HHS Public Access

Author manuscript

Meas Phys Educ Exerc Sci. Author manuscript; available in PMC 2020 January 01.

Published in final edited form as:

Meas Phys Educ Exerc Sci. 2019 ; 23(2): 135–147. doi:10.1080/1091367X.2018.1554577.

Factorial Invariance of the Abbreviated Neighborhood Environment Walkability Scale among Senior Women in the Nurses' Health Study Cohort

Heather A. Starnes[a], **Meghan H. McDonough**[b], **Jeffrey S. Wilson**[c], **Daniel K. Mroczek**[d], **Francine Laden**[e], **Philip J. Troped**[f]

[a]California Polytechnic State University, Department of Kinesiology, 1 Grand Ave, San Luis Obispo, CA 93401, hstarnes@calpoly.edu

[b]Purdue University, Department of Health and Kinesiology, 800 Stadium Ave, West Lafayette, IN 47907, mcdonough@purdue.edu

[c]Indiana University – Purdue University, Indianapolis, Department of Geography, 420 University Blvd, Indianapolis, IN 46202, jeswilso@iupui.edu

[d]Northwestern University, Department of Medical Social Sciences and Department of Psychology, 633 Clark St, Evanston, IL 60208, daniel.mroczek@northwestern.edu

[e]Harvard School of Public Health, 677 Huntington Ave, Boston, MA 02115 and Brigham and Women's Hospital Channing Laboratory, 181 Longwood Dr, Boston, MA 02115, francine.laden@channing.harvard.edu

[f]University of Massachusetts Boston, Department of Exercise and Health Sciences, 100 Morrissey Boulevard Boston, MA 02125, phil.troped@umb.edu

Abstract

The purpose of this study was to examine the factorial invariance of the Abbreviated Neighborhood Environment Walkability Scale (NEWS-A) across subgroups based on demographic, health-related, behavioral, and environmental characteristics among Nurses' Health Study participants ($N = 2{,}919$; age $M = 73.0$, $SD = 6.9$ years) living in California, Massachusetts, and Pennsylvania. A series of multi-group confirmatory factor analyses were conducted to evaluate increasingly restrictive hypotheses of factorial invariance. Factorial invariance was supported across age, walking limitations, and neighborhood walking. Only partial scalar invariance was supported across state residence and neighborhood population density. This evidence provides support for using the NEWS-A with older women of different ages, who have different degrees of walking limitations, and who engage in different amounts of neighborhood walking. Partial scalar invariance suggests that researchers should be cautious when using the NEWS-A to compare older adults living in different states and neighborhoods with different levels of population density.

Corresponding author: Heather A. Starnes, 1 Grand Avenue, San Luis Obispo, CA 93401; hstarnes@calpoly.edu, mailing phone: 1-805-756-2541.

Keywords

built environment; walkability; measurement; psychometrics

The current focus on the neighborhood built environment as a key approach to support regular physical activity such as walking is exemplified in part by the United States' Healthy People 2020 public health objectives (United States Department of Health and Human Services, n.d.) and the World Health Organization's recommendations for promoting physical activity (World Health Organization, 2010), both of which emphasize environmental strategies. Neighborhood walkability, often defined as residential-commercial land use mix, connectivity of street networks, and residential density, has been positively associated with physical activity, particularly walking, in a number of studies in adults and older adults (Hajna et al., 2015; Durand, Andalib, Dunton, Wolch, & Pentz, 2011; Van Cauwenberg et al., 2011). In their review of the built environment literature, Durand and colleagues (2011) found that 47% of studies reported associations in the expected direction between neighborhood walkability and walking, whereas 17% of studies found this for physical activity outcomes in general. There is also evidence among older adults that neighborhood walkability is positively related to walking for transport (Van Cauwenberg et al., 2011), with less consistent relationships found for leisure or recreational walking. In these studies of environmental correlates of physical activity, researchers have used both objective measures of walkability, for example with geographic information systems (GIS) data, and perceived measures based on individuals' self-reports. There has been a call though for further development and testing of both objective and perceived measures of the built environment for physical activity public health research (Brownson, Hoehner, Day, Forsyth, & Sallis, 2009).

A crucial consideration in testing for the construct validity of a measure of perceptions (e.g., a latent measure) of the built environment is determining whether the measure exhibits consistent or invariant measurement properties when applied across different groups or settings, so that valid comparisons can be made across populations, and research findings can be synthesized across studies combined in larger meta-analyses (Dimitrov, 2010). For example, invariance of a perceived neighborhood built environment scale was examined in one study among adults (age $M = 48$ years, $SD = 17$) in four locations in the southern United States (Gay, Evenson, & Smith, 2010). The measure included three underlying factors: crime/safety, neighborhood characteristics, and access to physical activity facilities. It was found to have invariant model configuration, invariant factor loadings, invariant variance-covariance matrices, and invariant errors across groups based on race/ethnicity, gender, level of total physical activity, and geographic location (i.e., urban areas [Jackson, Mississippi and Winston-Salem, North Carolina], and rural/suburban areas [Winston-Salem, North Carolina and Forsyth County, North Carolina]). However, the investigators did not examine invariance by key characteristics of the participants' neighborhoods, and did not test for scalar invariance, which is a prerequisite for comparing factor means across groups and for establishing that items are not biased (Vandenberg & Lance, 2000). Additionally, the investigators acknowledged that a limitation of the study was the use of a measure of total physical activity rather than neighborhood walking which may be more relevant for assessing perceptions of neighborhood characteristics. In another example of invariance testing, recreation researchers tested the Perceived Health Outcomes of Recreation Scale (PHORS) and found evidence of configural invariance (e.g., factorial structure) and metric invariance (e.g., factor loadings) across hikers recruited from three different major hiking trails (i.e., Appalachian Trail, Pacific Crest Trail, and First Landing State Park) (Gomez, Hill, Zhu, & Freidt, 2016). This evidence was used to suggest comparisons could be made between samples of hikers recruited on different trails in the U.S. However, a major limitation of their study was inconsistencies in how demographic data were collected across the three trails which prevented testing PHORS for invariance related to demographic factors such as gender, race, or education/income.

Tests of factorial invariance establish the equivalence of a measure's psychometric properties between groups and are a prerequisite for latent variable modeling and group comparisons on a latent variable (Dimitrov, 2010; Vandenberg & Lance, 2000). Vandenberg & Lance described methods for examining factorial invariance which involves testing several increasingly restrictive hypotheses to determine what properties of the scale are invariant across groups (2000). These increasingly restrictive hypotheses begin with testing configural invariance which is to determine whether the same hypothesized factor structure demonstrates an acceptable fit in all of the groups to be compared. This demonstrates that the basic pattern of associations between items and the latent factor are supported across groups and it establishes a baseline model for comparing subsequent models in testing invariance (Vandenberg & Lance, 2000). Then metric invariance is tested to determine whether factor loadings are equivalent between groups which establishes that associations between the latent factor and external variables can be validly examined (Vandenberg & Lance, 2000). For example, evidence of metric invariance across age would demonstrate that the NEWS-A may be used for examining built environment associations with physical activity across age groups. If metric invariance is supported, then scalar invariance may be tested, involves additionally demonstrating equality of the item intercepts (Vandenberg & Lance, 2000). This allows for comparison of factor means across groups (Vandenberg & Lance, 2000). Finally, uniqueness, the strictest form of invariance demonstrates the equivalence of item-level errors, suggesting that items are measured with equal precision across groups, and group differences are only due to differences on the latent factors (Vandenberg & Lance, 2010). Notably, strict invariance is often considered an overly restrictive constraint, and not necessary for supporting use of a measure for most research purposes (Vandenberg & Lance, 2010). If an instrument is found to have invariant measurement properties, investigators can be confident that cross-group differences in scores and associations with latent variables are not a function of differences in the interpretation or function of the measure according to group membership (Dimitrov, 2010).

There is no research examining the factorial invariance of one of the most commonly used perceived neighborhood environment scales in the United States, the Abbreviated Neighborhood Environment Walkability Scale (NEWS-A) (Brownson et al., 2009). Evidence that the NEWS-A measurement properties are equivalent across different U.S. states and areas with different built environment characteristics (e.g., varying in population density) could allow for the comparison and pooling of data across these settings. Furthermore, establishing NEWS-A invariance across populations varying in key behavioral and demographic characteristics bolsters confidence that such comparisons reflect meaningful variations in associations between study constructs, rather than fluctuations in how the measure operates across groups of participants.

The NEWS-A was developed in the United States, and has been used to measure underlying factors of neighborhood environment walkability that may be associated with walking for leisure and utilitarian purposes (Cerin, Saelens, Sallis, & Frank, 2006). Preliminary studies of the American and Australian versions of the Neighborhood Environment Walkability Scale supported its discriminant validity with evidence of significant differences between neighborhoods selected based upon objective measures of walkability (Saelens, Sallis, Black, & Chen, 2003; Leslie et al., 2005). In the first published factor analysis of the NEWS-A among adults (age $M = 44$ years, $SD = 11$) in King County, Washington, investigators confirmed the validity of a six-factor model that included access to destinations, infrastructure for walking, street connectivity, personal safety, traffic safety, and aesthetics (Cerin, Saelens, Sallis, & Frank, 2006). In addition, Cerin et al. demonstrated the construct validity of NEWS-A with six of the factors positively correlated with walking for transport and three factors positively correlated with walking for recreation (2006). In 2010 Cerin et al. reported on their adapted NEWS-A for use among Chinese older adults living in Singapore and found that this adapted instrument, NEWS-CS, had moderate test-retest reliability and factorial validity. The six subscales of NEWS-A were later cross-validated in a sample of adults (age $M = 47$ years, $SD = 11$) in Baltimore, Maryland (Cerin, Conway, Saelens, Frank, & Sallis, 2009), and in Nurses' Health Study participants (age $M = 73$ years, $SD = 7$) in California, Massachusetts, and Pennsylvania (Starnes et al., 2014). In a more recently published study of the Nurses' Health Study participants, the NEWS-A subscales were found to correlate with objective measures of the built environment, which provides evidence in support of its convergent validity (Troped et al., 2017).

The NEWS-A was found to have acceptable psychometric properties in samples of adults in several U.S. states including California, Maryland, Massachusetts, Pennsylvania, and Washington, (Cerin et al., 2006; Cerin et al., 2009; Starnes et al., 2014); but these assessments of NEWS-A did not directly compare factor models (i.e., invariance testing) across geographic regions or by other population characteristics. Given the relevance of geographic locale to research of the built environment, and given that efforts to examine associations between the built environment and physical activity are conducted in a wide variety of locations around the world (Cerin et al., 2013), it is important to determine whether the NEWS-A has the same conceptual meaning and measurement properties across groups that vary in environmental characteristics. Also, given the call for greater focus on supporting healthy "aging in place" in physical activity public health research (Yen & Anderson, 2012), testing needs to be conducted among older adults who vary in key behavioral (e.g., physical activity and sedentary behavior), and physical characteristics (e.g., physical abilities or limitations). Evidence that the NEWS-A scale can be used to assess perceptions across settings and among a heterogeneous population will support investigators' and practitioners' use of the scale to combine and compare data on perceptions of neighborhood walkability between groups.

An assessment of the factorial invariance of the NEWS-A would provide important information on the measurement properties of one of the most commonly used measures of perceived neighborhood environment. This psychometric information would inform the interpretation of findings that examine associations between the built environment and physical activity across various populations and geographic areas, which is particularly relevant when interpreting findings regarding contextually relevant constructs such as the built environment. It would also provide important background information regarding synthesizing research and the validity of group comparisons. Therefore, the purpose of this study was to test the factorial invariance of the NEWS-A to determine whether measurement properties were similar among older women of different ages, with different levels of health-related walking limitations and neighborhood walking, and who live in areas with different levels of population density and in different U.S. states.

Methods

Participants

Participants were a sub-sample of participants in the Nurses' Health Study (NHS), an ongoing prospective cohort study (NIH grant P01CA87969) started in 1976 with the enrollment of 121,700 registered nurses (Belanger, Hennekens, Rosner, & Speizer, 1978). NHS participants complete biennial questionnaires that assess several health outcomes and potential risk factors, including physical activity. In 2008, a supplemental survey was sent to 3900 NHS participants in California, Massachusetts, and Pennsylvania as part of a study to examine associations between perceived and objective built environment characteristics and physical activity and obesity (NIH 5R21CA125078-02). The survey response rate was 84% (n = 3,275). Respondents were excluded from the current analysis if any of the following conditions were met: 1) unable to walk (n = 75); 2) lived at current residence less than nine months of the year (n = 237); 3) lived at a different address during the four weeks prior to completing the supplemental survey (n = 26); 4) lived in an institutional setting (n = 6); or 5) were missing data on living situation (n = 13) or missing data on all NEWS-A subscales (n = 1). The final analytic sample was comprised of 2,919 participants.

Measures

Abbreviated Neighborhood Environment Walkability Scale (NEWS-A).— Participants completed the modified NEWS-A for seniors, which included 19 Likert-scale items from a previously published version of the NEWS-A (Cerin et al. 2006) plus an additional item previously reported in Starnes et al. (2014). Results of confirmatory factor analysis of the modified NEWS-A for seniors from almost the same sub-sample of NHS participants as in the current study supported a 6-factor structure that was the same as that found in the previous validity studies of NEWS-A (Starnes et al., 2014). In the current study the six subscales (comprised of twenty items) included: infrastructure for walking (four items), access to destinations (three items), street connectivity (three items), traffic safety (three items), personal safety (three items), and aesthetics (four items). For the purposes of this study, an additional item was added to the street connectivity subscale, which only had two items in previous studies, to increase the number of items per factor to the minimum amount of three. This new street connectivity item was developed by experts in urban planning, public health, and physical activity. As mentioned above, model fit and factor loadings for original NEWS-A items included in the current study sample were previously reported and found to be acceptable (Tables 1 and 2, Starnes et al., 2014). Associations between the six NEWS-A subscales, several objective built environment variables, and self-reported physical activity were also previously examined in NHS participants and correlations were in the expected directions (Troped et al., 2017).

Grouping variables: age, neighborhood walking, walking limitations, state of residence, and population density.—Grouping variables based on age, neighborhood walking, and walking limitations were created using responses to items in the 2008 NHS biennial questionnaire. A three-level age variable (61-64 years, 65-79 years, and 80-88 years) was created using participant age based on reported birthdate. The cutoff of 65 years was selected to correspond roughly with age of retirement. The cutoff of 80 years was selected to correspond with the approximate age of life expectancy for women. A binary neighborhood walking variable (< 2×/week, ≥ 2×/week) was created using an item that required a yes or no response to the statement "*I walk around my neighborhood twice a week or more for leisure or exercise*." This brief item was developed by NHS investigators to identify participants who walked in their neighborhood somewhat regularly. A three-level walking limitation variable was created using responses to the question "*Does your health now limit you from walking several blocks?*" Possible responses were 'a lot', 'a little', or 'not at all.' State of residence was based on home address reported in the biennial NHS survey. The objective measure of population density was created using Landscan™, a commercial spatial database (Oakridge National Laboratory, Oakridge, TN). A three-level population density variable was created by calculating the number of people per square kilometer of land in 1200m line-based street-network buffers around the geocoded home addresses (Forsyth, Van Riper, Larson, Wall, and Neumark-Sztainer, 2012). Home addresses were geocoded by Tele Atlas® which provided latitudes and longitudes for use in a geographical information system (ArcGIS®). Women were categorized as living in low (<500 people per square km), medium (500-1,499 people per square km), or high (≥1,500 people per square km) population density areas. These categories were selected to generally correspond with definitions of rural, suburban, and urban contexts.

Sample characteristics: demographics, outdoor walking, and other physical activities.—Items from the 2008 NHS biennial questionnaire were used to describe participants' race and ethnicity, education, and self-reported physical activity. Participants reported race (i.e., White, Black, Asian, American Indian/Alaska Native (AI/AN), or Native Hawaiian). Race categories were collapsed into two groups: White, and non-White. Participants reported their highest level of education (e.g., registered nursing (RN) degree only, bachelor's degree, master's degree, or doctoral degree). Because higher educational attainment is associated with higher socioeconomic status, education categories were collapsed into two groups: 1) RN degree only; and 2) bachelor's degree or higher. An RN degree only is the minimal educational attainment of the nurses in the study. A nurse with both an RN degree and a bachelor's degree or higher degree was categorized as having a bachelor's degree or higher degree. Participants reported the average time per week spent in various physical activities including swimming, strength training, walking, and more.

Activities were each assigned a metabolic equivalent value (MET) which was then multiplied by the weekly volume of activity to calculate MET-hours per week (Ainsworth, Haskell, Leon, Jacobs, Montoye, Sallis, & Paffenbarger, 1993). For the outdoor walking variable participants reported the average time per week spent walking outdoors and their usual walking pace. Walking pace responses were assigned a MET value: easy=2.5 METS, normal=3.0 METS, brisk=4.0 METS, very brisk=4.5 METS. To calculate self-reported MET-minutes per week of outdoor walking we multiplied weekly minutes of outdoor walking by its assigned MET value. In a previous study of NHS participants the Pearson correlation coefficient between MET scores derived from 7-day activity diaries and MET scores derived from the NHS questionnaire items for physical activity was r =.46 (Wolf et al., 1994).

Statistical Analysis

Patterns of missing data were examined to determine whether data were missing at random and data were screened for univariate and multivariate normality (Tabachnick & Fidell, 2007). Univariate descriptive statistics (means, frequency distributions) were used to summarize all variables. Overall sample and group characteristics were examined using chi-square (for categorical variables), and t-tests and ANOVA with Tukey post hoc comparisons in the cases of three groups. An overall confirmatory factor analysis (CFA) of a 6-factor model of the NEWS-A measure was examined for the full sample. Detailed findings from a CFA of the NEWS-A for seniors, including correlations between the factors and predictive validity with weekly outdoor walking in the current study sample of NHS participants, have been previously published (Starnes et al., 2014, Troped et al., 2017) and support the validity of this measure. In the current analysis associations between the NEWS-A subscales, neighborhood walking, and two other physical activities (e.g., strength training and swimming) were examined using Spearman correlation coefficients to account for non-normal distributions of the strength training and swimming variables and logistic regression for examining NEWS-A associations with a binary neighborhood walking variable. Slight difference in sample size between the current analysis and the previously reported one was due to additional exclusion criteria applied in the analysis of associations with walking outcomes (Troped et al., 2017). This CFA model, and all subsequent measurement models were specified with a total of 20 items (the 19 original NEWS-A items plus a third item for the street connectivity subscale) loading on one of six latent factors. The metric of each latent variable was set by specifying one item in the subscale as having a loading of one. The six factors were allowed to freely correlate in the CFA. Models were analyzed using full information maximum likelihood estimation in MPlus 6.12 for UNIX (Muthén and Muthén, 2010). Single-group CFAs were conducted to examine the baseline measurement model fit for the full sample and each subgroup separately. To determine the goodness of fit of these baseline measurement models, normed Chi-Square ($\chi^2/df < 5$), (CFI ≥ .90), Tucker-Lewis index (TLI ≥ .90), root mean square error of approximation (RMSEA ≤ .08), and standardized root mean square residual (SRMR ≤ .08) were examined (Little, 2013; Wheaton, Muthen, Alwin, & Summers, 1977).

Four increasingly strict hypotheses were tested to examine the level of invariance using Multigroup CFA procedures in MPlus 6.12 for UNIX (Dimitrov, 2010; Muthén and Muthén, 2010). The statistical test for each hypothesis was the difference between the fit of the constrained model and that of the less constrained model in the previous step, represented by Δ CFI (Dimitrov, 2010). It was hypothesized that the more constrained model would not be substantially different than the less constrained model in the previous step, therefore when comparing model fit, the CFI was expected to decrease by no more than −.01 (Cheung and Rensvold, 2002). The first hypothesis of configural invariance was tested by examining the fit of the hypothesized model in all groups within a grouping, with the same items loading on the same factors, while allowing factor loadings, item intercepts, and error terms were free to vary. Configural invariance was supported if the model fit indices were acceptable for all groups. If configural invariance was supported, then a series of multi-group CFAs were conducted to test the degree of measurement invariance. The second step involved testing metric invariance, also known as weak invariance. Metric invariance is supported if the model does not have significantly worse fit when the factor loadings are constrained to be equal across the groups. Findings of metric invariance would suggest that the associations between the items and the latent factors are the same across groups, which allows valid comparison of the associations between the latent variable and other constructs across the groups (Dimitrov, 2010). If metric invariance was demonstrated, a third, more restrictive hypothesis of scalar invariance, or strong invariance, was tested by adding an additional equality constraint of equal item intercepts across groups. Scalar invariance suggests that comparing factor means across groups is valid, and if it is not supported, it is evidence that there is item bias or differential item functioning across groups (Dimitrov, 2010). If scalar invariance was demonstrated, a fourth hypothesis of uniqueness invariance, or strict invariance, was tested by also constraining the error variances and covariances to be equivalent across groups. Uniqueness invariance suggests that items were measured with the same error across groups, suggesting that group differences on subscale scores are due to group differences on the latent construct and not the result of measurement error (Dimitrov, 2010). Uniqueness invariance is considered overly restrictive and not essential to support the validity of the measure across groups (Dimitrov, 2010). For each of the four hypothesis tests described above, if invariance was not supported (i.e., Δ CFI $< -.01$), then a less constrained model was tested by iteratively freeing constraints for the parameters that had the greatest contribution to model misfit and then re-testing for invariance. Items were manually removed based on modification indices. Partial invariance is a matter of the degree of invariance and suggests that only certain subscales or items are invariant across groups (Dimitrov, 2010).

Analysis of variance (ANOVA) techniques were used to evaluate differences in NEWS-A subscale scores across the groups for the subscales found to have at least full scalar invariance. Subscale scores were calculated using the composite mean scores. ANOVA followed by Tukey post-hoc tests, where appropriate in the case of three groups, were conducted using PROC GLM ANOVA in SAS 9.3 for UNIX.

Results

Data Screening and Sample Characteristics

Tests for normality showed no concerns that required any corrective action such as transformation or removal and there were no non-random patterns of missing data. Table 1 shows demographic, walking, and objective built environment characteristics for the entire sub-sample and by group. Participants' ages ranged from 61.5 to 88.4 years. The majority was Caucasian and there were few differences between groups in terms of race. Lower percentages of women living in California and in high population density areas were Caucasian (93% and 94%), compared to women living in the other two states (99.8% and 99.2%) and in lower population density areas (99.5% and 99.2%). Overall, the majority had an RN degree only (67%) and the percentage of participants with an RN degree only was found to be highest in the oldest sub-group of participants (73%), in those with a little or a lot of health-related walking limitations (74% and 73%), and in Pennsylvania (76%). Overall, average weekly MET-minutes of walking was 350 (SD = 541) which was less than the recommended 500 weekly MET-minutes of physical activity and varied significantly by age, frequency of neighborhood walking, walking limitations, and state. Participants in California had the highest average MET-minutes per week of walking ($M = 399$, $SD = 604$) followed by women in Massachusetts ($M = 353$, $SD = 536$) and Pennsylvania ($M = 297$, $SD = 468$). Population density ranged from less than one person to approximately 30,000 people per square kilometer and varied significantly between most groups, except between the walking limitations groups. Participants in California had an average population density of 1,916 people per square kilometer ($SD = 1{,}292$) which was significantly higher than population density for participants in Massachusetts ($M = 1{,}153$, $SD = 1{,}984$) and Pennsylvania ($M = 1{,}149$, $SD = 1{,}724$).

Invariance of NEWS-A

Table 2 shows the baseline single-group CFA for the six-factor NEWS-A model in the overall sample and for each group. Factor loadings from the CFA with the full sample are available in Appendix A. One item in the aesthetics factor had a low factor loading of .41 which met the threshold of .40 to continue with the analysis, but should be noted with appropriate caution. This item was designed to assess the presence of trees along the streets in the neighborhood. Fit indices indicated the six-factor model provided an acceptable fit overall and in each group, with the only exceptions of normed Chi-Square exceeding the threshold of 5 in the overall sample and in the three largest groups (i.e., middle-aged group, neighborhood walking less than twice a week group, no walking limitations group) and TLI being slightly lower than .90 for those with a lot of walking limitations. Table 3 shows the model fit indices and invariance testing results for each set of groups. Configural and metric invariance were supported for all grouping variables. Overall, scalar invariance was supported across age, neighborhood walking, and walking limitation groups, but not across population density groups (Δ CFI = −.05) and states (Δ CFI = −.02). Partial (13 of 20 items) scalar invariance by population density was supported when item intercepts of four items in the infrastructure for walking subscale and three items in the access to destinations subscale were allowed to vary (Δ CFI = −.01). Partial (16 of 20 items) scalar invariance by state of residence was supported when intercepts of four items in the infrastructure for walking subscale were free to vary (Δ CFI = −.01). Because full scalar invariance was not supported for state of residence and population density, strict invariance or uniqueness invariance was not tested. However, tests of uniqueness invariance did result in support for strict invariance for age, neighborhood walking, and walking limitation groups.

Group Differences in NEWS-A Subscales

Table 4 shows the means for each of the NEWS-A subscale composite scores overall and by group. The oldest age group compared to the youngest age group scored higher on perceptions of infrastructure for walking, access to destinations, and street connectivity and lower on perceptions of crime safety. There were no differences between the age groups for the aesthetics and traffic safety subscales. Frequent neighborhood walkers scored higher on all six of the NEWS-A subscales (i.e., more positive perceptions of the neighborhood environment). Those with no walking limitations compared to those with “a little” or “a lot” scored higher on access to destinations, aesthetics, traffic safety, and crime safety and lower on infrastructure for walking. Participants in low population density areas scored lower on traffic safety and street connectivity and higher on crime safety compared to those in medium and high population density areas. Participants in California scored higher on access to destinations, traffic safety, and street connectivity and lower on the crime safety subscale compared to those in Massachusetts and Pennsylvania.

Associations between NEWS-A subscales and physical activity variables

Associations between NEWS-A subscales and physical activity variables are shown in Table 5. NEWS-A subscales were moderately correlated with each other as expected. The strongest correlations were observed among the access to destinations, infrastructure, and connectivity subscales. Weaker correlations were observed among the aesthetics, crime safety, and traffic safety subscales. All of the NEWS-A subscales were positively associated with frequency of neighborhood walking (at least twice per week vs. less than twice per week). No associations were observed between NEWS-A subscales and other physical activities such as swimming and strength training.

Discussion

This study provides further support for the construct validity of the NEWS-A in a large cohort by demonstrating its factorial invariance between groups that differ in demographic, health-related, behavioral, and environmental characteristics. This analysis focused on factorial invariance, an important aspect of construct validity which demonstrates that the probability of an observed score does not depend on group membership (Dimitrov, 2010). In other words, this research supports the contention that participants from different sub-groups, but with the same underlying score on perceived neighborhood environment walkability, can be expected to have the same observed score on NEWS-A. Therefore, this study supports the use of the NEWS-A in research that aims to combine and compare participants across these groups, and is important support for researchers looking to synthesize findings across studies and populations that cross these groups.

The evidence for NEWS-A invariance supports the conclusion that differences in subscale scores reflect underlying differences in neighborhood environment perceptions. NEWS-A demonstrated strong scalar invariance and can be employed among groups who vary in age, walking limitations, and frequency of neighborhood walking. Partial scalar invariance of certain subscales across state of residence (i.e., infrastructure for walking) and across different levels of population density (e.g., infrastructure for walking and access to destinations) suggests that researchers and public health practitioners should use caution when comparing or combining these NEWS-A subscale scores for groups who have very different environmental contexts. That caution is extended to the group comparison results across population density and states for infrastructure for walking and access to destinations that were undertaken in this study, as lack of full scalar invariance suggests the group means may be biased. The lack of full scalar invariance in these subscales leads researchers to question why women in different states and areas with different levels of population density would respond differently to the items in the NEWS-A subscales. The differences in how they respond to these items may reflect differences in the relative importance or meaningfulness of the items with respect to the construct of walkability as it relates to their environmental context or location. However, the support for strong metric invariance does support comparing associations between these latent variables and other constructs across groups, which is a very common analysis in this literature examining associations between neighborhood walkability and physical activity.

Although mean group comparisons were not the focus in the current study, interesting observations of mean group differences were observed in all five sets of groups. Differences between population groups were in the expected direction, with the lower population density group overall scoring lower on street connectivity and traffic safety, and higher on safety from crime compared to the medium and high population density groups. These patterns reflect common observations of differences between rural and urban or suburban areas. Perhaps most notable were patterns in group differences between the two neighborhood walking groups (twice a week or more compared to once a week or less). Overall, the more frequent neighborhood walkers (twice a week or more) scored higher on all six NEWS-A factors compared to those who walked in their neighborhood less often. The finding that neighborhood walkers have more positive perceptions of their neighborhood environment was not surprising. However, longitudinal studies are needed to determine whether these differences are causal in nature or the result of biases, such as selection bias (e.g., frequent walkers choose to live in more walkable neighborhoods) or cognitive bias (e.g., frequent walkers are more able to readily observe and judge their neighborhood as more walkable).

The current findings of configural and metric invariance by neighborhood walking and by state were similar to findings reported in a recent study of a different, 3-factor measure of perceived neighborhood environment (Gay et al., 2010). In that study, investigators found evidence for configural and metric invariance across groups that met and did not meet physical activity recommendations and who lived in four geographic locations. Scalar invariance was not examined in that study. The current study extends the literature by providing support for the factorial invariance of another neighborhood walkability scale, the NEWS-A, that assesses a wider variety of neighborhood walkability factors. It also extends the construct validity evidence by providing support for scalar and uniqueness invariance for the aesthetics, traffic safety, crime safety, and street connectivity subscales, and partial scalar invariance for the infrastructure for walking and access to destinations factors. Furthermore, the current study examined differences in objective characteristics of participants' neighborhoods, and highlighted limitations of measurement invariance for two of the NEWS-A subscales when looking across groups that vary in objectively-measured population density and geographic state of residence, important considerations when conducting geographically diverse studies, or considering the generalizability of findings across geographic regions.

Implications

Results of this study have important implications for future research in which the NEWS-A is employed. In the design phase, researchers should consider the extent to which participants will be drawn from different geographic locations with varying levels of population density. This consideration may play a role in the selection of instruments to measure participants' perceptions of their neighborhood environments, and consideration for what kind of interpretations can be made across such groups. For example, there is growing recognition of the need for measures appropriate for use in rural areas (Yousefian et al., 2010). Furthermore, in the analysis phase, when using latent variables such as the ones in NEWS-A, researchers should test for factorial invariance in their sample before making group comparisons or combining data from different groups.

Limitations

This study has several limitations. First, the use of self-report measures of neighborhood walking behavior and walking limitations may have resulted in inaccurate classification of group membership. For example, the brief binary item to assess whether participants walked in their neighborhood at least twice per week would ideally be expanded to include frequency and duration of neighborhood walking or for greater accuracy the use of an objective measure of location-based walking using wearable GPS-enabled accelerometers. Second, the sample was entirely female, primarily White, and relatively homogenous in age and education level. These characteristics are representative of the larger Nurse's Health Study cohort from which the current study sample was drawn. Therefore, conclusions about invariance of NEWS-A do not apply to populations and groups different from those examined in this study. Culture, race, ethnicity and socioeconomic background could play a role in how individuals interpret the NEWS-A items, but would need to be tested with samples that include greater ethnic, racial, and socioeconomic diversity.

There are also limitations associated with how participants were divided by grouping variables. For example, in large states there is the potential for significant heterogeneity within that may be masked by considering all residents of one state as part of the same group. While invariance across states was supported, it is possible that sub-divisions within a state could exhibit factorial non-invariance when divided along another characteristic not tested here. As support for validity is an ongoing process of accumulating psychometric evidence, it would be prudent for future studies to further examine factorial invariance across other relevant groupings.

Conclusion

This study provided valuable information about the concept and measurement of neighborhood walkability perceptions. Few studies have examined invariance of NEWS-A, especially in older adults, and this information is important to support the validity of using these measures and interpreting results in this aging population. The overall confirmation that the NEWS-A is measuring the same concepts of the perceived neighborhood environment in older women who vary in important demographic and behavioral characteristics provides continued support for the use of this measure. Researchers should use caution though when examining group mean differences using measures of infrastructure for walking and access to destinations across large geographic areas and across neighborhood contexts that vary greatly in terms of population density. This study represents an important step in the development and testing of instruments used to measure individuals' perceptions of neighborhood environments. Future areas for research include further examination of factorial invariance of perceived built environment measures by location, gender, race and ethnicity, and socioeconomic status

Appendix

Appendix A.

Standardized factor loadings in the baseline 6-factor model using 20 items in the modified NEWS-A among NHS participants in California, Massachusetts, and Pennsylvania, 2008, *N*=2919

Factor and items	Factor loading
1. Access to destinations factor	
Stores within easy walking distance	.82
Many places within easy walking distance	.81
Easy to walk to a transit stop	.65
2. Street connectivity factor	
Short distance between intersections	.53
Many alternative routes	.61
Straight streets, not curvy*	.52
3. Infrastructure for walking factor	
Sidewalks on most streets	.91
Cars divide sidewalk and traffic	.71
Grass/dirt strip divides sidewalk and traffic	.64
Streets are well lit at night	.54
4. Aesthetics factor	
Trees along the streets	.41
Interesting things to look at	.79
Attractive natural sights, views	.86
Attractive buildings, homes	.68
5. Traffic safety factor	
Traffic makes it difficult to walk	.76

Factor and items	Factor loading
Traffic speed is usually slow	.64
Most drivers exceed the speed limit	.61
6. Personal safety factor	
High crime rate	.82
Crime makes it unsafe to walk during day	.66
Crime makes it unsafe to walk during night	.77

*Item found only in modified NEWS-A, not in original NEWS-A

References

Ainsworth BE, Haskell WL, Leon AS, Jacobs DR Jr, Montoye HJ, Sallis JF, & Paffenbarger RS Jr. (1993). Compendium of physical activities: classification of energy costs of human physical activities. Med Sci Sports Exerc, 25(1):71–80. [PubMed: 8292105]

Belanger CF, Hennekens CH, Rosner B, & Speizer FE (1978). The nurses' health study. American Journal of Nursing, 78, 1039–1040. [PubMed: 248266]

Brownson R, Hoehner C, Day K, Forsyth A, & Sallis J (2009). Measuring the built environment for physical activity: State of the science. American Journal of Preventive Medicine, 36, S99–123. doi: 10.1016/j.amepre.2009.01.005 [PubMed: 19285216]

Cerin E, Conway T, Cain K, Kerr J, De Bourdeaudhuij I, Owen N, Reis R, Sarmiento O, Hinckson E, Salvo D, Christiansen L, Macfarlane D, Davey R, Mitáš J, Aguinaga-Ontoso I, & Sallis JF (2013). Sharing good NEWS across the world: developing comparable scores across 12 countries for the Neighborhood Environment Walkability Scale (NEWS). BMC Public Health, 13, 309. doi: 10.1186/1471-2458-13-309 [PubMed: 23566032]

Cerin E, Conway T, Saelens B, Frank L, & Sallis J (2009). Cross-validation of the factorial structure of the Neighborhood Environment Walkability Scale (NEWS) and its abbreviated form (NEWS-A). International Journal of Behavioral Nutrition and Physical Activity, 6, 32. doi: 10.1186/1479-5868-6-32 [PubMed: 19508724]

Cerin E, Saelens B, Sallis J, & Frank L (2006). Neighborhood Environment Walkability Scale: Validity and development of a short form. Medicine and Science in Sports and Exercise, 38, 1682–1691. doi: 10.1249/01.mss.0000227639.83607.4d [PubMed: 16960531]

Cerin E, Sit CHP, Cheung M, Ho S, Lee LJ, & Chan W. (2010). Reliable and valid NEWS for Chinese seniors: Measuring perceived neighborhood attributes related to walking. International Journal of Behavioral Nutrition and Physical Activity, 7, 84. doi: 10.1186/1479-5868-7-84 [PubMed: 21108800]

Cheung GW, & Rensvold RB (2002). Evaluating goodness-of-fit indexes for testing measurement invariance. Structural Equation Modeling, 9, 233–255. doi: 10.1207/S15328007SEM0902_5

Dimitrov DM (2010). Testing for factorial invariance in the context of construct validation. Measurement and Evaluation in Counseling and Development, 43, 121–149. doi: 10.1177/0748175610373459

Durand CP, Andalib M, Dunton GF, Wolch J, & Pentz MA (2011). A systematic review of built environment factors related to physical activity and obesity risk: implications for smart growth urban planning. Obesity Reviews, 12, 173–182. doi: 10.1111/j.1467-789X.2010.00826.x

Forsyth A, Van Riper D, Larson N, Wall M, & Neumark-Sztainer D (2012). Creating a replicable, valid cross-platform buffering technique: The sausage network buffer for measuring food and physical activity built environments. International Journal of Health Geography, 11, 14. doi: 10.1186/1476-072X-11-14

Gay JL, Evenson KR, & Smith J (2010). Developing measures on the perceptions of the built environment for physical activity: A confirmatory analysis. International Journal of Behavioral Nutrition and Physical Activity, 7, 72. doi: 10.1186/1479-5868-7-72 [PubMed: 20929571]

Gómez E, Hill E, Zhu X, & Freidt B (2016). Perceived Outcomes of Recreation Scale (PHORS): Reliability, validity and invariance. Measurement in Physical Education and Exercise Science, 20(1), 27. doi: 10.1080/1091367X.2015.1089245

Hajna S, Ross NA, Brazeau AS, Bélisle P, Joseph L, & Dasgupta K (2015). Associations between neighbourhood walkability and daily steps in adults: A systematic review and meta-analysis. BMC Public Health, 15, 768. doi: 10.1186/s12889-015-2082-x [PubMed: 26260474]

Leslie E, Saelens B, Frank L, Owen N, Bauman A, Coffee N, & Hugo G (2005). Residents' perceptions of walkability attributes in objectively different neighbourhoods: A pilot study. Health & Place, 11(3), 227–236. doi: 10.1016/j.healthplace.2004.05.005

Little TD (2013). Longitudinal structural equation modeling. New York, NY: Guilford Press.

Muthén LK, & Muthén BO (2010). Mplus user's guide (6th ed.). Los Angeles, CA: Muthén & Muthén.

Saelens BE, Sallis JF, Black JB, & Chen D (2003). Neighborhood-based differences in physical activity: An environment scale evaluation. American Journal of Public Health, 93(9), 1552–1558. [PubMed: 12948979]

Starnes HA, McDonough MH, Tamura K, James P, Laden F, & Troped PJ (2014). Factorial validity of an abbreviated neighborhood environment walkability scale for seniors in the nurses' health study. International Journal of Behavioral Nutrition & Physical Activity, 11, 126. doi: 10.1186/s12966-014-0126-8

Tabachnick BG, & Fidell LS (2007). Using multivariate statistics (5th ed.). Boston, MA: Pearson.th

Troped PJ, Tamura K, McDonough MH, Starnes HA, James P, Ben-Joseph E, Cromley E, Puett R, Melly SJ, & Laden F (2017). Direct and indirect associations between the built environment and leisure and utilitarian walking in older women. Annals of Behavioral Medicine, 51(2), 282–291. doi: 10.1007/s12160-016-9852-2 [PubMed: 27807683]

United States Department of Health and Human Services. (n.d.). Healthy People 2020. Available at http://www.healthypeople.govAccessibility verified June 27, 2018.

Van Cauwenberg J, De Bourdeaudhuij I, De Meester F, Van Dyck D, Salmon J, Clarys P, & Deforche B (2011). Relationship between the physical environment and physical activity in older adults: A systematic review. Health & Place, 17, 458–469. doi: 10.1016/j.healthplace.2010.11.010

Vandenberg RJ, & Lance CE (2000). A review and synthesis of the measurement invariance literature: Suggestions, practices, and recommendations for organizational research. Organizational Research Methods, 3, 4–70. doi: 10.1177/109442810031002

Wheaton B, Muthen B, Alwin DF, & Summers G (1977) Assessing reliability and stability in panel models. Sociological Methodology, 8(1), 84–136.

Wolf AM, Hunter DJ, Colditz GA, Manson JE, Stampfer MJ, Corsano KA, Rosner B, Kriska A, & Willett WC (1994). Reproducibility and validity of a self-administered physical activity questionnaire. International Journal of Epidemiology, 23(5), 991–999. doi: 10.1093/ije/23.5.991 [PubMed: 7860180]

World Health Organization. (2010). Global recommendations on physical activity for health. Geneva, Switzerland Retrieved from http://www.who.int/dietphysicalactivity/publications/9789241599979/en/ December 18, 2016.

Yen I, & Anderson L, (2012), Built environment and mobility of older adults: Important policy and practice efforts. Journal of the American Geriatrics Society, 60(5), 951–956. doi: 10.1111/j.1532-5415.2012.03949.x [PubMed: 22568533]

Yousefian A, Hennessy E, Umstattd MR, Economos CD, Hallam JS, & Hyatt RR (2010). Development of the rural active living assessment tools: Measuring rural environments. Preventive Medicine, 50(S1), S86–S92. doi: 10.1016/j.ypmed.2009.08.018 [PubMed: 19818362]

Table 1

Demographic, Walking, and Objective Built Environment Characteristics of Sample, Overall and by Subgroups

	Age yrs *M* (*SD*)	White % (*N*)	RN Degree Only % (*N*)	Walking *M* (*SD*)	Population Density *M* (*SD*)
Overall *N*=2919	73.0 (6.9)	2841 (97.3%)	1845 (66.9%)	350.1 (541.3)	1411.1 (1726.0)
Age					
Younger (61-64 years) *n*=377	63.4^{a} (1.1)	375 (99.5%)	239^{a} (66.6%)	368.9^{a} (544.3)	1153.1^{a} (1288.6)
Middle (65-79 years) *n*=1963	71.9^{b} (4.3)	1904 (97.0%)	1204^{a} (65.2%)	388.7^{a} (557.9)	1378.3^{a} (1756.8)
Older (80-88 years) *n*=579	83.2^{c} (2.0)	562 (97.1%)	402^{b} (72.6%)	204.9^{b} (449.7)	1690.6^{b}(1832.3)
Neighborhood walking					
≥2×/week *n*=1378	72.4^{a} (6.6)	1346^{a} (97.7%)	816^{a} (62.9%)	566.4^{a} (622.3)	1516.4^{a} (1920.6)
< 2×/week *n*=1524	73.5^{b} (7.0)	1479^{a} (97.1%)	1019^{b} (70.5%)	154.8^{b} (357.7)	1319.0^{b} (1530.8)
Health-related walking limitation					
Yes, a lot *n*=439	76.9^{a} (6.7)	429^{a} (97.7%)	299^{a} (72.6%)	39.3^{a} (150.7)	1521.4^{a} (1401.5)
Yes, a little *n*=609	75.4^{b} (6.7)	593^{a} (97.4%)	423^{a} (74.2%)	124.4^{b} (306.7)	1378.7^{a} (1375.5)
No, not at all *n*=1833	71.2^{c} (6.3)	1781^{a} (97.2%)	1093^{b} (62.7%)	500.7^{c} (601.7)	1403.2^{a} (1903.9)
Population density					
Low *n*=817	71.7^{a} (6.6)	813^{a} (99.5%)	546^{a} (70.3%)	338.3^{a} (532.0)	215.3^{a} (142.8)
Medium *n*=1037	72.6^{b} (6.8)	1029^{a} (99.2%)	674^{a} (69.0%)	368.2^{a} (544.0)	948.5^{b} (278.9)
High *n*=1065	74.3^{c} (6.9)	999^{b} (93.8%)	625^{b} (62.1%)	341.4^{a} (545.7)	2778.9^{c} (2213.4)
State					
California *n*=993	75.6^{a} (6.5)	925^{a} (93.1%)	533^{a} (56.5%)	399.0^{a} (604.0)	1916.2^{a} (1292.4)
Massachusetts *n*=968	71.8^{b}(6.6)	966^{b} (99.8%)	627^{b} (68.3%)	$352.7^{a,b}$ (536.1)	1152.7^{b} (1983.9)
Pennsylvania *n*=958	71.6^{b} (6.7)	950^{b} (99.2%)	685^{b} (76.3%)	296.7^{b} (468.1)	1148.7^{b} (1724.4)

Note:

[(a,b,c)] Letters indicate statistically significant differences between groups based on χ^2, *t*-value, or *f*-value with Tukey post hoc comparisons (in the case of three groups). Walking was defined as MET-minutes of walking per week based on self-reported walking pace and weekly volume. Population density was defined as number of people/km^2 of area in 1200-m residential network buffer.

Table 2

Baseline Model Fit Indices for 6-factor NEWS-A Measurement Model, Overall and by Subgroup

Group	*N*	CFI (≥.90)	TLI (≥.90)	RMSEA (≤.08)	SRMR (≤.08)	χ^2/df (<5)
Overall	2919	.93	.92	.05	.05	9.14
Age group						
Younger (61-64 years)	377	.94	.93	.05	.05	1.99
Middle (65-79 years)	1963	.93	.91	.06	.05	7.03
Older (80-88 years)	579	.93	.91	.05	.06	2.69
Neighborhood walking group						
≥ 2×/week	1378	.93	.92	.05	.05	4.62
< 2×/week	1524	.93	.92	.05	.05	5.44
Walking limitation group						
Yes, a lot	439	.91	.88	.07	.06	2.83
Yes, a little	609	.92	.90	.06	.06	2.84
No, not at all	1833	.94	.93	.05	.05	5.76
Population density group						
Low (<500 people/km^2)	817	.95	.93	.04	.05	2.61
Medium (500-1499 people/km^2)	1037	.95	.93	.04	.04	2.86
High (≥1500 people/km^2)	1065	.92	.91	.05	.06	3.78
State						
California	993	.92	.91	.05	.06	3.88
Massachusetts	968	.92	.91	.06	.05	3.94
Pennsylvania	958	.93	.91	.06	.06	4.61

Note: CFI = Comparative Fit Index, TLI = Tucker-Lewis Index, RMSEA = Root Mean Square Error of Approximation, SRMR = Standardized Root Mean Square Residual. Thresholds are presented in parentheses

Table 3

Invariance by Age, Neighborhood Walking, Walking Limitations, Population Density, and State

	CFI	Δ CFI	TLI	RMSEA	SRMR	Invariant
Age groups						
Configural invariance	.93		.91	.06	.05	Yes
Metric invariance	.93	.00	.92	.05	.06	Yes
Scalar invariance	.93	.00	.92	.05	.06	Yes
Residual invariance	.92	−.01	.92	.05	.06	Yes
Neighborhood walking groups						
Configural invariance	.93		.92	.05	.05	Yes
Metric invariance	.93	.00	.92	.05	.06	Yes
Scalar invariance	.93	.00	.92	.05	.06	Yes
Residual invariance	.92	−.01	.92	.05	.07	Yes
Walking limitation groups						
Configural invariance	.93		.92	.05	.05	Yes
Metric invariance	.93	.00	.92	.05	.06	Yes
Scalar invariance	.93	.00	.92	.05	.06	Yes
Residual invariance	.92	−.01	.92	.05	.06	Yes
Population density groups						
Configural invariance	.94		.92	.05	.05	Yes
Metric invariance	.93	−.01	.92	.05	.06	Yes
Scalar invariance	.88	−.05	.87	.06	.07	No
Partial scalar invariance[a]	.92	−.01	.91	.05	.06	Partial
State groups						
Configural invariance	.92		.91	.06	.06	Yes
Metric invariance	.92	.00	.91	.06	.06	Yes
Scalar invariance	.90	−.02	.89	.06	.07	No
Partial scalar invariance[b]	.91	−.01	.90	.06	.07	Partial

Note: Δ CFI = difference in Comparative Fit Index between less constrained and more constrained model in previous step (threshold ≥ −.01), CFI = Comparative Fit Index (threshold ≥ .90), TLI = Tucker-Lewis Index (threshold ≥.90), RMSEA = Root Mean Square Error of Approximation (≤.08), SRMR = Standardized Root Mean Square Residual (≤0.08).

[a]Intercepts for four items in the Infrastructure for Walking subscale and three items in the Access to Destinations subscale allowed to vary across population density groups.

[b]Intercepts for four items in the Infrastructure for Walking subscale allowed to vary across states. Because of a lack of full scalar invariance, residual invariance was not tested across state of residence or population density.

Table 4

Means (SD) for NEWS-A Subscales, Overall and by Subgroup

	Infrastructure for Walking	Access to Destinations	Aesthetics	Traffic Safety	Crime Safety	Street Connectivity
Overall	2.36 (0.97)	2.06 (0.97)	3.28 (0.63)	2.83 (0.77)	3.64 (0.55)	2.68 (0.82)
Age groups						
Younger (61-64 years)	2.18 (0.95)^{a}	1.95 (0.93)^{a}	3.28 (0.62)^{a}	2.80 (0.77)^{a}	3.71 (0.51)^{a}	2.54 (0.85)^{a}
Middle (65-79 years)	2.36 (0.97)^{b}	2.04 (0.96)^{a}	3.29 (0.61)^{a}	2.84 (0.77)^{a}	3.66 (0.54)^{a}	2.68 (0.81)^{b}
Older (80-88 years)	2.50 (0.98)^{c}	2.21 (0.99)^{b}	3.25 (0.67)^{a}	2.84 (0.78)^{a}	3.56 (0.58)^{b}	2.78 (0.80)^{b}
Neighborhood walking groups						
< 2×/week	2.26 (0.98)^{a}	1.88 (0.89)^{a}	3.16 (0.65)^{a}	2.71 (0.81)^{a}	3.61 (0.59)^{a}	2.59 (0.83)^{a}
≥ 2×/week	2.48 (0.96)^{b}	2.27 (1.00)^{b}	3.40 (0.57)^{b}	2.96 (0.70)^{b}	3.68 (0.50)^{b}	2.79 (0.79)^{b}
Walking limitations groups						
Yes, a lot	2.45 (0.96)^{a}	1.94 (0.93)^{a}	3.15 (0.67)^{a}	2.76 (0.78)^{a}	3.56 (0.61)^{a}	2.72 (0.82)^{a}
Yes, a little	2.43 (0.97)^{a,b}	2.01 (0.90)^{a,b}	3.22 (0.63)^{a}	2.78 (0.78)^{a}	3.61 (0.55)^{a}	2.70 (0.83)^{a}
No, not at all	2.32 (0.98)^{b}	2.11 (0.99)^{b}	3.33 (0.60)^{b}	2.87 (0.77)^{a,b}	3.68 (0.52)^{b}	2.67 (0.81)^{a}
Population density groups						
Low (< 499 people/km^2)	1.64 (0.79)	1.41 (0.64)	3.31 (0.63)^{a}	2.69 (0.87)^{a}	3.81 (0.40)^{a}	2.18 (0.80)^{a}
Medium (500-1499 people/km^2)	2.32 (0.89)	1.98 (0.87)	3.26 (0.63)^{a}	2.87 (0.77)^{b}	3.72 (0.44)^{b}	2.70 (0.72)^{b}
High (≥1500 people/km^2)	2.96 (0.76)	2.64 (0.91)	3.27 (0.62)^{a}	2.89 (0.68)^{b}	3.45 (0.66)^{c}	3.05 (0.71)^{c}
States						
California	2.64 (0.95)	2.36 (0.97)^{a}	3.37 (0.59)^{a}	2.98 (0.71)^{a}	3.57 (0.57)^{a}	2.80 (0.78)^{a}
Massachusetts	2.23 (0.87)	1.99 (0.95)^{b}	3.32 (0.61)^{a}	2.74 (0.77)^{b}	3.72 (0.49)^{b}	2.58 (0.80)^{b}
Pennsylvania	2.21 (1.03)	1.83 (0.90)^{c}	3.15 (0.66)^{b}	2.77 (0.81)^{b}	3.65 (0.57)^{c}	2.67 (0.85)^{b}

Note: NEWS-A subscales are scored on a continuous scale, ranging 1-4. Higher scores reflect more favorable walking perceptions.

(a,b,c) Different letters indicate statistical differences between groups based on *t*-value or *f*-value with Tukey post hoc comparisons (in the case of three groups). The percentage of missing data for the subscales ranged from 0% to 0.5%. Because of lack of scalar invariance, comparisons were not made between states and population density groups on the Infrastructure for Walking subscale, nor were comparisons made between population density groups on the Access to Destinations subscale.

Table 5

Associations between NEWS-A subscales, neighborhood walking, and other physical activity variables

	Access to Destinations	Infrastructure	Street Connectivity	Aesthetics	Crime Safety	Traffic Safety
Access to Destinations	1					
Infrastructure	.50 (p<.0001) *N*=2913	1				
Street Connectivity	.45 (p<.0001) *N*=2899	.49 (p<.0001) *N*=2903	1			
Aesthetics	.12 (p<.0001) *N*=2905	.08 (p<.0001) *N*=2907	.05 (p=.0033) *N*=2898	1		
Crime Safety	−.19 (p<.0001) *N*=2904	−.19 (p<.0001) *N*=2905	−.14 (p<.0001) *N*=2893	.21 (p<.0001) *N*=2902	1	
Traffic Safety	.12 (p<.0001) *N*=2905	.18 (p<.0001) *N*=2907	.19 (p<.0001) *N*=2897	.26 (p<.0001) *N*=2906	.28 (p<.0001) *N*=2902	1
Strength training (MET-hrs/wk)	.00 (p=.9285) *N*=2897	−.03 (p=.1519) *N*=2899	−.01 (p=.5751) *N*=2887	.07 (p<.0001) *N*=2892	.03 (p=.1291) *N*=2890	.02 (p=.1796) *N*=2892
Swimming (MET-hrs/wk)	.04 (p=.045) *N*=2897	−.00 (p=.9789) *N*=2899	−.02 (p=.2904) *N*=2887	.08 (p<.0001) *N*=2892	.02 (p=.3070) *N*=2890	.02 (p=.3928) *N*=2892
Neighborhood walking (twice a week or more)	1.52 (1.41,1.65) *N*=2898	1.27 (1.18, 1.37) *N*=2900	1.34 (1.22, 1.47) *N*=2887	1.91 (1.68, 2.16) *N*=2893	1.27 (1.11, 1.45) *N*=2890	1.53 (1.39, 1.69) *N*=2892

Note: Spearman correlation coefficients presented for continuous variables with non-normal distributions. Odds ratio and (95% CI) presented for binary outcome variable of neighborhood walking at least twice a week vs. fewer times per week.