Walk Score and objectively measured physical activity within a national cohort

Erica Twardzik, Suzanette Judd, Aleena Bennett, Steven Hooker, Virginia Howard, Brent Hutto, Philippa Clarke, Natalie Colabianchi

ABSTRACT

Background There have been mixed findings regarding the relationship between walkability and level of physical activity in adults. Methods Participants from The REasons for Geographic and Racial Differences in Stroke (REGARDS) national cohort (N=7561) were used to examine the association between Walk Score and physical activity measured via accelerometry. The subsample included geographically diverse adults, who identified as black or white, and were over the age of 45. Linear regression was used to examine the direct effects, as well as the interaction, of Walk Score by sex, age and race. Results The majority of participants lived in a ‘Very Car-Dependent’ location (N=4115). Only 527 lived in a location that was ‘Very Walkable/Walker’s Paradise’. Living in a location with a Walk Score of ‘Very Car-Dependent’ compared with ‘Very Walkable/Walker’s Paradise’ was associated with 19% (0.81; 95% CI 0.73 to 0.90) lower predicted minutes of moderate to vigorous physical activity per day, after adjustment for covariates. There was no evidence of statistically significant interactions between Walk Score and sex, age or race (p>0.05). Conclusion Accumulated daily time in moderate to vigorous physical activity was higher for residents living in neighbourhoods designated as ‘Very Walkable/Walker’s Paradise’. This effect was not moderated by sex, age or race of participants.

INTRODUCTION

There is a large body of work examining aspects of the built environment in relation to physical activity (PA) behaviour, in particular the walkability of a neighbourhood. The walkability of a neighbourhood is often characterised by distance to amenities, length and connectivity of streets, and availability of green space within a community. Previous work has used geographical information systems (GIS) to create a walkability index surrounding a specific address. Among these, the majority have found positive associations between GIS-derived walkability of a neighbourhood and objectively measured PA. However, GIS-derived scores are created using many different algorithms, making comparisons across studies challenging. Walk Score is one measure of walkability that is a publicly available tool. Walk Score was developed by professionals in urban planning and measures pedestrian friendliness through the use of multiple data sources (eg, Google). The 2018 measure of Walk Score uses hundreds of walking routes to nearby amenities from a particular address. This measure has consistently been found to be a valid assessment of neighbourhood walkability when compared with the gold standard of other research-based walkability indices. Two studies have previously examined Walk Score of a neighbourhood and its association with objectively measured PA and found inconsistent results. One study reported a positive association between Walk Score and objectively measured PA while the other reported a null result. A potential reason for this disagreement may be the demographics of the populations studied, and limitations in geographical and socioeconomic variability. Inconsistent findings of the association between Walk Score and PA may be best explained by allowing for interactions between Walk Score and demographic characteristics in order to capture potential differential associations across groups.

Few studies capture objectively measured PA and objective built environment measures in large samples with significant demographic variability to investigate these moderating effects. This has limited the opportunity to observe associations between Walk Score and PA within different demographic groups. Demographic factors have been shown to influence the association between environmental characteristics and PA behaviour. Therefore, it is important to allow for differential relationships between built environments and PA among participants with varying age, sex and race. This paper examines the heterogeneity of effects that Walk Score has on PA behaviour using a racially diverse sample over multiple ages. It is hypothesised that higher Walk Scores are associated with greater PA. Furthermore, among individuals self-identifying as black, women and those under the age of 65, the association between Walk Score and PA would be of greater magnitude than among whites, men and those over the age of 65.2,4,11

METHODS

Study population Participants were drawn from the REasons for Geographic and Racial Differences in Stroke (REGARDS) cohort. REGARDS is a prospective closed cohort study investigating the risk factors associated with incident stroke. Potential participants were randomly selected from a commercially available national list; black participants and those living in the stroke belt (states of AL, AR, GA, LA, MS, NC, SC and TN) were oversampled due to their higher stroke mortality. Participants...
### Table 1  Participant characteristics, REasons for Geographic and Racial Differences in Stroke, M (SD) or N (%)

<table>
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<tr>
<th></th>
<th>Overall (n=7561)</th>
<th>Very Car-Dependent (n=4115)</th>
<th>Car-Dependent (n=1892)</th>
<th>Somewhat Walkable (n=1027)</th>
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<td>Obese</td>
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<td>Moderate to vigorous physical activity (min/day)‡</td>
<td>13.6 (17.9)</td>
<td>14.2 (17.8)</td>
<td>12.4 (17.3)</td>
<td>12.2 (17.4)</td>
<td>15.7 (21.3)</td>
<td>&lt;0.0001</td>
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<tr>
<td>Total physical activity (min/day)$</td>
<td>204.1 (85.6)</td>
<td>212.7 (85.2)</td>
<td>198.0 (87.6)</td>
<td>188.8 (84.5)</td>
<td>188.2 (89.6)</td>
<td>&lt;0.0001</td>
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*P value from χ² test for categorical variables and a one-way ANOVA for continuous variables.
†Normal weight: 18.5–24.9 kg/m²; overweight: 25.0–29.9 kg/m²; obese: >30.0 kg/m².
‡All accumulated activity counts greater than 1065 cpm.
§All accumulated activity counts greater than 50 cpm.
SES, socioeconomic status.
were recruited from the commercially available national list via mass mailing between January 2003 and October 2007 and are being followed by telephone every 6 months for incident medical events. Participants in the study met the following inclusion criteria: over the age of 45 years, self-identified as black or white, no recent history of a cancer diagnosis that required chemotherapy, English speaker and not on a waiting list to enter a nursing home.22

After verbal consent, study participants completed a computer-assisted telephone interview where demographic and medical information was obtained. Three to 4 weeks after the telephone interview, health professionals from the Examination Management Services, Inc. completed an in-home physical examination with study participants.22 23 A total of 30 239 participants completed the initial interview and home visit.22 The final sample comprised 56% from stroke belt, 42% black and 55% women.22 Written informed consent was obtained at the in-home visit and the study was approved by all participating Institutional Review Boards.

From May 2009 to January 2013, screening and enrollment for an ancillary REGARDS study collecting accelerometer data was undertaken. Participants were eligible for the ancillary study if they were enrolled in REGARDS and answered ‘yes’ to the question “on a typical day, are you physically able to go outside where you live and walk, whether or not you actually do?” Eligible participants (N=20 076) were invited to participate, of whom 12 146 (60.5%) consented and enrolled in the accelerometer study. Among the 8096 participants, 43.97% were over the age of 65, 31.61% were black and 54.17% were women.22 Additional details on study design, sampling strategy, recruitment and study procedures have been previously described.22 23 25

### Physical activity

Objective measures of PA were captured using the Actical accelerometer. Participants were asked to place the accelerometer over their right hip and complete a daily wear log indicating when the device was taken off for water activities or sleep. All Actical devices were staff initialised to collect data in 60 s epochs. Participants were classified as having usable accelerometer data if (1) device was worn for >10 hours per day on at least 4 days of the week, (2) legible dates and times were available from the daily wear logs, and (3) self-reported wear dates corresponded with valid Actical data. Activity cut-points of 1065 cpm and 50
Demographic characteristics

Age, race, sex, marital status, annual household income, education level and self-rated health were classified according to self-report. Neighbourhood socioeconomic status (nSES) and urbanicity were calculated at the census tract for the 2000 US Census. A summary of nSES was created using six items representing wealth/income, education and occupation. Urban group is defined as the size of census tract where the participant lived, where rural is defined as ≤25% urban, mixed is defined as 25%–75% urban, and urban is ≥75% urban. The region in which a participant lived was dichotomised as within the stroke belt region or not. Lastly, BMI was calculated from height and weight measured during the in-home examination.

Statistical analysis

All participants included in the current study analysis needed to have usable accelerometer data, a calculated Walk Score, not suffered a stroke prior to accelerometer data collection and all demographic variables of interest. Differences in demographic characteristics and MVPA or total PA across the four Walk Score groups were examined using ANOVA \( \chi^2 \) tests. Mean MVPA had a right skewed distribution; therefore, MVPA was log transformed for use in regression models. Linear regression models were used to estimate the association between Walk Score and log-transformed mean MVPA and mean total PA while adjusting for demographic characteristics. All models were adjusted for age (centred at age 65), sex, nSES, race, region, education, income, marital status, self-rated health, urbanicity and BMI. Separate linear regression models were used to investigate the interaction effects of categorical age (<65 years, ≥65 years), sex and race on the association between Walk Score and log-transformed MVPA or mean total PA. Statistical significance was assessed with a two-tailed alpha of \( p \) value < 0.05, and all analyses were conducted using SAS V.9.4 (SAS Institute, Cary, North Carolina, USA).

RESULTS

Of the 8096 participants with usable accelerometer data, 131 were missing covariates of interest, 399 had a stroke prior to obtaining accelerometer data and 5 were missing Walk Score information. This resulted in a total of 7561 participants eligible for the current study.

Age of participants ranged from 45 to 94 years, with a mean of 63.4 years. As shown in Table 1, more than half (54.6%) of the sample were women, with the proportion of women increasing as the neighbourhood became more walkable. Approximately one-third (31.5%) of the sample was black, and with increasing...
The overall objective of this study was to examine the association between composite neighbourhood walkability and objectively measured PA in a diverse sample. This study showed that accumulated daily MVPA was greatest for participants living in ‘Very Walkable/Walker’s Paradise’, compared with ‘Very Car-Dependent’ neighbourhoods, independent of covariates. Living in a neighbourhood with a Walk Score of ‘Very Car-Dependent’ was associated with 20% lower (0.80; 95% CI 0.73 to 0.89) for those living in ‘Somewhat Walkable’ neighbourhoods compared with ‘Very Walkable/Walker’s Paradise’ neighbourhoods, independent of covariates. Living in a neighbourhood with a Walk Score of ‘Car-Dependent’ and ‘Very Car-Dependent’ neighbourhoods in comparison with those living in ‘Very Walkable/Walker’s Paradise’, adjusted for all other covariates (table 2). Using the beta coefficient for each Walk Score category, the percentage change in accumulated daily time in MVPA was calculated by raising each coefficient to a power of $e^{-2.72}$. Accumulated daily time in MVPA was predicted to be 20% lower (0.80; 95% CI 0.72 to 0.89) for those living in ‘Somewhat Walkable’, ‘Car-Dependent’ and ‘Very Car-Dependent’ neighbourhoods in comparison with those living in ‘Very Walkable/Walker’s Paradise’, adjusted for all other covariates (table 2). Daily minutes of total PA was predicted to be on average 7.84 minutes less for those living in ‘Very Car-Dependent’ neighbourhoods compared with ‘Very Walkable/Walker’s Paradise’ neighbourhoods, independent of covariates. Living in a neighbourhood with a Walk Score of ‘Car-Dependent’ and ‘Very Car-Dependent’ was not significantly associated with average daily minutes of total PA.

As shown in table 5, there was no evidence of statistical interactions between Walk Score and sex, age or race.

### DISCUSSION

The overall objective of this study was to examine the association between composite neighbourhood walkability and objectively measured PA in a diverse sample. This study showed that accumulated daily MVPA was greatest for participants living in ‘Very Walkable/Walker’s Paradise’, compared with ‘Very Car-Dependent’ neighbourhoods. The relationship between neighbourhood walkability and accumulated daily MVPA remained after further adjustment for demographic characteristics, nSES and urbanicity. However, there was no evidence of a differential relationship between Walk Score and MVPA between men and women, blacks and whites, or those older or younger than 65 years of age, as was hypothesised. Conversely, when examining the association between Walk Score and total PA, there appears to be an inverse association, where decreased walkability is associated with an increase in mean total PA. This may be because total PA captures movement occurring

### Table 4

| **Table 4** Multiple linear regression analysis examining the relationship between Walk Score and total physical activity (light physical activity, moderate physical activity and vigorous physical activity) adjusted for demographic and area-level characteristics |
|-----------------|-----------------|-----------------|
| *B (SE)* | *P value* |
| Intercept | 230.77 (4.32) | <0.0001 |
| Walk Score |  |  |
| Very Walkable/Walker’s Paradise | 0 | – |
| Somewhat Walkable | −0.79 (4.01) | 0.843 |
| Car-Dependent | 6.09 (3.76) | 0.1051 |
| Very Car-Dependent | 7.84 (3.79) | 0.0385 |
| Age (years)* | −4.52 (0.11) | <0.0001 |
| Sex |  |  |
| Male | 0 | – |
| Female | −6.07 (1.85) | 0.0011 |
| Neighbourhood SES |  |  |
| High neighbourhood SES | 0 | – |
| Mid neighbourhood SES | −4.55 (2.23) | 0.0409 |
| Low neighbourhood SES | −3.86 (2.53) | 0.126 |
| Race |  |  |
| White | 0 | – |
| Black | −5.42 (2.16) | 0.012 |
| Region |  |  |
| Non-Belt | 0 | – |
| Belt | 0.09 (1.92) | 0.9644 |
| Education |  |  |
| College graduate and above | 0 | – |
| Some college | 2.99 (2.18) | 0.1703 |
| High school graduate | 7.63 (2.42) | 0.0016 |
| Less than high school | 5.2 (4.04) | 0.1983 |
| Income |  |  |
| US$75k and above | 0 | – |
| US$35k–US$74k | −1.1 (2.43) | 0.6504 |
| US$20k–US$34k | −6.65 (2.95) | 0.0241 |
| Less than US$20k | −23.16 (3.86) | <0.0001 |
| Refused | −4.88 (3.45) | 0.1577 |
| Marital status |  |  |
| Married | 0 | – |
| Single | −5.49 (4.28) | 0.199 |
| Divorced | −8.82 (2.79) | 0.0016 |
| Widowed | −6.54 (2.82) | 0.0203 |
| Other | 4.26 (6.79) | 0.53 |
| Self-rated health |  |  |
| Excellent | 0 | – |
| Very good | −11.39 (2.31) | <0.0001 |
| Good | −23.69 (2.47) | <0.0001 |
| Fair | −33.13 (3.65) | <0.0001 |
| Poor | −54.11 (7.98) | <0.0001 |
| Urban group |  |  |
| Urban | 0 | – |
| Mixed | 10.2 (2.78) | 0.0002 |
| Rural | 10.92 (2.8) | <0.0001 |
| Body mass index† |  |  |
| Normal | 0 | – |

### Table 4 Continued

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<th><em>B (SE)</em></th>
<th><em>P value</em></th>
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<tr>
<td>Overweight</td>
<td>−10.45 (2.17)</td>
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<td>Obese</td>
<td>−33.22 (2.33)</td>
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*Age centred at age 65 years.
†Normal weight: 18.5–24.9 kg/m²; overweight: 25.0–29.9 kg/m²; obese: >30.0 kg/m². SES, socioeconomic status.
throughout the day which is more likely to be indoors (eg, light housework, occupational activities) and therefore may not be influenced by the built environment.

This study's findings are inconsistent with previous research finding no direct association between neighbourhood walkability and individual walking behaviour. This may, in part, be due to the heterogeneity found no association between Walk Score and daily steps among Canadian adults. This study's findings are inconsistent with previous research reporting walking behaviour over the past 12 months, whereas in Brawn et al, participants self-reported walking. Disagreement may be due to the differences in measurement of walking behaviour. Within Richardson et al, participants were recruited from a single US city, where participants predominately self-identified as black (92%) and were less than 65 years of age (68%).

Disagreement may be due to the differences in measurement of walking behaviour. Within Richardson et al, participants were recruited from a single US city, where participants predominately self-identified as black (92%) and were less than 65 years of age (68%). Van Dyck et al used a measure that collected built environment perceptions from participants. Perceptions of built environments likely influence by the built environment.

There are many strengths to our study. This study used accelerometer data from a diverse sample of individuals across the continental USA, and participants within this sample had great variability in terms of socioeconomic status, urban and rural environment, age and sex. Therefore, this study was well suited to examine differential relationships between the built environment and PA among demographic groups. Other major strengths include a large sample size, the use of software that is publicly available.

Despite the disagreement discussed above, several studies have found a positive association between walkability and PA behaviour. Among these studies, a number have found evidence of a positive association between walkability of a neighbourhood and accumulated MVPA. In addition, our findings are in agreement with research using self-reported PA levels. Notably, our findings echo those from the Multi-Ethnic Study of Atherosclerosis (MESA), which used self-report measures of PA. Using data from six cities across the USA, of different race-ethnic groups (41.1% white, 11.6% non-Hispanic Chinese, 26.3% non-Hispanic black, 21.0% Hispanic), the results suggested that a higher Walk Score was associated with lower odds of not walking for transport and with more minutes per week of transport walking among study participants. The current study complements the MESA investigation, with REGARDS having greater variation in participants' geographical location and capturing objectively measured PA levels through accelerometry. Lastly, our findings are in agreement with results from a longitudinal study examining the association between Walk Score and utilitarian walking. Wasi et al found that moderate utilitarian walking increased over the study period and was moderated by neighbourhood walkability, where those living in more walkable neighbourhoods had larger increases in moderate utilitarian walking. This study, along with previous research, provides convincing evidence that the walkability of a neighbourhood is positively associated with PA behaviour.

Research report

Table 5  Multiple linear regression analysis examining the interaction between Walk Score and gender, Walk Score and age, Walk Score and race, and their effect on total physical activity (light physical activity, moderate physical activity and vigorous physical activity) adjusted for demographic and area-level characteristics

<table>
<thead>
<tr>
<th>Model 1*</th>
<th>Model 2*</th>
<th>Model 3*</th>
<th>Model 4*</th>
</tr>
</thead>
<tbody>
<tr>
<td>B (SE)</td>
<td>P value</td>
<td>B (SE)</td>
<td>P value</td>
</tr>
<tr>
<td>Walk Score</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Very Walkable/Walker's Paradise</td>
<td>Ref</td>
<td>–</td>
<td>Ref</td>
</tr>
<tr>
<td>Somewhat Walkable</td>
<td>3.74 (3.82)</td>
<td>0.3267</td>
<td>0.13 (6.06)</td>
</tr>
<tr>
<td>Car-Dependent</td>
<td>10.98 (3.58)</td>
<td>0.0022</td>
<td>6.64 (5.54)</td>
</tr>
<tr>
<td>Very Car-Dependent</td>
<td>13.14 (3.61)</td>
<td>0.0003</td>
<td>11.51 (5.39)</td>
</tr>
<tr>
<td>Female</td>
<td>2.97 (1.76)</td>
<td>0.0911</td>
<td>−0.85 (6.35)</td>
</tr>
<tr>
<td>Age 65+ years</td>
<td>−49.8 (1.76)</td>
<td>&lt;0.0001</td>
<td>−50.9 (1.76)</td>
</tr>
<tr>
<td>Black</td>
<td>−2.3 (2.05)</td>
<td>0.2621</td>
<td>−1.72 (2.05)</td>
</tr>
<tr>
<td>Female×Somewhat Walkable</td>
<td>–</td>
<td>–</td>
<td>7.04 (7.72)</td>
</tr>
<tr>
<td>Female×Car-Dependent</td>
<td>–</td>
<td>–</td>
<td>7.71 (7.09)</td>
</tr>
<tr>
<td>Female×Very Car-Dependent</td>
<td>–</td>
<td>–</td>
<td>2.72 (6.69)</td>
</tr>
<tr>
<td>Age 65+ years×Somewhat Walkable</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Age 65+ years×Car-Dependent</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Age 65+ years×Very Car-Dependent</td>
<td>–</td>
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<td>Black×Somewhat Walkable</td>
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<tr>
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<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Black×Very Car-Dependent</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>

*Models adjusted for neighbourhood socioeconomic status, race, region, education, income, relationship status, self-rated health, urban group and body mass index.
This study was 15 hours. There may be other important unmeasured variables, such as neighbourhood crime or safety, which were not accounted for in our analysis. In addition, PA captured via accelerometry does not provide information on the form of activity undertaken (eg, participation in sports, walking on a treadmill vs outdoor environment), thus future studies that objectively measure form and location of PA can further specify the degree of association between Walk Score and specific types of PA. Lastly, our study results are limited in external validity. Participants included in the current study may not be representative of the full REGARDS cohort or of the whole US population. Therefore, our study is limited in its generalisability to only black and white adults over the age of 45 years who agreed to participate and provided usable accelerometer data.

In this national study of black and white older adults across the USA, increased Walk Score was associated with greater amounts of accumulated time in MVPA, for both men and women, blacks and whites, and across age groups. Increasing the walkability of the environment may facilitate higher levels of MVPA of residents. Future research should examine the influence that non-home-based environmental features have on accumulated MVPA and whether this association holds in populations outside of the USA.

What is already known on this subject?

- The association between neighbourhood environments and physical activity has been well studied.
- The majority of studies within this area have found a positive association between geographical information systems–derived walkability of a neighbourhood and objectively measured physical activity.
- To date, most studies have had limited geographical and demographic variability to explore moderating effects on this relationship.

What this study adds?

- This study found that Walk Score had a positive association with accumulated daily time spent in moderate to vigorous physical activity.
- There was no evidence of this association changing by sex, race or age within a national sample.

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Contributors ET made substantial contributions to study conception, data analysis, interpretation of the data and drafting the manuscript. SJ made substantial contributions to study conception, data acquisition and interpretation of the data. AB made substantial contributions to data acquisition and data analysis. SH made substantial contributions to study conception, data acquisition and interpretation of the data. VH made substantial contributions to study conception and data acquisition. BH made substantial contributions to study conception, data acquisition and data analysis. PC made substantial contributions to interpretation of the data. NC made substantial contributions to study conception, data acquisition, data analysis, interpretation of the data and drafting the manuscript. All authors critically revised drafts of the work for intellectual content, read and approved the final manuscript to be published, and agree to be accountable for all aspects of the work.

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