positive environmental perceptions were associated with higher PA levels (4).

Previous analyses from the Multi-Ethnic Study of Atherosclerosis (MESA) have demonstrated significant associations between the environment and health outcomes that are relevant to sustain an adequate healthy lifestyle. For example, cross-sectional analyses have shown that living in areas with a high density of recreational resources for PA is positively associated with participation in these activities(5). More contemporary longitudinal analysis confirmed that greater density of recreational facilities was associated with less decline in PA, suggesting possible benefits of living close to recreational facilities to sustain an active lifestyle(6). Notably, additional cross-sectional analyses of MESA participants showed that living in areas with greater PA resources and access to healthy foods was also associated with lower insulin resistance (7) and lower incidence of type 2 diabetes mellitus (8).

The perceived environment is another relevant factor that may be associated with health outcomes. In Chicago, perceiving the neighborhood as safe was positively associated with walking levels, while perceived lower violence was associated with higher levels of leisure walking. However, in the same study, no significant associations were identified for perceived safety or police-recorded measures of crime and leisure PA (9). To date, no analyses of the MESA cohort have investigated the associations of perceived environment and longitudinal patterns of PA.

Given this, our study aimed to assess if the perceived environment is significantly associated with longitudinal patterns of PA. We hypothesized that better perceptions of the environment would be associated with the adoption or maintenance of PA over time, while worse perceptions of the environment would be associated with being insufficiently active or not maintaining sufficient PA behavior over time.

The work presented in the Introduction is co-authored by Professor Augusto Cesar Ferreira de Moraes, Dr. Marcus Vinícius Nascimento Ferreira, Professor Paul J Mills, and Professor Matthew Allison.

## Methods

Study design

The current study is an analysis of MESA data. The MESA is a multi-site prospective cohort in the United States that included men and women, free of cardiovascular disease, aged 45-84 years old at baseline, residing in one of the site locations: New York, New York; Baltimore, Maryland; Chicago, Illinois; Los Angeles, California; St. Paul, Minnesota and Forsyth County, North Carolina. The Institutional Review Boards from all participating institutions approved the study and written informed consent was obtained. Detailed information about the MESA study can be found elsewhere (10).

Participants

Participants were enrolled in the study between July 2000 and August 2002 (baseline visit) and returned for follow-up visits approximately every two years. MESA is composed of diverse ethnic backgrounds: White (38%), African American (28%), Hispanic (23%), and Asian (mostly Chinese American) (11%) individuals (10). MESA participants who had available data for leisure-time physical activity at Exam 6 composed our sample (n = 3,097).

Exposure

The primary exposure variables were measured by questionnaire on the perceived aspects of the neighborhood environment at baseline. One question concerning safety asked, “How safe from crime do you consider your neighborhood to be?”, and participants rated their perception on a scale from 1-5, being 1 “very safe”, 3 “safe” and 5 “not at all safe”. A second question asked, “Think about your neighborhood as a whole, then please check one box for each of the following to show how much of a problem each one is in your neighborhood”. The items are excessive noise, heavy traffic or speeding cars, lack of access to adequate food shopping, lack of parks or

playgrounds, trash or litter, no sidewalk or poorly maintained sidewalks, and violence. For each item, the response options were very serious problem (1), somewhat serious problem (2), minor problem (3), not really a problem (4).

Outcome

At baseline and the subsequent study visits (except visit 4), physical activity (PA) was assessed using the MESA Typical Week Physical Activity Survey, adapted from the Cross-Cultural Activity Participation study (10,11). We defined intentional exercise as the sum of walking for exercise, playing sports, dancing, and conditioning exercise, expressed in metabolic equivalents of a task (MET) per min/week. We classified participants according to the Physical Activity Guidelines for Adult Americans (12) as meeting or not meeting the recommendations (defined as an engagement in at least 150 minutes of moderate-to-vigorous-intensity PA per week). Because the intentional exercise was expressed as MET-minutes per week, the equivalent of 150min/week of MVPA equals the range of 500-1,000 MET-minutes/week (13). Therefore, we considered the cut point of 500 MET-minutes/week to categorize individuals meeting ($\geq$ 500 MET-minutes/week) versus not meeting the guidelines (<500 MET-minutes/week).

Covariates

At the clinic visits, standardized questionnaires were used to collect information on participants' sociodemographic characteristics. These included age, sex, race/ethnicity, household assets, educational level, marital status (married/living as married versus other, which included widowed, divorced, separated, never married and, individuals who preferred not to answer), occupation/employment, and city of residency. An additional covariate, neighborhood-level socioeconomic status (SES), was available. This variable used 2000 U.S Census estimates linked to residential data of MESA participants(14). A summary SES was built by factor analysis of six

indicators of neighborhood-level SES, including the median household income, household wealth (median value of housing units and percent of households with interest, dividend, or net rental income), education (the percentage of adults who completed high school and the percentage of adults who completed college education), percentage of employment among people aged 16 years or older in an executive, managerial or professional occupation.

During the clinic visits, participants completed a health history questionnaire, which included questions on current alcohol consumption and smoking habits (never, former or current smoker). Chronic diseases were defined as follows: 1) diagnosis of diabetes mellitus type II according to the American Diabetes Association algorithm published in 2003 (15) and 2) diagnosis of hypertension by the JNC VI (1997) criteria as normal (<130/<85 mmHg), high-normal (130-139/85-89 mmHg), stage 1 hypertension (140-159/90-99 mmHg), or stage 2 or greater hypertension (≥160/≥ 100 mmHg) (16). Other self-reported chronic diseases were emphysema, asthma, and arthritis. Additionally, physical symptoms that could interfere with physical activity were self-reported pain in the lower limbs ("Do you ever get leg pain in either leg or buttock while walking?") and swelling of feet and ankles ("Have you ever had swelling of your feet and ankles?").

Anthropometric measures were taken with height and weight measured to the nearest 0.1 cm and 0.5 kg, respectively, and the body mass index (BMI) was calculated ($kg/m^2$). Waist circumference was assessed at the umbilicus, and the hip circumference was assessed at the maximal circumference of the buttocks using a steel measuring tape (standard 4 oz, tension) to the nearest 0.1 cm. Blood pressure was assessed in the right arm after five minutes of the participant resting in a sitting position. An automated oscillometric method (model Dinamap, GE Medical Systems Information Technologies, Inc., Milwaukee, Wisconsin, USA) and appropriate cuff size

were used. Three readings were taken, and the average between the last two readings was considered for analyses. Fasting blood samples (75 ml) were drawn and used to determine the levels of low-density lipoprotein (LDL) cholesterol, high-density lipoprotein (HDL) cholesterol, total cholesterol, and triglycerides. These were categorized according to the National Cholesterol Education Program (NCEP) report (17).

Statistical analyses

We created descriptive statistics including means and standard deviations (SDs) or medians and interquartile ranges (IQRs) for continuous variables and frequencies for categorical variables. Physical activity was presented for all exams in which it was assessed (except Exam 4), including the prevalence of participants meeting the recommended guidelines of at least 150 min/week of moderate to vigorous PA (MVPA) (12). We conducted an additional analysis comparing the characteristics of individuals at baseline who were part of our analytical sample (with complete data available at baseline and Exam 6) with individuals who were excluded from the analysis (due to incomplete data, mortality, or excluded for another reason). For these analyses, we tested differences between groups using independent t-tests for continuous variables and, Chi-square test for categorical variables.

We created categories and classified participants according to their physical activity behavior into the following groups: adopters (those who did not meet guidelines at baseline but met guidelines at Exam 6), relapsers (individuals who met the guidelines at baseline but did not meet guidelines at Exam 6), maintainers (individuals who met guidelines both at baseline and Exam 6) and insufficiently active (individuals who did not meet the guidelines at either baseline or Exam 6). We considered the maintainers' group was as the reference category in our analyses.

We conducted Poisson multinomial regression models to estimate the risk ratio (RR) according to methods proposed by Zou G(18). The absolute differences were calculated according to each exposure variable. The models were adjusted sequentially where Model 1 was adjusted for the contextual level variables (study site and contextual markers of socioeconomic status [SES]); Model 2 was further adjusted for individual-level sociodemographic variables (age, sex, race/ethnicity, educational level, marital status, occupation); and Model 3 was further adjusted for individual-level health variables (obesity assessed through waist circumference, LDL cholesterol, HDL cholesterol, and triglycerides levels, hypertension diagnosis, diabetes diagnosis, smoking status, alcohol consumption, emphysema, asthma, arthritis, pain in the lower limbs and swelling of the feet and ankles). Figure 1 below provides a visual description of the multi-level adjustment.

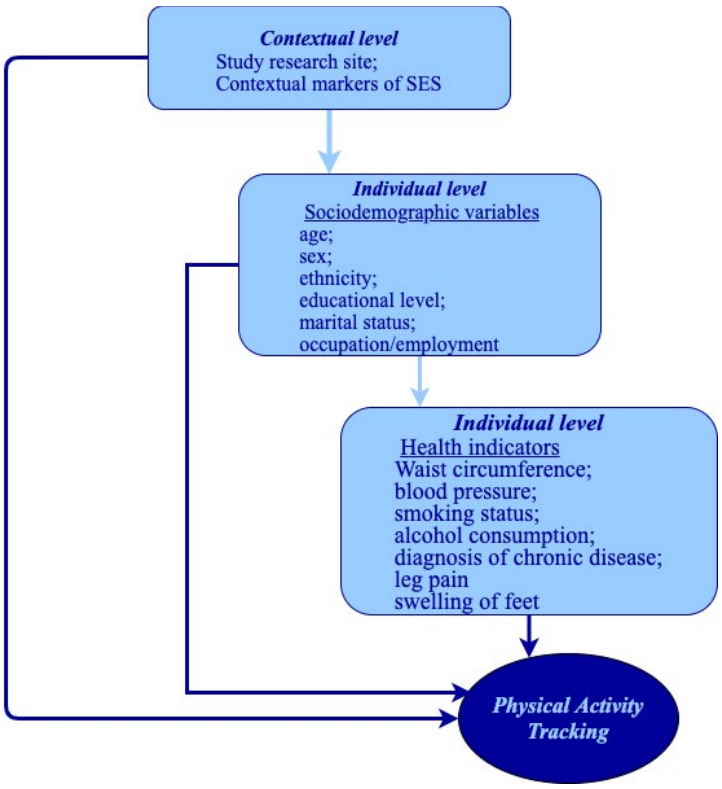


Figure 1 – Conceptual multi-levels framework of exposure effects on physical activity patterns

The work presented in the Methods is co-authored by Professor Augusto Cesar Ferreira de Moraes, Dr. Marcus Vinícius Nascimento Ferreira, Professor Paul J Mills, and Professor Matthew Allison.

## Results

At baseline, 6,814 individuals were enrolled and evaluated. The analytical sample for our study includes 3,097 of these individuals who had data available for intentional exercise at Exam 6. The characteristics of individuals included in the analytical sample are detailed in Table 1. They were on average 57.9 years old, 52.9% were female, 39.9% were White, 25.2% Black, 21.5% Hispanic/Latinos, and 13.3% Chinese American. Most had completed high school or less (28%), and the minority completed a graduate degree (21.54%). The majority were married (65.2%) and employed (61.5%). The average BMI was 28.2 $kg/m^2$, 34.9% had a diagnosis of hypertension, 6.2% had a diagnosis of diabetes type II, 11.4% were current smokers and, 61.5% currently consumed alcohol. Emphysema was prevalent in 0.8% of participants, 10.1% had asthma, 28.2% had arthritis, 22.7% experienced pain in the leg or buttock, while 27.4% experienced swelling of feet and ankles.

Table 1 –Characteristics of participants at baseline (n = 3,097) expressed as mean (95% CI) or frequencies (95% CI) (continued)

| Characteristics | n | |
|---|---|---|
| **Study Site (%)** | 3,037 | |
| Winstom-Salem, NC | | 11.62 (10.54, 12.80) |
| New York, NY | | 17.99 (16.77, 19.38) |
| Baltimore, MD | | 13.63 (12.46, 14.88) |
| Twin Cities, MN | | 17.95 (16.64, 19.35) |
| Chicago, IL | | 20.96 (19.56, 22.43) |
| Los Angeles, CA | | 17.86 (16.55, 19.55) |
| **Age (years)** | 3,097 | 57.96 (57.65, 58.26) |
| **Sex (%)** | 3,097 | |
| Male | | 47.11 (51.13, 54.64) |
| Female | | 52.89 (45.36, 48.87) |
| **Contextual marker of SES (%)** | 3,064 | |
| Low SES | | 35.61 (33.93, 37.32) |
| Medium SES | | 29.01 (27.43, 30.65) |
| High SES | | 35.38 (33.70, 37.09) |
| **Race/ethnicity (%)** | 3,097 | |
| White | | 39.97 (38.26, 41.71) |
| Asian (mostly Chinese American) | | 13.27 (12.12, 14.51) |
| African American/Black | | 25.22 (23.72, 26.78) |
| Hispanic/Latino | | 21.54 (20.12, 23.02) |
| **Education (%)** | 3,091 | |
| High school or less | | 28.28 (26.71, 29.89) |
| Incomplete or technical school | | 23.75 (22.28, 25.28) |
| College degree | | 24.91 (23.42, 26.47) |
| Graduate degree | | 23.07 (21.61, 24.59) |
| **Marital status (%)** | 3,091 | |
| Married/living as married | | 65.22 (63.52, 66.88) |
| Other | | 34.78 (33.12, 36.48) |

Table 1 –Characteristics of participants at baseline (n = 3,097) expressed as mean (95% CI) or frequencies (95% CI) (continued)

| Characteristics | n | |
|---|---|---|
| **Occupation (%)** | 3,091 | |
| Employed full-time/homemaker | | 61.47 (59.74, 63.17) |
| Employed part-time | | 10.32 (9.30, 11.44) |
| Unemployed/on leave | | 3.53 (2.93, 4.24) |
| Retired | | 24.68 (23.20, 26.24) |
| **BMI (kg/m$^2$)** | 3,097 | 28.20 (28.01, 28.39) |
| **Waist circumference (cm)** | 3,097 | 96.83 (96.33, 97.32) |
| **Blood pressure(mmHg)** | 3,097 | |
| Systolic | | 121.75 (121.06, 122.45) |
| Diastolic | | 71.84 (71.49, 72.20) |
| **Hypertension diagnosis (%)** | 3,097 | 34.90 (0.33, 0.37) |
| **Diabetes type II (%)** | 3,097 | 6.23 (5.43, 7.14) |
| **Total cholesterol (mg/dl)** | 3,086 | 194.82 (193.58, 196.06) |
| High, ≥240 mg/dl | | 9.49 (8.51, 10.58) |
| **HDL Cholesterol (mg/dl)** | 3,086 | 51.06 (50.54, 51.58) |
| Low, < 40 mg/dl (%) | | 21.08 (20.26, 23.17) |
| **LDL Cholesterol (mg/dl)** | 3,056 | 118.18 (31.14) |
| Borderline high, 130-159 (%) | | 24.21 (22.73, 25.77) |
| High, 160-189 (%) | | 7.30 (6.43, 8.28) |
| Very high, ≥190 (%) | | 1.83 (1.41, 2.37) |
| **Triglycerides (mg/dl)** | 3,086 | 128.79 (125.97, 131.61) |
| Borderline high, 150-199 (%) | | 15.23 (14.00, 16.54) |
| High, 200-499 (%) | | 13.29 (12.13, 14.53) |
| Very high, ≥ 500 (5%) | | 0.39 (0.22, 0.68) |
| **Smoking (%)** | 3,091 | |
| Never | | 52.86 (51.10, 54.62) |
| Former | | 35.78 (34.11, 37.49) |

Table 1 –Characteristics of participants at baseline (n = 3,097) expressed as mean (95% CI) or frequencies (95% CI) (continued)

| Characteristics | n | |
|---|---|---|
| Current | | 11.36 (10.28, 12.52) |
| **Alcohol consumption (%)** | 3,080 | |
| Never | | 18.57 (17.14, 19.88) |
| Former | | 19.97 (18.59, 21.42) |
| Current | | 61.56 (59.83, 63.26) |
| **Emphysema (%)** | 3,096 | 0.84 (0.57, 1.23) |
| **Asthma (%)** | 3,095 | 10.15 (9.13, 11.26) |
| **Arthritis (%)** | 3,096 | 28.20 (26.64, 29.81) |
| **Leg or buttock pain (%)** | 3,096 | 22.71 (21.26. 24.22) |
| **Swelling of feet or ankle (%)** | 3,094 | 27.44 (25.90, 29.04) |

BMI: body mass index; HDL: high-density lipoprotein; LDL: low-density lipoprotein; SES: socioeconomic status

At baseline, a small proportion of individuals perceived elements in the environment as a "very serious problem", with frequencies being below 10% for all other exposures; excessive noise (3.6%), traffic and speeding cars (6.9%), no access to adequate food shopping (1.3%), lacking parks and playgrounds (2.4%), trash and litter (3.1%), lack of poor sidewalks (1.9%), violence (1.8%). Excessive noise was perceived as "not being really a problem" (48%) or a "minor problem" (35.8%). Heavy traffic or speeding cars were also perceived as "not really a problem" (42%) or a "minor problem" (34.5%). The lack of access to adequate food shopping and lacking parks and playgrounds were perceived as "not really a problem" (81% and 76.2%, respectively). Additionally, trash or litter, poor sidewalks, and violence were also perceived as "not really a problem" by most individuals (61.9%, 76.6%, and 65.5%, respectively). Most perceived their

neighborhoods as “safe” (44.8%), and 39.6% perceived it as “more than safe” to “very safe”, while 3.2% perceived it as “not at all safe”, and 12.46% perceived it “below safe”.

Table 2 – Perceptions of the neighborhood environment at baseline expressed in frequencies (95% CI)

| | n | Very serious problem | Somewhat serious problem | Minor problem | Not really a problem |
|---|---|---|---|---|---|
| **Excessive noise** | 3,092 | 3.62 (3.02, 4.34) | 12.48 (11.36, 3.70) | 35.87 (34.19, 37.57) | 48.03 (46.27, 49.79) |
| **Traffic/ speeding cars** | 3,092 | 6.18 (5.38, 7.08) | 16.95 (15.66, 18.31) | 34.54 (32.88, 36.24) | 42.34 (40.60, 44.09) |
| **No access to food shopping** | 3,093 | 1.26 (0.92, 1.72) | 3.72 (3.11, 4.45) | 14.03 (12.85, 15.30) | 80.99 (79.57, 82.33) |
| **Lacking parks and playgrounds** | 3,084 | 2.4 (1.91, 3.00) | 5.03 (4.31, 5.86) | 16.37 (15.11, 17.72) | 76.20 (74.66, 77.67) |
| **Trash and litter** | 3,087 | 3.14 (2.58, 3.82) | 7.13 (6.27, 8.09) | 27.79 (26.94, 29.40) | 61.94 (60.21, 63.64) |
| **Poor sidewalks** | 3,087 | 1.98 (1.54, 2.53) | 4.18 (3.53, 4.94) | 17.23 (15.94, 18.61) | 76.61 (75.08, 78.07) |
| **Violence** | 3,087 | 1.81 (1.40, 2.35) | 8.13 (7.22, 9.15) | 24.46 (22.97, 26.01) | 65.50 (63.90, 67.25) |

| | n | Not at all safe (5) | (4) | Safe (3) | (3) | Very safe (1) |
|---|---|---|---|---|---|---|
| **Safety** | 3,082 | 3.21 (2.64, 3.90) | 12.46 (11.34, 13.67) | 44.78 (43.03, 46.54) | 19.73 (18.36, 21.17) | 19.92 (18.45, 21.27) |

Intentional exercise across multiple time points is shown in Table 3. At baseline and exam 6, the median values for intentional exercise were 900 (IQR: 210-2130) and 945 (IQR: 157.5 – 2,280) METs-min/week, respectively. Self-reported intentional exercise was higher at Exam 5, compared to other time points (1,860; IQR: 802.5 – 3,780) METs-min/week. At this time point, most individuals reported enough PA to meet physical activity guidelines (82.8%). Categories created to discriminate patterns of PA were distributed as follows: 46.5% were classified as maintainers, 17.0% were adopters, 17.7% were relapsers, and 18.6% were insufficiently active (Figure 2).

Table 3 – Intentional PA reported as METs-min/week and prevalence of individuals meeting PA guidelines per Exam (≥ 500 METS-min/week)

| | **Exam 1** | **Exam 2** | **Exam 3** | **Exam 5** | **Exam 6** |
|---|---|---|---|---|---|
| **Median (IQR)** | 900 (210-2,130) | 810 (105-1,890) | 945 (210-2,073.75) | 1860 (802.5-3,780) | 945 (157.5-2,280) |
| **n** | 3,092 | 3,044 | 3,032 | 2,956 | 3,097 |
| **IMRs (%)** | 64.26 | 60.58 | 64.35 | 82.78 | 63.58 |

IMRs: individuals meeting recommendations; QR: interquartile range; MET: metabolic equivalent of task; PA: physical activity

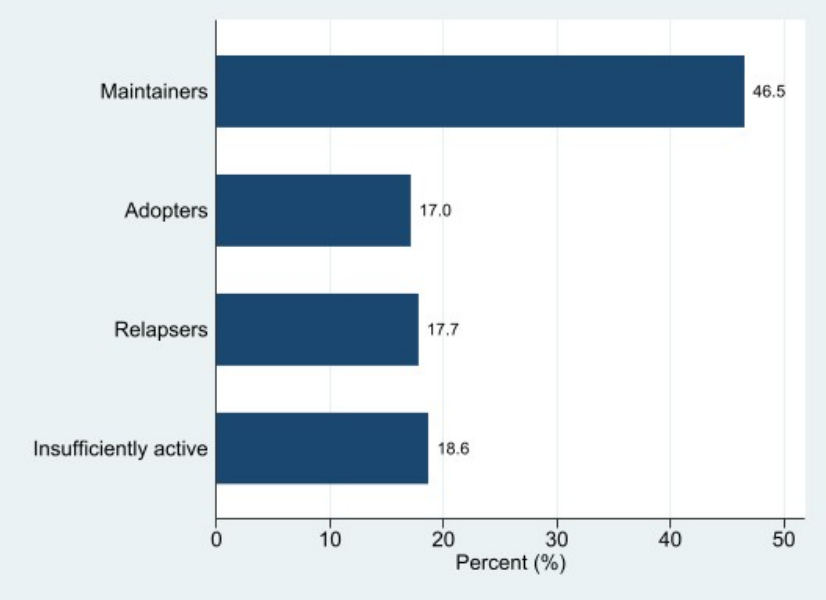


Figure 2 – Frequency (%) of individuals in each category of physical activity patterns according to the recommendations of physical activity guidelines (500 METs-min/week)

We performed additional analyses to assess potential differences in baseline characteristics of individuals who had missing data versus those who answered the PA questionnaire at Exam 6. Appendix 1 summarizes the overall sample characteristics and details the two groups (included and excluded in the analyses). The two groups were not meaningfully different in terms of distribution of sex, BMI, diastolic blood pressure, the prevalence of diabetes, total cholesterol, and HDL cholesterol. Included individuals were younger, and there was a higher prevalence of participants of high SES compared to excluded participants. Regarding the individual-level characteristics, more White and Chinese individuals and fewer Black and Latinos composed the included sample. Included participants were also more educated (23.1% completed graduate degrees versus 13.7%) and more likely to be married (65.2% vs. 56.8%).

Participants included in the analysis had lower waist circumference, a lower mean systolic blood pressure, a lower prevalence of hypertension diagnosis, and lower mean triglycerides. Included participants also had a lower prevalence of emphysema, arthritis, pain in the legs or

buttock, and swelling of feet and ankles. On the other hand, included participants had a higher prevalence of asthma. Regarding health behaviors, there was a lower prevalence of current smokers (11.4% vs. 14.5%) and higher consumption of current alcoholic drinks (61.6% vs. 50.3%) among included participants.

No differences were identified for the perception of lacking adequate access to food shopping ($p = 0.32$), perception of lacking parks and playgrounds ($p = 0.57$), and the perception of poor sidewalks ($p = 0.08$) between included and excluded participants. There were statistically significant differences in the distribution of frequencies for the perception of excessive noise, perception of heavy traffic and speeding cars, perception of trash or litter, perception of violence, and perception of safety between included and excluded participants. A higher proportion of included participants perceived excessive noise, traffic and speeding cars, trash or litter, and violence as a "minor problem" compared to excluded participants. Also, a smaller proportion of included participants perceived excessive noise, traffic and speeding cars, trash or litter, and violence as "not really a problem" compared to excluded participants. Lastly, a smaller proportion of included participants perceived the neighborhood as safe (44.8% vs. 47.3%).

Using our sample, the results of the multinomial regression models showed no statistically significant associations between the perception of excessive noise (Appendix 3), perception of heavy traffic and speeding cars (Appendix 4), perception of the lack of access to adequate food shopping (Appendix 5), perception of the presence of trash or litter (Appendix 6), and perceived violence (Appendix 7) with longitudinal patterns of PA.

Individuals who reported that lack of parks and playgrounds was "not a problem" in their neighborhood had a 2.3-times higher risk of decreasing their physical activity (i.e. "relapser" category), compared to maintainers (RR: 2.29, 95% CI: 1.02, 5.14). There were no significant

associations between perceptions of the lack of parks and playgrounds in the neighborhood and being categorized as adopters or insufficiently active (Table 4).

Table 4 – Multinomial regression models assessing the association between the perception of lack of parks and playgrounds in the neighborhood and patterns of PA (continued)

| | | Model 1 (n = 3,050) | Model 2 (n = 3,048) | Model 3 (n = 3,023) |
|---|---|---|---|---|
| | | RR 95% CI | RR 95% CI | RR 95% CI |
| Maintainers (ref) | | - | - | - |
| Adopters | Serious problem (ref) | - | - | - |
| | Somewhat serious | 1.97 (0.81, 4.79) | 1.88 (0.77, 4.62) | 1.99 (0.80, 4.95) |
| | Minor problem | 1.62 (0.72, 3.66) | 1.50 (0.66, 3.41) | 1.57 (0.68, 3.60) |
| | Not a problem | 1.78 (0.81, 3.89) | 1.72 (0.78, 3.80) | 1.82 (0.82, 4.06) |
| Relapsers | Serious problem (ref) | - | - | - |
| | Somewhat serious | 1.38 (0.57, 3.33) | 1.72 (0.69, 4.32) | 1.91 (0.75, 4.89) |
| | Minor problem | 1.58 (0.72, 3.43) | 1.93 (0.85, 4.37) | 2.07 (0.90, 4.78) |
| | Not a problem | 1.74 (0.83, 3.69) | 2.01 (0.91, 4.42) | 2.29 (1.02, 5.14) |
| Insufficiently Active | Serious problem (ref) | - | - | - |
| | Somewhat serious | 0.96 (0.48, 1.92) | 1.04 (0.51, 2.11) | 1.26 (0.602, 2.63) |
| | Minor problem | 0.75 (0.41, 1.38) | 0.81 (0.44, 1.52) | 0.97 (0.51, 1.86) |
| | Not a problem | 0.80 (0.45, 1.42) | 0.86 (0.48, 1.54) | 1.08 (0.59, 2.00) |

Model 1: adjusted for study site and contextual markers of SES
Model 2: model 1 + age, sex, race/ethnicity, educational level, marital status, and occupation
Model 3: model 2 + waist circumference, LDL cholesterol, HDL cholesterol, triglycerides, hypertension, diabetes, smoking, alcohol, emphysema, asthma, arthritis, pain in the lower limbs, and swelling of feet and ankles.
CI: confidence interval; RR: risk ratio; PA: physical activity

We observed adopters were less likely than maintainers to report perceiving lack of or poor sidewalks as "somewhat serious problem". That is, and after full adjustment, to perceive poor sidewalks as "somewhat a serious problem" was associated with a 64% (RR: 0.36, 95% CI: 0.14, 0.93) lower risk of becoming an adopter than maintainer. There were no significant associations seen for "relapsers" and "insufficiently active" categories.

Table 5 – Multinomial regression models assessing the association between the perception of poor sidewalks in the neighborhood and patterns of PA

| | | Model 1 (n = 3,086) | Model 2 (n = 3,053) | Model 3 (n = 3,051) |
|---|---|---|---|---|
| | | RR 95% CI | RR 95% CI | RR 95% CI |
| Maintainers (ref) | | - | - | - |
| Adopters | Serious problem (ref) | - | - | - |
| | Somewhat serious | 0.37 (0.15, 0.91) | 0.38 (0.15, 0.96) | 0.36 (0.14, 0.93) |
| | Minor problem | 0.74 (0.35, 1.58) | 0.77 (0.15, 0.96) | 0.76 (0.35, 1.66) |
| | Not a problem | 0.68 (0.33, 1.40) | 0.72 (0.34, 1.50) | 0.72 (0.34, 1.52) |
| Relapsers | Serious problem (ref) | - | - | - |
| | Somewhat serious | 0.48 (0.20, 1.18) | 0.52 (0.21, 1.28) | 0.49 (0.19, 1.22) |
| | Minor problem | 0.79 (0.37, 1.70) | 0.88 (0.41, 1.92) | 0.88 (0.40, 1.94) |
| | Not a problem | 0.68 (0.33, 1.43) | 0.73 (0.34, 1.54) | 0.74 (0.34, 1.58) |
| Insufficiently Active | Serious problem (ref) | - | - | - |
| | Somewhat serious | 0.47 (0.21, 1.08) | 0.57 (0.25, 1.34) | 0.56 (0.23, 1.33) |
| | Minor problem | 0.64 (0.31, 1.08) | 0.79 (0.38, 1.66) | 0.83 (0.39, 1.77) |
| | Not a problem | 0.60 (0.30, 1.20) | 0.70 (0.35, 1.43) | 0.76 (0.37, 1.58) |

Model 1: adjusted for study site and contextual markers of SES
Model 2: model 1 + age, sex, race/ethnicity, educational level, marital status, and occupation

Table 5 – Multinomial regression models assessing the association between the perception of poor sidewalks in the neighborhood and patterns of PA

| | Model 1 (n = 3,086) | Model 2 (n = 3,053) | Model 3 (n = 3,051) |
|---|---|---|---|
| | RR 95% CI | RR 95% CI | RR 95% CI |

Model 3: model 2 + waist circumference, LDL cholesterol, HDL cholesterol, triglycerides, hypertension, diabetes, smoking, alcohol, emphysema, asthma, arthritis, pain in the lower limbs, and swelling of feet and ankles.
CI: confidence interval; RR: risk ratio; PA: physical activity

When compared to those who perceive the neighborhood as “very safe”, perception of the neighborhood as “safe” to “not at all safe” (rating 3, 4, and 5 in the perceived safety scale) was significantly associated with being classified in the adopter category. Additionally, and when compared to the same reference group, individuals who perceived the neighborhood as “safe” (rating 3) or as category 4 in the safety rating had a 1.5 and 1.8 (respectively) higher risk of being categorized as insufficiently active. No significant associations were observed for individuals categorized as “relapsers” (Table 6).

Table 6 - Multinomial regression models assessing the association of perceived safety in the neighborhood and patterns of PA

| | | Model 1 (n = 3,048) | Model 2 (n = 3,046) | Model 3 (n = 3,021) |
|---|---|---|---|---|
| | | RR 95% CI | RR 95% CI | RR 95% CI |
| Maintainers (ref) | | - | - | - |
| Adopters | Very safe (1) (ref) | - | - | - |
| | (2) | 1.16 (0.83, 1.62) | 1.23 (0.87, 1.73) | 1.27 (0.90, 1.80) |
| | Safe (3) | 1.51 (1.11, 2.04) | 1.56 (1.15, 2.13) | 1.62 (1.18, 2.22) |
| | (4) | 1.50 (1.00, 2.23) | 1.61 (1.07, 2.44) | 1.66 (1.09, 2.52) |
| | Not at all safe (5) | 2.10 (1.10, 4.00) | 2.20 (1.14, 4.26) | 2.14 (1.10, 4.17) |
| Relapsers | Very safe (1) (ref) | - | - | - |
| | (2) | 0.88 (0.64, 1.21) | 0.91 (0.65, 1.26) | 0.92 (0.66, 1.29) |
| | Safe (3) | 1.14 (0.86, 1.52) | 1.08 (0.81, 1.44) | 1.07 (0.79, 1.43) |
| | (4) | 1.05 (0.71, 1.56) | 1.00 (0.67, 1.49) | 1.03 (0.68, 1.55) |
| | Not at all safe (5) | 1.80 (0.98, 3.29) | 1.45 (0.78, 2.68) | 1.23 (0.65, 2.31) |
| Insufficiently Active | Very safe (1) (ref) | - | - | - |
| | (2) | 0.84 (0.59, 1.19) | 0.93 (0.65, 1.33) | 0.97 (0.67, 1.39) |
| | Safe (3) | 1.48 (1.10, 2.00) | 1.45 (1.07, 1.96) | 1.48 (1.09, 2.02) |
| | (4) | 1.78 (1.22, 2.59) | 1.78 (1.20, 2.63) | 1.81 (1.21, 2.70) |
| | Not at all safe (5) | 2.03 (1.10, 3.74) | 1.64 (0.87, 3.06) | 1.43 (0.75, 2.71) |

Model 1: adjusted for study site and contextual markers of SES
Model 2: model 1 + age, sex, race/ethnicity, educational level, marital status, and occupation
Model 3: model 2 + waist circumference, LDL cholesterol, HDL cholesterol, triglycerides, hypertension, diabetes, smoking, alcohol, emphysema, asthma, arthritis, pain in the lower limbs and swelling of feet and ankles.
CI: confidence interval; RR: risk ratio; PA: physical activity

The work presented in the Results is co-authored by Professor Augusto Cesar Ferreira de Moraes, Dr. Marcus Vinícius Nascimento Ferreira, Professor Paul J Mills, and Professor Matthew Allison.

## Discussion

The findings of our analyses suggest that perceived lack of parks and playgrounds, perception of no sidewalks or poorly maintained sidewalks, and perceived safety were associated with patterns of PA. Specifically, perceiving the lack of sidewalks or poorly maintained ones as "somewhat a serious problem" was associated with a lower risk of "adopting" PA over time. Also, we demonstrated that a perceived lack of safety was associated with being consistently insufficiently active over time. Of note, we also identified significant associations that were contrary to our hypothesis. That is, perceived lack of parks/playgrounds as "not problematic" was associated with relapsing PA, and perceived unsafety was also associated with being an adopter of PA. We demonstrated no significant associations between perceived excessive noise, heavy traffic, and speeding cars, lack of access to adequate food shopping, presence of trash or litter, and perceived violence with patterns of PA. Taken together, these results suggest that problematic perception of poor sidewalks is associated with lower rates of PA adoption and that perceived lack of safety is associated with sustaining insufficient PA levels. Also, other significant mixed results, as well as, insignificant associations between the perceived environment and patterns of PA were detected.

We identified that the perception of lack of parks and playgrounds as "not being problematic" increased the risk of an individual being a relapser (compared to those who maintained PA over time), which contradicted our initial hypothesis that perceiving the lack of parks and playgrounds as problematic would be associated with being a relapser or insufficiently active. A previous study from MESA that objectively assessed the density of recreational facilities identified a greater increase in density was associated with a lesser decline in physical activity over time (6) after adjustment for individual-level perception of the environment. Still, this study did

not assess the perceived environment alone and its association with levels of PA. Moreover, a cross-sectional analysis from the International Physical Activity and Environment Network, the IPEN study, demonstrated that the number of parks in the neighborhood was associated with higher levels of PA (19), while a cross-sectional analysis of participants from Australia showed that non-retired individuals reporting living near a park were more likely to participate in recreational walking (20) but not other types of recreational MVPA. Given the difference between our results and these and others, additional longitudinal analyses are warranted to understand better the role of the perception of parks and engagement in intentional PA.

Our study showed that adopters were less likely than maintainers to report perceiving the lack of sidewalks or poorly maintained ones as "somewhat a serious problem". Our findings are supported by previous literature regarding the perception of sidewalks. A study manipulated photographs of streets to determine the appeal of a street for older adults' transportation walking. In this study, sidewalk evenness was a relevant actor for adults to walk for transportation (21). In a cross-sectional population-level survey, significant associations were seen between the presence of sidewalks and meeting PA recommendations in Colombia, Hong Kong, Japan, and Lithuania (22). In contrast, for the U.S, the association was not statistically significant. In Germany, perceived well-maintained sidewalks were associated with self-reported MVPA(23). In Brazil, lack of sidewalks was associated with a lower likelihood of leisure walking(24). In summary, the presence of sidewalks, perceived adequate esthetics, and evenness of sidewalks evident in the literature corroborate our findings. It is noteworthy that previous literature is cross-sectional, and our longitudinal design demonstrates that this association is consistent independent of contextual SES and individual-level characteristics.

Perceptions of an unsafe neighborhood were associated with being classified as an "adopter" of PA and "insufficiently active". The former contradicts our hypothesis, while the association between perceived lack of safety and being insufficiently active aligns with our hypothesis. Within MESA, a previous cross-sectional analysis identified that perceiving a safe neighborhood was positively associated with transport walking but not with leisure walking or intentional PA engagement (9). Cross-sectional evidence has demonstrated that among individuals of higher SES, perceived lack of safety was associated with higher physical inactivity (25), and perceived safety was associated with a higher likelihood of engaging in intentional PA (26) and meeting PA recommendations (27). Previous literature has also highlighted inconsistent findings of the association of perceived safety and PA engagement (28).

There was no significant association between the perception of excessive noise and patterns of PA in our study. A longitudinal analysis identified that noise annoyance from transportation was associated with a decrease in PA, and such association was stronger among women (29) among Swedish individuals. Another analysis in Denmark also identified that railroad noise was associated with a higher prevalence odds ratio of not participating in intentional (sports) activities. Still, longitudinal analyses did not confirm this finding for railroad or traffic noise (30), corroborating our findings. We demonstrated no significant associations between the perception of heavy traffic/speeding cars and patterns of PA. The absence of PA-hindering characteristics, such as heavy traffic, was associated with higher MVPA in a cross-sectional design in the Netherlands(31). This finding was seen only among those who reported pain related to performing daily living activities.

We did not see significant associations between the perception of lacking access to adequate food shopping and patterns of PA. A Finish study evaluated perceptions of the

environment and how these relate to walking to grocery stores among older adults. Researchers identified that those who perceived parks or green areas in their neighborhood were more likely to walk to the grocery store(32). In our study, there was no significant association between the presence of trash or litter and patterns of intentional PA. Our findings corroborate with a study among older adults, where objectively assessed trash/litter was not associated with leisure walking(33). Moreover, a study among African Americans demonstrated that perceived trash, additionally with other environment aesthetics factors, was not associated with PA engagement, but worse aesthetics perception was associated with more TV viewing among women(34).

We demonstrated no significant association between perceptions of violence in the neighborhood and patterns of PA. Previous cross-sectional analysis of the MESA cohort with residents from Chicago has shown that perceiving violence as not being a problem or a minor problem was associated with engaging in leisure walking, but no associations were found for other non-walking intentional PA(9). An intervention to increase walking among African-Americans in Chicago did not found associations between walking and perceived neighborhood crime(35). Lastly, a cross-sectional analysis has demonstrated that less crime was associated with less MVPA among adults (31). Therefore, our findings strengthen previous evidence among participants of the MESA study.

Our study has strengths and limitations. Strengths include a large multi-ethnic sample size and a longitudinal design. Moreover, our study has a long period between assessments (approximately 16 to 18 years), which can also be pointed out as a limitation, as sparse data can increase the probability for residual confounding in our analyses.

As for limitations, our inclusion criteria may have introduced selection bias, and both the exposure and the physical activity levels were self-reported. Differences between self-reported and

objectively measured PA have been demonstrated in the literature (36,37). Also, we considered intentional PA, and we did not include other domains of PA (e.g., transportation, activities of daily living). Additionally, we did not adjust our analyses for individuals who may have moved within the period analyzed.

The main implication for practice of our findings includes the awareness that perceived poor sidewalks or poor sidewalks was associated with prevention of PA adoption and, that perceived lack of safety was associated with insufficient PA behavior independently of contextual and individual-level factors. Our study can inform policymakers and professionals involved in developing residential areas by emphasizing adequate sidewalks and aspects that can increase the perception of safety.

Based on our results and those mentioned above, we recommend additional longitudinal study designs investigating the perceived environment and patterns of PA. We recommend objectively measured physical activity to decrease potential recall bias. Future analyses should also consider that participants may have moved during the period analyzed. Therefore, moving patterns should be considered. Also, physical activity from a one-time point to the following be considered in addition to the overall time analyzed (baseline to Exam 6). The development of chronic diseases, physical symptoms, and limitations during the period analyzed could influence one's ability to engage in intentional physical activity and should also be considered. We also recommend that future studies consider other domains of PA. Finally, objective measures of the environment and perceptions of it should be used in combination (39) to understand better how the environment relates to patterns of PA.

The work presented in the Discussion is co-authored by Professor Augusto Cesar Ferreira de Moraes, Dr. Marcus Vinícius Nascimento Ferreira, Professor Paul J Mills, and Professor Matthew Allison.

## Conclusion

Aspects of the perceived environment are associated with being physically active lifestyle in adults over approximately 18 years. Problematic perception of the lack of, or poorly maintained sidewalks was associated with adopting PA guidelines, and perceived lack of safety was associated with insufficiently active behavior. Such findings should be considered in public health initiatives to promote physical activity. More studies are warranted to understand the directionality of these associations better.

The work presented in the Introduction, Methods, Results, Discussion, and Conclusion is co-authored by Professor Augusto Cesar Ferreira de Moraes, Dr. Marcus Vinícius Nascimento Ferreira, Professor Paul J Mills, and Professor Matthew Allison

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Appendix 1 – Sensitivity analysis comparing the characteristics of the overall sample at baseline, included, and excluded participants in the analytical sample

| | Overall sample (n = 6,814) | Excluded (n = 3,717) | Included (n = 3,097) | p-value |
|---|---|---|---|---|
| **Study Site (%)** | | | | <0.001 |
| Winstom-Salem, NC | 15.81 (14.96, 16.69) | 19.29 (18.05, 20.59) | 11.62 (10.54, 12.80) | |
| New York, NY | 16.17 (15.32, 17.07) | 14.66 (13.56, 15.84) | 17.99 (16.77, 19.38) | |
| Baltimore, MD | 15.94 (15.09, 16.83) | 17.86 (16.67, 19.13) | 13.63 (12.46, 14.88) | |
| Twin Cities, MN | 15.64 (14.80, 16.53) | 13.72 (12.65, 14.87) | 17.95 (16.64, 19.35) | |
| Chicago, IL | 17.08 (16.21, 17.99) | 13.86 (12.78, 15.00) | 20.96 (19.56, 22.43) | |
| Los Angeles, CA | 19.36 (18.44, 20.31) | 20.61 (19.34, 21.94) | 17.86 (16.55, 19.55) | |
| **Age (years)** | 62.15 (61.91, 62.39) | 65.65 (65.32, 65.97) | 57.96 (57.65, 58.26) | <0.001 |
| **Sex (%)** | | | | 0.948 |
| Male | 47.15 (45.97, 48.34) | 47.19 (45.59, 48.80) | 47.11 (51.13, 54.64) | |
| Female | 52.85 (51.66, 54.03) | 52.81 (51.20, 54.41) | 52.89 (45.36, 48.87) | |
| **Contextual marker of SES (%)** | | | | 0.003 |
| Low SES | 36.75 (35.55, 37.96) | 37.86 (36.18, 39.58) | 35.61 (33.93, 37.32) | |
| Medium SES | 29.93 (28.80, 31.08) | 30.83 (29.23, 32.47) | 29.01 (27.43, 30.65) | |
| High SES | 33.32 (32.16, 34.51) | 31.31 (29.71, 32.96) | 35.38 (33.70, 37.09) | |
| **Race/ethnicity (%)** | | | | <0.001 |
| White | 38.48 (37.33, 39.64) | 37.23 (35.69, 38.80) | 39.97 (38.26, 41.71) | |
| Asian (mostly Chinese American) | 11.80 (11.05, 12.59) | 10.57 (9.62, 11.60) | 13.27 (12.12, 14.51) | |
| African American/Black | 27.77 (26.72, 28.84) | 29.89 (28.44, 31.38) | 25.22 (23.72, 26.78) | |

Appendix 1 – Sensitivity analysis comparing the characteristics of the overall sample at baseline, included, and excluded participants in the analytical sample

| | Overall sample (n = 6,814) | Excluded (n = 3,717) | Included (n = 3,097) | p-value |
|---|---|---|---|---|
| Hispanic/Latino | 21.95 (20.99, 22.95) | 22.30 (20.99, 23.67) | 21.54 (20.12, 23.02) | |
| **Education (%)** | | | | <0.001 |
| High school or less | 36.24 (35.10, 37.39) | 42.89 (41.30, 44.49) | 28.28 (26.71, 29.89) | |
| Incomplete or technical school | 23.52 (22.52, 24.54) | 23.32 (21.99, 24.72) | 23.75 (22.28, 25.28) | |
| College degree | 22.25 (21.28, 23.26) | 20.03 (18.77, 21.35) | 24.91 (23.42, 26.47) | |
| Graduate degree | 17.99 (17.10, 18.93) | 13.76 (12.68, 14.91) | 23.07 (21.61, 24.59) | |
| **Marital status (%)** | | | | <0.001 |
| Married/living as married | 60.64 (59.48, 61.80) | 56.82 (55.22, 58.41) | 65.22 (63.52, 66.88) | |
| Other | 39.36 (38.20, 40.52) | 43.18 (41.59, 44.78) | 34.78 (33.12, 36.48) | |
| **Occupation (%)** | | | | <0.001 |
| Employed full-time/homemaker | 49.91 (98.72, 51.10) | 40.25 (38.68, 41.84) | 61.47 (59.74, 63.17) | |
| Employed part-time | 8.62 (7.97, 9.31) | 7.19 (6.40, 8.07) | 10.32 (9.30, 11.44) | |
| Unemployed/on leave | 3.42 (3.01, 3.88) | 3.33 (2.79, 3.95) | 3.53 (2.93, 4.24) | |
| Retired | 38.06 (36.91, 39.22) | 49.23 (47.62, 50.84) | 24.68 (23.20, 26.24) | |
| **BMI ($kg/m^2$)** | 28.34 (28.21, 28.47) | 28.46 (28.28, 28.64) | 28.20 (28.01, 28.39) | 0.052 |
| **Waist circumference (cm)** | 98.16 (97.82, 98.50) | 99.27 (98.80, 99.74) | 96.83 (96.33, 97.32) | <0.001 |
| **Blood pressure(mmHg)** | | | | |
| Systolic | 126.59 (126.08, 127.10) | 130.63 (129.91, 131.34) | 121.75 (121.06, 122.45) | <0.001 |

Appendix 1 – Sensitivity analysis comparing the characteristics of the overall sample at baseline, included, and excluded participants in the analytical sample

| | Overall sample (n = 6,814) | Excluded (n = 3,717) | Included (n = 3,097) | p-value |
|---|---|---|---|---|
| Diastolic | 71.91 (71.67, 72.16) | 71.97 (71.64, 72.31) | 71.84 (71.49, 72.20) | 0.598 |
| **Hypertension diagnosis (%)** | 44.88 (43.70, 46.06) | 53.19 (51.58, 54.79) | 34.9 (0.33, 0.37) | <0.001 |
| **Diabetes type II (%)** | 9.83 (9.15, 10.56) | 12.53 (11.80, 13.95) | 6.23 (5.43, 7.14) | 0.439 |
| **Total cholesterol (mg/dl)** | 194.16 (193.31, 195.01) | 193.60 (192.43, 194.77) | 194.82 (193.58, 196.06) | 0.160 |
| High, ≥240 mg/dl (%) | 9.62 (8.94, 10.34) | 9.72 (8.80, 10.71) | 9.49 (8.51, 10.58) | 0.189 |
| **HDL Cholesterol (mg/dl)** | 50.96 (50.61, 51.31) | 50.88 (50.40, 51.36) | 51.06 (50.54, 51.58) | 0.335 |
| Low, < 40 mg/dl (%) | 22.22 (21.24, 23.22) | 22.66 (21.34, 24.04) | 21.08 (20.26, 23.17) | |
| **LDL Cholesterol (mg/dl)** | 117.20 (116.45, 117.96) | 116.38 (115.35, 117.41) | 118.18 (31.14) | 0.020 |
| Borderline high, 130-159 (%) | 23.19 (22.20, 24.22) | 22.33 (21.01, 23.71) | 24.21 (22.73, 25.77) | |
| High, 160-189 (%) | 7.43 (6.83, 8.08) | 7.54 (6.73, 8.45) | 7.30 (6.43, 8.28) | |
| Very high, ≥190 (%) | 1.72 (1.43, 2.06) | 1.62 (1.26, 2.08) | 1.83 (1.41, 2.37) | |
| **Triglycerides (mg/dl)** | 131.59 (129.48, 133.71) | 133.93 (194.77, 137.01) | 128.79 (125.97, 131.61) | 0.018 |
| Borderline high, 150-199 (%) | 15.03 (14.20, 15.90) | 14.87 (13.76, 16.05) | 15.23 (14.00, 16.54) | |
| High, 200-499 (%) | 14.08 (13.27, 14.93) | 14.74 (13.76, 16.05) | 13.29 (12.13, 14.53) | |
| Very high, ≥ 500 (%) | 0.50 (0.36, 0.70) | 0.59 (0.39, 0.90) | 0.39 (0.22, 0.68) | |
| **Smoking (%)** | | | | <0.001 |
| Never | 50.32 (49.13, 51.51) | 48.20 (46.60, 49.81) | 52.86 (51.10, 54.62) | |
| Former | 36.62 (35.48, 37.77) | 37.31 (35.77, 38.89) | 35.78 (34.11, 37.49) | |

Appendix 1 – Sensitivity analysis comparing the characteristics of the overall sample at baseline, included, and excluded participants in the analytical sample

| | Overall sample (n = 6,814) | Excluded (n = 3,717) | Included (n = 3,097) | p-value |
|---|---|---|---|---|
| Current | 13.06 (12.28, 13.88) | 14.48 (13.38, 15.65) | 11.36 (10.28, 12.52) | |
| **Alcohol consumption (%)** | | | | <0.001 |
| Never | 20.55 (19.61, 21.53) | 22.29 (20.98, 23.67) | 18.57 (17.14, 19.88) | |
| Former | 24.01 (23.01, 25.05) | 27.40 (25.98, 28.86) | 19.97 (18.59, 21.42) | |
| Current | 55.43 (54.25, 56.62) | 50.31 (48.70, 51.93) | 61.56 (59.83, 63.26) | |
| **Emphysema (%)** | 1.53 (1.26, 1.85) | 2.1 (1.68, 2.61) | 0.84 (0.57, 1.23) | 0.008 |
| **Asthma (%)** | 9.81 (9.12, 10.54) | 9.52 (8.66, 10.51) | 10.15 (9.13, 11.26) | <0.001 |
| **Arthritis (%)** | 35.75 (34.62, 36.89) | 42.03 (40.46, 43.63) | 28.20 (26.64, 29.81) | <0.001 |
| **Leg or buttock pain (%)** | 24.45 (23.45, 25.49) | 25.91 (24.52, 27.37) | 22.71 (21.26. 24.22) | 0.002 |
| **Swelling of feet or ankle (%)** | 21.24 (30.15, 32.35) | 34.40 (32.89, 35.95) | 27.44 (25.90, 29.04) | <0.001 |

BMI: body mass index; HDL: high-density lipoprotein; LDL: low-density lipoprotein; SES: socioeconomic status

Appendix 2 – Sensitivity analysis comparing the perception of the environment between individuals included and excluded in the analytical sample expressed as means and SDs

| | Very serious problem | Somewhat serious problem | Minor problem | Not really a problem | p-value |
|---|---|---|---|---|---|
| **Excessive noise** | | | | | |
| Included | 112 (3.62) | 386 (12.48) | 1,109 (35.87) | 1,485 (48.03) | 0.006 |
| Excluded | 133 (3.6) | 419 (11.34) | 1,212 (32.8) | 1,931 (52.26) | |
| **Traffic/speeding cars** | | | | | |
| Included | 191 (6.18) | 524 (16.95) | 1,068 (34.54) | 1,309 (42.34) | 0.001 |
| Excluded | 241 (6.53) | 671 (18.18) | 1,104 (29.92) | 1,674 (45.37) | |
| **No access to food shopping** | | | | | |
| Included | 39 (1.26) | 115 (3.72) | 434 (14.03) | 2,505 (80.99) | 0.321 |
| Excluded | 61 (1.65) | 144 (3.9) | 555 (15.02) | 2,936 (79.44) | |
| **Lacking parks and playgrounds** | | | | | |
| Included | 74 (2.4) | 155 (5.03) | 505 (16.37) | 2,350 (76.20) | 0.574 |
| Excluded | 105 (2.85) | 198 (5.37) | 614 (16.65) | 2,770 (75.13) | |
| **Trash and litter** | | | | | |
| Included | 97 (3.14) | 220 (7.13) | 858 (27.79) | 1,912 (61.94) | <0.001 |
| Excluded | 122 (3.3) | 294 (7.96) | 807 (21.86) | 2,469 (66.87) | |
| **Poor sidewalks** | | | | | |
| Included | 61 (1.98) | 129 (4.18) | 532 (17.23) | 2,365 (76.61) | 0.083 |

Appendix 2 – Sensitivity analysis comparing the perception of the environment between individuals included and excluded in the analytical sample expressed as means and SDs

| | Very serious problem | Somewhat serious problem | Minor problem | Not really a problem | p-value |
|---|---|---|---|---|---|
| Excluded | 99 (2.68) | 178 (4.82) | 590 (15.98) | 2,824 (76.51) | |
| **Violence** | | | | | |
| Included | 56 (1.81) | 251 (8.13) | 755 (24.46) | 2,025 (65.50) | 0.002 |
| Excluded | 68 (1.84) | 243 (6.58) | 805 (21.81) | 2,575 (69.76) | |

| | Not at all safe (1) | (2) | Safe (3) | (4) | Not at all safe (5) | p-value |
|---|---|---|---|---|---|---|
| **Safety** | | | | | | |
| Included | 99 (3.21) | 384 (12.46) | 1,308 (44.78) | 608 (19.73) | 611 (19.82) | 0.011 |
| Excluded | 125 (3.39) | 457 (12.39) | 1,744 (47.29) | 606 (16.43) | 756 (20.5) | |

Appendix 3 – Multinomial regression model assessing the association of perceived excessive noise in the neighborhood and patterns of PA

| | | Model 1 (n = 3,058) | Model 2 (n = 3,056) | Model 3 (n = 3,030) |
|---|---|---|---|---|
| | | RR (95% CI) | RR (95% CI) | RR (95% CI) |
| Maintainers (ref) | | - | - | - |
| Adopters | Serious problem (ref) | - | - | - |
| | Somewhat serious | 1.05 (0.54, 2.06) | 1.10 (0.56, 2.17) | 1.15 (0.58, 2.29) |
| | Minor problem | 1.16 (0.62, 2.18) | 1.19 (0.63, 2.25) | 1.25 (0.65, 2.37) |
| | Not a problem | 1.39 (0.74, 2.61) | 1.32 (0.70, 2.51) | 1.39 (0.73, 2.66) |
| Relapsers | Serious problem (ref) | - | - | - |
| | Somewhat serious | 0.62 (0.36, 1.07) | 0.65 (0.37, 1.14) | 0.68 (0.38, 1.21) |
| | Minor problem | 0.75 (0.45, 1.24) | 0.77 (0.46, 1.29) | 0.84 (0.50, 1.41) |
| | Not a problem | 0.77 (0.46, 1.27) | 0.73 (0.44, 1.23) | 0.84 (0.46, 1.32) |
| Insufficiently Active | Serious problem (ref) | - | - | - |
| | Somewhat serious | 1.03 (0.55, 1.90) | 1.18 (0.62, 2.21) | 1.27 (0.67, 2.42) |
| | Minor problem | 1.07 (0.60, 1.92) | 1.18 (0.65, 2.14) | 1.32 (0.72, 1.92) |
| | Not a problem | 1.40 (0.78, 2.50) | 1.36 (0.75, 2.47) | 1.52 (0.83, 2.79) |

Model 1: adjusted for study site and contextual markers of SES
Model 2: model 1 + age, sex, race/ethnicity, educational level, marital status, and occupation
Model 3: model 2 + waist circumference, LDL cholesterol, HDL cholesterol, triglycerides, hypertension, diabetes, smoking, alcohol, emphysema, asthma, arthritis, pain in the lower limbs and swelling of feet and ankles.
CI: confidence interval; RR: risk ratio; PA: physical activity

Appendix 4 – Multinomial regression model assessing the association between the perception of heavy traffic and speeding cars in the neighborhood and patterns of PA

| | | Model 1 (n = 3,058) | Model 2 (n = 3,056) | Model 3 (n = 3,030) |
|---|---|---|---|---|
| | | RR 95% CI | RR 95% CI | RR 95% CI |
| Maintainers (ref) | | - | - | - |
| Adopters | Serious problem (ref) | - | - | - |
| | Somewhat serious | 1.03 (0.63, 1.69) | 1.10 (0.66, 1.81) | 1.15 (0.69, 1.90) |
| | Minor problem | 1.11 (0.70, 1.75) | 1.15 (0.72, 1.84) | 1.19 (0.74, 1.92) |
| | Not a problem | 1.19 (0.75, 1.89) | 1.10 (0.69, 1.76) | 1.12 (0.70, 1.81) |
| Relapsers | Serious problem (ref) | - | | - |
| | Somewhat serious | 1.20 (0.75, 1.94) | 1.34 (0.82, 2.17) | 1.43 (0.87, 2.34) |
| | Minor problem | 1.20 (0.76, 1.87) | 1.31 (0.83, 2.07) | 1.40 (0.88, 2.24) |
| | Not a problem | 1.28 (0.82, 2.01) | 1.36 (0.86, 2.15) | 1.41 (0.88, 2.26) |
| Insufficiently Active | Serious problem (ref) | - | | - |
| | Somewhat serious | 1.03 (0.65, 1.63) | 1.22 (0.76, 1.95) | 1.27 (0.78, 2.06) |
| | Minor problem | 1.14 (0.74, 1.76) | 1.37 (0.88, 2.14) | 1.50 (0.95, 2.36) |
| | Not a problem | 1.03 (0.67, 1.59) | 1.08 0.69, 1.69) | 1.12 (0.71, 1.77) |

Model 1: adjusted for study site and contextual markers of SES
Model 2: model 1 + age, sex, race/ethnicity, educational level, marital status, and occupation
Model 3: model 2 + waist circumference, LDL cholesterol, HDL cholesterol, triglycerides, hypertension, diabetes, smoking, alcohol, emphysema, asthma, arthritis, pain in the lower limbs and swelling of feet and ankles.
CI: confidence interval; RR: risk ratio; PA: physical activity

Appendix 5 – Multinomial regression models assessing the association between the perception of lack of access to adequate food shopping in the neighborhood and patterns of PA

| | | Model 1 (n = 3,059) | Model 2 (n = 3,057) | Model 3 (n = 3,030) |
|---|---|---|---|---|
| | | RR 95% CI | RR 95% CI | RR 95% CI |
| Maintainers (ref) | | - | - | - |
| Adopters | Serious problem (ref) | - | - | - |
| | Somewhat serious | 0.56 (0.20, 1.63) | 0.56 (0.19, 1.64) | 0.57 (0.19, 1.67) |
| | Minor problem | 0.82 (0.33, 1.99) | 0.75 (0.30, 1.87) | 0.73 (0.29, 1.82) |
| | Not a problem | 0.89 (0.38, 2.09) | 0.77 (0.32, 1.84) | 0.76 (0.32, 1.83) |
| Relapsers | Serious problem (ref) | - | - | - |
| | Somewhat serious | 1.13 (0.39, 3.31) | 1.03 (0.35, 3.07) | 1.02 (0.34, 3.10) |
| | Minor problem | 0.91 (0.34, 2.42) | 0.88 (0.32, 2.38) | 0.89 (0.32, 2.44) |
| | Not a problem | 1.20 (0.47, 3.09) | 1.10 (0.42, 2.89) | 1.13 (0.42, 3.02) |
| Insufficiently Active | Serious problem (ref) | - | - | - |
| | Somewhat serious | 1.45 (0.55, 3.82) | 1.52 (0.56, 4.12) | 2.00 (0.70, 5.76) |
| | Minor problem | 0.85 (0.35, 2.08) | 0.87 (0.34, 2.17) | 1.06 (0.40, 2.83) |
| | Not a problem | 0.93 (0.39, 2.19) | 0.90 (0.37, 2.19) | 1.16 (0.45, 2.99) |

Model 1: adjusted for study site and contextual markers of SES
Model 2: model 1 + age, sex, race/ethnicity, educational level, marital status, and occupation
Model 3: model 2 + waist circumference, LDL cholesterol, HDL cholesterol, triglycerides, hypertension, diabetes, smoking, alcohol, emphysema, asthma, arthritis, pain in the lower limbs and swelling of feet and ankles.
CI: confidence interval; RR: risk ratio; PA: physical activity

Appendix 6 – Multinomial regression model assessing the association between the perception of the presence of trash or litter in the neighborhood and patterns of PA

| | | Model 1 (n = 3,053) | Model 2 (n = 3.051) | Model 3 (n = 3,026) |
|---|---|---|---|---|
| | | RR 95% CI | RR 95% CI | RR 95% CI |
| Maintainers (ref) | | - | - | - |
| Adopters | Serious problem (ref) | - | - | - |
| | Somewhat serious | 1.02 (0.50, 2.11) | 1.21 (0.58, 2.53) | 1.22 (0.58, 2.57) |
| | Minor problem | 1.22 (0.64, 2.34) | 1.46 (0.75, 2.84) | 1.49 (0.77, 2.89) |
| | Not a problem | 1.09 (0.57, 2.07) | 1.17 (0.61, 2.25) | 1.19 (0.62, 2.29) |
| Relapsers | Serious problem (ref) | - | - | - |
| | Somewhat serious | 0.58 (0.30, 1.12) | 0.62 (0.32, 1.22) | 0.65 (0.33, 1.28) |
| | Minor problem | 0.81 (0.46, 1.43) | 0.88 (0.49, 1.56) | 0.87 (0.49, 1.57) |
| | Not a problem | 0.85 (0.49, 1.49) | 0.87 (0.49, 1.54) | 0.88 (0.49, 1.56) |
| Insufficiently Active | Serious problem (ref) | - | - | - |
| | Somewhat serious | 1.03 (0.53, 1.99) | 1.25 (0.63, 2.48) | 1.27 (0.63, 2.53) |
| | Minor problem | 0.99 (0.54, 1.82) | 1.24 (0.67, 2.29) | 1.28 (0.69, 2.39) |
| | Not a problem | 1.16 (0.64, 2.10) | 1.27 (0.70, 2.33) | 1.33 (0.72, 2.45) |

Model 1: adjusted for study site and contextual markers of SES
Model 2: model 1 + age, sex, race/ethnicity, educational level, marital status, and occupation
Model 3: model 2 + waist circumference, LDL cholesterol, HDL cholesterol, triglycerides, hypertension, diabetes, smoking, alcohol, emphysema, asthma, arthritis, pain in the lower limbs, and swelling of feet and ankles.
CI: confidence interval; RR: risk ratio; PA: physical activity

Appendix 7 – Multinomial regression models assessing the association between perceived violence in the neighborhood and patterns of PA

| | | Model 1 (n = 3,053) | Model 2 (n = 3,051) | Model 3 (n = 3,026) |
|---|---|---|---|---|
| | | RR 95% CI | RR 95% CI | RR 95% CI |
| Maintainers (ref) | | - | - | - |
| Adopters | Serious problem (ref) | - | - | - |
| | Somewhat serious | 0.61 (0.28, 1.34) | 0.71 (0.32, 1.60) | 0.73 (0.32, 1.64) |
| | Minor problem | 0.71 (0.34, 1.46) | 0.82 (0.39, 1.72) | 0.85 (0.40, 1.80) |
| | Not a problem | 0.75 (0.37, 1.54) | 0.82 (0.39, 1.69) | 0.87 (0.42, 1.81) |
| Relapsers | Serious problem (ref) | - | - | - |
| | Somewhat serious | 0.74 (0.33, 1.62) | 0.78 (0.35, 1.73) | 0.79 (0.35, 1.78) |
| | Minor problem | 0.88 (0.42, 1.83) | 0.93 (0.44, 1.96) | 0.94 (0.44, 2.00) |
| | Not a problem | 0.76 (0.37, 1.58) | 0.78 (0.37, 1.63) | 0.81 (0.38, 1.73) |
| Insufficiently Active | Serious problem (ref) | - | - | - |
| | Somewhat serious | 1.45 (0.60, 3.51) | 1.78 (0.72, 4.37) | 1.89 (0.76, 4.72) |
| | Minor problem | 1.43 (0.62, 3.33) | 1.83 (0.77, 4.34) | 1.98 (0.83, 4.74) |
| | Not a problem | 1.42 (0.62, 3.29) | 1.71 (0.73, 4.02) | 1.89 (0.80, 4.50) |

Model 1: adjusted for study site and contextual markers of SES
Model 2: model 1 + age, sex, race/ethnicity, educational level, marital status, and occupation
Model 3: model 2 + waist circumference, LDL cholesterol, HDL cholesterol, triglycerides, hypertension, diabetes, smoking, alcohol, emphysema, asthma, arthritis, pain in the lower limbs, and swelling of feet and ankles.
CI: confidence interval; RR: risk ratio; PA: physical activity

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