# Neighborhood Walkability
## Field Validation of Geographic Information System Measures

Samantha Hajna, MSc, Kaberi Dasgupta, MD, MSc, FRCPC, Max Halparin, BA, Nancy A. Ross, PhD

**Background:** Given the health benefits of walking, there is interest in understanding how physical environments favor walking. Although GIS-derived measures of land-use mix, street connectivity, and residential density are commonly combined into indices to assess how conducive neighborhoods are to walking, field validation of these measures is limited.

**Purpose:** To assess the relationship between audit- and GIS-derived measures of overall neighborhood walkability and between objective (audit- and GIS-derived) and participant-reported measures of walkability.

**Methods:** Walkability assessments were conducted in 2009. Street-level audits were conducted using a modified version of the Pedestrian Environmental Data Scan. GIS analyses were used to derive land-use mix, street connectivity, and residential density. Participant perceptions were assessed using a self-administered questionnaire. Audit, GIS, and participant-reported indices of walkability were calculated. Spearman correlation coefficients were used to assess the relationships between measures. All analyses were conducted in 2012.

**Results:** The correlation between audit- and GIS-derived measures of overall walkability was high (R=0.7 [95% CI=0.6, 0.8]); the correlations between objective (audit and GIS-derived) and participant-reported measures were low (R=0.2 [95% CI=0.06, 0.3]; R=0.2 [95% CI=0.04, 0.3], respectively). For comparable audit and participant-reported items, correlations were higher for items that appeared more objective (e.g., sidewalk presence, R=0.4 [95% CI=0.3, 0.5], versus safety, R=0.1 [95% CI=0.003, 0.3]).

**Conclusions:** The GIS-derived measure of walkability correlated well with the in-field audit, suggesting that it is reasonable to use GIS-derived measures in place of more labor-intensive audits. Interestingly, neither audit- nor GIS-derived measures correlated well with participants' perceptions of walkability.
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## Introduction

The global prevalence of physical activity is alarmingly low.[1] To facilitate population-level increases in physical activity, understanding how urban designs affect physical activity behavior is important.[2,3] Although GIS-derived measures of land-use mix, street connectivity, and residential density[3–6] are commonly combined into indices to capture the overall degree to which neighborhoods are conducive to walking, the criterion-related validity of these measures is unknown. The aims of the current study were to assess the relationships between audit- and GIS-derived measures of overall neighborhood walkability, where street-level audits are considered the gold standard in environmental assessment, and between objective (audit- and GIS-derived) and participant-reported measures of neighborhood walkability.

## Methods

Walkability assessments were conducted in 2009 on 200 Montréal (Quebec, Canada; Figure 1) neighborhoods. All participants were adults from these neighborhoods who had type 2 diabetes and who

From the Department of Epidemiology, Biostatistics and Occupational Health (Hajna, Dasgupta, Ross), the Department of Medicine, Division of Clinical Epidemiology (Dasgupta), and the Department of Geography (Ross, Halparin), McGill University Health Centre, McGill University, Montréal, Quebec, Canada

Address correspondence to: Nancy A. Ross, PhD, McGill University, Department of Geography, 805 Sherbrooke Street West, Montréal, QC H3A 2K6 Canada. E-mail: nancy.ross@mcgill.ca.

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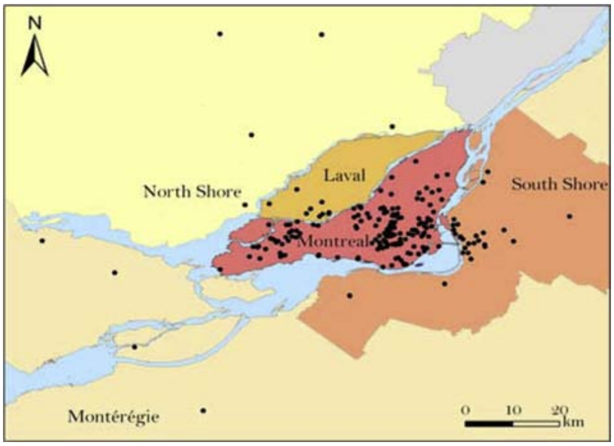


Figure 1. Locations of the neighborhoods on which audit, GIS, and participant-reported assessments were conducted

participated in a longitudinal study of walking and vascular disease risk.[7–10] Ethics approval was obtained from McGill University's Faculty of Medicine IRB.

### Neighborhood Audits

Five street segments located within 500 meters of the centroid of each participant's home postal code were selected randomly and audited by research assistants (blinded to the GIS-derived measures) using a 21-item modified version of the Pedestrian Environmental Data Scan (PEDS; Appendix A).[11] Based on a priori analyses, a five-street segment sampling strategy was found to adequately capture the neighborhood characteristics of interest.

### Geographic Information System–Derived Assessments

Polygonal buffers of 500 meters were constructed around the centroid of each participant's home postal code. Land-use mix, street connectivity, and residential density were derived for each buffer using ArcGIS 10.1. Land-use mix was based on an entropy score (higher score implied greater diversity).[12] Street connectivity equaled the number of four- or more-way intersections per square kilometer. Residential density equaled the number of residences per square kilometer of residential land area.

### Participant Reports

Perceptions of walkability were assessed using nine items derived from three previously used surveys (Appendix B).[13]

### Data Analysis

Indices of walkability were calculated by summing and standardizing the responses of the audit and survey items onto scales of 0 to 1. The GIS-derived walkability index was calculated by summing the $z$-scores of the three GIS-derived variables.[3–6] Higher index scores represented greater walkability. Correlations between measures were assessed using Spearman correlation coefficients (R). Principal components analyses with varimax rotations were used to identify key factors in the audit and survey tools. Regression-based factor scores were summed to produce audit and participant-reported indices of overall walkability. Sensitivity analyses were conducted to determine if use of regression-based factor scores altered study findings. All analyses were performed in 2012 using SAS 9.2.

## Results

The audit walkability index ranged from 0.30 to 0.71 (M=0.50, SD 0.08 [95% CI=0.47, 0.49]); the GIS-derived walkability index ranged from −4.35 to 6.55 (M=0, SD 2.36 [95% CI=−0.33, 0.33]); and the participant-reported walkability index ranged from 0.15 to 1.00 (M=0.74, SD 0.15 [95% CI=0.72, 0.76]). The interrater agreement in audit-based assessments was high (Pearson correlation coefficient=0.95 [95% CI=0.94, 0.97]). A total of 199 participants (99.5%) completed the neighborhood survey. Respondents were aged 59.8 years (±10.4). Respondents were mostly female (53.0%); university educated (39.0%); and Europid (69.0%).

Audit- and GIS-derived walkability were highly correlated (Table 1). Moderate to high correlations were observed between audit-derived walkability and GIS-derived land-use mix, street connectivity, and residential density; and between audit- and GIS-derived land-use mix (Table 1). Low correlations were observed between participant-reported walkability and GIS-derived walkability, land-use mix, street connectivity, and residential density; and between comparable participant-reported, audit- and GIS-derived items (Table 1). For comparable audit and participant-reported items, correlations were higher for items that appeared more objective (e.g., sidewalk presence versus safety) (Table 1). Correlations between GIS-derived measures were moderate (residential density versus land-use mix R=0.6 [95% CI=0.5, 0.7]; residential density versus street connectivity R=0.6 [95% CI=0.5, 0.7]; land-use mix versus street connectivity R=0.4 [95% CI=0.3, 0.5].

Three factors accounting for 73% of the variance in the retained items were identified in the audit tool (amenities, neighborhood aesthetics and safety, sidewalks; Table 2). Three factors accounting for 59% of the total variance were identified in the survey tool (amenities, neighborhood aesthetics and activity, and safety; Appendix C). No differences in correlations were observed when using factor scores.

## Discussion

Audit- and GIS-derived measures of walkability were highly correlated, suggesting that GIS-derived measures can be used in place of labor-intensive neighborhood auditing. Residential density correlated most with overall audit-derived walkability, suggesting that residential density alone may be an adequate proxy for in-field audits. Audit- and GIS-derived land-use mix were more weakly

**Table 1.** Correlations between audit, GIS, and participant-reported measures of neighborhood walkability

| GIS measure | Audit measure | R (95% CI)[a] |
|---|---|---|
| Walkability | Walkability | 0.7 (0.6, 0.8) |
| Land-use mix | Walkability | 0.5 (0.4, 0.6) |
| Street connectivity | Walkability | 0.6 (0.5, 0.7) |
| Residential density | Walkability | 0.7 (0.6, 0.8) |
| Land-use mix | Number of land uses | 0.5 (0.4, 0.6) |
| **GIS measure (objective)[b]** | **Participant-reported measure[b]** | **R (95% CI)[a]** |
| Walkability | Walkability | 0.2 (0.04, 0.3) |
| Land-use mix | Walkability | 0.2 (0.1, 0.3) |
| Street connectivity | Walkability | 0.1 (−0.02, 0.3) |
| Residential density | Walkability | 0.2 (0.1, 0.3) |
| Residential density | Stores within walking distance | 0.4 (0.2, 0.5) |
| **Audit measure** | **Participant-reported measure** | **R (95% CI)[a]** |
| Walkability | Walkability | 0.2 (0.06, 0.3) |
| Sidewalk presence | Sidewalk presence | 0.4 (0.3, 0.5) |
| Sidewalk conditions | Sidewalk conditions | 0.3 (0.2, 0.4) |
| Pedestrian lighting | Street lighting conditions | 0.2 (0.1, 0.3) |
| Roadway lighting | Street lighting conditions | 0.2 (0.1, 0.3) |
| Number of land uses | Stores within walking distance | 0.2 (0.1, 0.4) |
| Bus stop or metro | Easy walk, transit stop | 0.2 (0.04, 0.3) |
| Safe | Safe | 0.1 (0.003, 0.3) |

[a]Spearman correlation coefficients
[b]Based on a sample size of 199

correlated, likely because audits are limited in their ability to assess factors that are not restricted to a street view. For variables such as land-use mix, the "bird's-eye view" provided by GIS may be more informative that an in-field audit. Low correlations were observed between objective and participant-reported measures, suggesting that they capture different constructs.

Two previous studies examined the concordance between audit- and GIS-derived measures of walkability,[13,14] but to our knowledge, this is the first study to quantify the correlation between these two measures. Several previous studies also have examined the validity of GIS-derived measures of specific neighborhood characteristics.[14–17] In contrast to the high correlations observed herein, most of these studies reported low to moderate concordances between measures.[14–16] The difference may be because the focus in the current study was on urban design factors, whereas the focus in previous studies has been on small-scale characteristics (e.g., presence of food outlets[16]). Because maintaining spatial files on small-scale factors is more challenging because of their dynamic nature, it is not surprising that lower correlations were observed.

Although use of participant-reported measures may be important for understanding certain types of physical activity (e.g., leisure-time physical activity),[18,19] the unique challenges associated with these measures should not be overlooked. First, because increased physical activity may lead to better perceptions and better perceptions also may lead to higher levels of physical activity, disentangling the directionality of the relationship in cross-sectional studies is challenging. Second, the population-level impact of interventions aimed at improving perceptions is limited.

Arguably, the greatest improvements to public health have come through environmental changes (e.g., sanitation reform in 19th-century England,[20] tobacco sale restrictions[21]). In line with this perspective, it is proposed here that designing neighborhoods that are supportive of physical activity will have the largest impact on facilitating population-level increases in physical activity and that when these walkable neighborhoods are designed, individual-level interventions also will be more likely to succeed. This is because, even though individuals must first recognize the importance of physical activity, in the absence of choice-enabling environments, volitional attempts at increasing physical activity will be met with limited success. For physical activity interventions to reach their peak effectiveness, both individual perceptions and the built environment should be targeted.

## Limitations

Two study limitations must be addressed. One consideration is that although audit and GIS measures were compared, there was a lack of alignment between the items

Table 2. Eigenvalues (EV) and factor loadings from the principal components analysis of the items that were assessed using the modified version of the Pedestrian Environmental Data Scan[a]

| Item | | Factor 1: amenities (4.16) | Factor 2: neighborhood aesthetics and safety (1.99) | Factor 3: sidewalks (1.16) |
|---|---|---|---|---|
| 1 | Number of land uses | 0.84[b] | −0.15 | 0.15 |
| 2 | Sidewalk presence | 0.33 | −0.16 | 0.89[b] |
| 3 | Sidewalk condition | 0.22 | 0.03 | 0.94[b] |
| 4 | Crossing aids | 0.63[b] | −0.01 | 0.27 |
| 5 | Street amenities | 0.80[b] | 0.09 | 0.20 |
| 6 | Articulation in building designs | 0.24 | 0.81[b] | −0.01 |
| 7 | Bus stops or metro | 0.56[b] | −0.23 | 0.08 |
| 8 | Attractiveness | −0.20 | 0.88[b] | −0.13 |
| 9 | Safety | −0.36 | 0.81[b] | 0.00 |
| 10 | Utilitarian | 0.89[b] | −0.07 | 0.22 |

*Note:* Eigenvalues are shown in parentheses following column headings.
[a]Several of the original audit items ($n$=11) were removed during the principal components analyses because they overlapped with another factor and thus could not contribute uniquely to any one factor. The removed items included slope steepness, buffers between road and sidewalk, sidewalk width, number of lanes, number of trees shading walking area, overall cleanliness and maintenance, pedestrian lighting, roadway lighting, green space, medium- to high-volume driveways, and traffic control devices.
[b]Factor loadings $\geq$0.40

assessed by these tools. However, the primary aim of this study was to examine the correlation between overall measures of walkability using these tools. A high correlation between audit- and GIS-derived walkability was demonstrated, suggesting that although these tools assess walkability in different ways, the final picture is similar. Second, survey respondents had diabetes mellitus 2, a metabolic disorder that affects blood glucose control and places individuals at an increased risk for various health complications,[22] including depressive symptoms.[23] Because the perceptions of this population may differ from those of the general population, the correlations between perceived and objective measures may be lower than those that would have been observed in the general population.

## Conclusion

This study provides evidence that GIS-derived measures can be used in place of labor-intensive neighborhood auditing. Neither audit- nor GIS-derived measures correlated well with participants' perceptions of walkability, suggesting that these measures capture different constructs that may affect walking differently. Further research on the differential role of these measures in predicting physical activity is warranted.

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## Appendix

### Supplementary data

Supplementary data associated with this article can be found at http://dx.doi.org/10.1016/j.amepre.2013.01.033.