Development and reliability of a streetscape observation instrument for international use: MAPS-global

Kelli L. Cain1,12*, Carrie M. Geremia1,12, Terry L. Conway1,12, Lawrence D. Frank1,2,3, James E. Chapman3, Eric H. Fox3, Anna Timperio4, Jenny Veitch4, Delfien Van Dyck5,6, Hannah Verhoeven5, Rodrigo Reis7, Alexandre Augusto8, Ester Cerin9, Robin R. Mellecker9, Ana Queralt10, Javier Molina-García11 and James F. Sallis1,12

Abstract

Background: Relationships between several built environment factors and physical activity and walking behavior are well established, but internationally-comparable built environment measures are lacking. The Microscale Audit of Pedestrian Streetscapes (MAPS)-Global is an observational measure of detailed streetscape features relevant to physical activity that was developed for international use. This study examined the inter-observer reliability of the instrument in five countries.

Methods: MAPS-Global was developed by compiling concepts and items from eight environmental measures relevant to walking and bicycling. Inter-rater reliability data were collected in neighborhoods selected to vary on geographic information system (GIS)-derived macro-level walkability in five countries (Australia, Belgium, Brazil, Hong Kong-China, and Spain). MAPS-Global assessments (n = 325) were completed in person along a ≥ 0.25 mile route from a residence toward a non-residential destination, and a commercial block was also rated for each residence (n = 82). Two raters in each country rated each route independently. A tiered scoring system was created that summarized items at multiple levels of aggregation, and positive and negative valence scores were created based on the expected effect on physical activity. The intraclass correlation coefficient (ICC) was computed for scales and selected items using one-way random models.

Results: Overall, 86.6% of individual items and single item indicators showed excellent agreement (ICC ≥ 0.75), and 13.4% showed good agreement (ICC = 0.60–0.74). All subscales and overall summary scores showed excellent agreement. Six of 123 items were too rare to compute the ICC. The median ICC for items and scales was 0.92 with a range of 0.50–1.0. Aesthetics and social characteristics showed lower ICCs than other subscales, but reliabilities were still in the excellent range (ICC ≥ 0.75).

Conclusion: Evaluation of inter-observer reliability of MAPS-Global across five countries indicated all items and scales had “good” or “excellent” reliability. The results demonstrate that trained observers from multiple countries were able to reliably conduct observations of both residential and commercial areas with the new MAPS-Global instrument. Next steps are to evaluate construct validity in relation to physical activity in multiple countries and gain experience with using MAPS-Global for research and practice applications.

Keywords: Exercise, Walking, Built environment, Walkability, Measurement
Background

Relationships between several built environment factors and physical activity are well established [1]. Neighborhood environment features have been classified into two broad categories. Macroscale features include larger, structural and urban form characteristics, such as street connectivity, land use mix, and residential density that are not easily modifiable [2–5]. Microscale features, or smaller details of environments, such as sidewalk or street-crossing quality and aesthetics, are believed to affect people’s confidence, comfort, and safety for walking [6, 7]. In contrast to their macroscale counterparts, microscale features generally can be modified more easily as part of efforts to provide more supportive environments for physical activity.

Numerous observational measures of microscale environments with similar content but different formats have been published and showed good inter-observer reliability [3, 8]. These observational instruments have been developed and used across a wide range of environment types, but they are tailored to local environments. However, we could locate no measures that were designed for international use or evaluated in multiple countries. Physical inactivity is a global health problem that is not improving [9], and built environments have been related to physical activity internationally [10]. Therefore, a common reliable tool designed to capture the diversity of microscale environments found across the globe would foster international comparisons and generate data to inform international initiatives such as United Nations actions to reduce non-communicable diseases [11].

The purpose of the present study was to describe the development and inter-rater reliability of a streetscape observation tool developed for international use and evaluated in several countries. The new measure was based on items, format, and scoring of the Microscale Audit of Pedestrian Streetscapes (MAPS) that was developed in the United States, with several versions shown to be related to physical activity in multiple age groups, including the original 120-item version [6], a 54-item abbreviated version [12], and a 15-item version suitable for use by practitioners [7]. The name of the new measure is MAPS-Global.

Methods

Development of MAPS-global

MAPS was originally developed as an observation tool based on prior instruments [8, 13]. MAPS has been shown to be a valid [6] and reliable [14] tool for surveying pedestrian environments and microscale urban form features, with some coverage of macroscale attributes such as land use. However, data on the validity and reliability of MAPS were collected in the United States only, and the tool was not designed for international use.

The development of MAPS-Global was part of the International Physical Activity and the Environment Network (IPEN) Adolescent study and led by the IPEN Coordinating Center [15] (www.ipenproject.org). MAPS-Global was intended to be applicable for all ages, from childhood to older adulthood and drew from measures designed for general populations and specific age groups. MAPS-Global was designed to have important physical activity-relevant attributes from every continent in one instrument to allow cross-country comparisons.

To develop a version of MAPS appropriate for global use, the original MAPS and eight additional tools developed for different countries and purposes were identified, and selected items and constructs were adapted to include in MAPS-Global: Bikeability Toolkit (Bicycle Federation of Australia) [16], Assessing Levels of Physical Activity and fitness (ALPHA; Europe) [17], Environment in Asia Scan Tool (EAST; Hong Kong) [18], Residential Environment Assessment Tool (REAT; UK) [19], Forty Area Study Street View tool (FASTVIEW; UK) [20], Systematic Pedestrian and Cycling Environmental Scan (SPACES; Australia) [21], Sport, Physical activity and Eating behavior: Environmental Determinants in Young people audit tool (SPEEDY; UK) [22], and International Study of Childhood Obesity, Lifestyle and the Environment audit tool (ISCOLE; international) [23]. In addition, a self-report neighborhood environment measure tailored to Africa was considered to enable the use of MAPS-Global in African environments [24, 25]. A document showing the source(s) for each item in the MAPS Global tool can be downloaded at http://salli.su.edu/measure_maps.html#MAPSGLOBAL [26].

A draft of the MAPS-Global instrument was created through a three-step revision process. First, items from other tools that covered a similar construct as a MAPS item were used to revise the MAPS item to reflect internationally appropriate terms. Second, other modifications were made to existing MAPS items to adapt to international settings, such as increasing the upper range for land uses and building heights. Third, items from all eight instruments were reviewed and considered for inclusion if they met one of the following criteria: the item was found in more than one of the reviewed tools, was considered policy relevant, or captured a feature unique to a region. As most previous tools focused on pedestrian use, special attention was paid to incorporating a bicycling component for MAPS-Global. Table 1 presents a comparison between the original MAPS and MAPS-Global to highlight the changes.

After this revision process, a draft of MAPS-Global was distributed to IPEN investigators from 15 countries for review and input. Recommendations for additional items were also solicited during this process. The tool was then finalized for use in the current study and contained 123 items. The tool is available for download [26].
| Items deleted for MAPS Global (examples) | Items added for MAPS Global | Modifications for MAPS Global |
|-----------------------------------------|-----------------------------|-----------------------------|
| **Destinations & Land Use (DLU)**       |                             |                             |
| Positive DLU                            | Trail, bicycle shop, open air market, bakery | Response scale increased from 2+ to 5+ as upper limit for all land uses except open air markets, strip malls, and shopping centers (shopping mall and shopping arcade combined into 1 item) |
| Big box store, health/social services, library/museum, post office, senior center, parking facilities, retirement/senior living facility, community garden | Trail, bicycle shop, open air market, bakery | Response scale increased from 2+ to 5+ as upper limit for all land uses except open air markets, strip malls, and shopping centers (shopping mall and shopping arcade combined into 1 item) |
| Negative DLU                            | Age-restricted bar/nightclub | None                        |
| Warehouse, casino, abandoned building, unmaintained lot/field, med-large parking lot | Age-restricted bar/nightclub | None                        |
| Items not in subscale                   | Pedestrian street or zone   | None                        |
| Non-residential buildings with parking lots between walkway and entrance, non-residential buildings adjacent to walkway | Pedestrian street or zone | None                        |
| **Streetscape Characteristics**         |                             |                             |
| Positive streetscape                    | BRT, train, subway, tram/streetcar, tuktuk/auto rickshaw, bicycle share, hawkers/shops/carts | Modified number of driveways to be collected at the segment level |
| Posted speed limit, drainage ditches, drinking fountain, public phones | BRT, train, subway, tram/streetcar, tuktuk/auto rickshaw, bicycle share, hawkers/shops/carts | Modified number of driveways to be collected at the segment level |
| Negative streetscape                    | None                        | None                        |
| Driveways/alleys, lack of street lights | None                        | None                        |
| Items not in subscale                   | Senior transit, drainage ditches | None                        |
| **Aesthetics & Social Characteristics** |                             |                             |
| Positive aesthetics/social              | Natural bodies of water     | None                        |
| Neighborhood watch signs, commercial signage | Natural bodies of water | None                        |
| Negative aesthetics/social              | Dog fouling                 | Modified extent of graffiti and litter to include “dog fouling”; combined litter in yards and on street/sidewalk into 1 item |
| Railroad tracks, extent social disorder, abandoned cars, | Dog fouling | Modified extent of graffiti and litter to include “dog fouling”; combined litter in yards and on street/sidewalk into 1 item |
| Items not in subscale                   | Historic/cultural features, Beer/liquor bottles/cans | None                        |
| **Crossings/Intersections**             |                             |                             |
| Positive crossing                       | Crossing on an overpass, underpass or bridge, bicycle signal, tactile paving, bike box | None                        |
| Stop lines on road, one-way streets through crossing, audible walk signal, dedicated turn arrows | Crossing on an overpass, underpass or bridge, bicycle signal, tactile paving, bike box | None                        |
| Negative crossing                       | None                        | None                        |
| Gutters, steep slope, temporary obstructions, poor visibility at corners | None | None                        |
| Items not in subscale                   | Crosswalk timing, number of legs at intersection, poor condition of crossing surface | None                        |
| **Street Segments**                    |                             |                             |
| Positive segment                        | Hawkers or shops, sidewalk or pedestrian street/zone obstructions, pedestrian bridge/overpass/tunnel, covered or air conditioned place to walk along the street or connecting buildings, quality of the bicycle lane/zone | Modified number of traffic lanes to include pedestrian street; modified coverage of sidewalk/walkway to isolate trees (1 item) and overhangs/awnings (1 item); modified building height to collect shortest (1 item) and tallest (1 item) and upper limit increased from 11+ to 21+ stories; modified bicycle lane/zone with different options; modified street lights to specify for cars (1 item) and for pedestrians (1 item) |
| Building façade colors, building accent colors, building materials | Hawkers or shops, sidewalk or pedestrian street/zone obstructions, pedestrian bridge/overpass/tunnel, covered or air conditioned place to walk along the street or connecting buildings, quality of the bicycle lane/zone | Modified number of traffic lanes to include pedestrian street; modified coverage of sidewalk/walkway to isolate trees (1 item) and overhangs/awnings (1 item); modified building height to collect shortest (1 item) and tallest (1 item) and upper limit increased from 11+ to 21+ stories; modified bicycle lane/zone with different options; modified street lights to specify for cars (1 item) and for pedestrians (1 item) |
| Negative segment                        | Gates/walls/tall fences around properties | Modified sidewalk or pedestrian zone obstructions to isolate cars; slope estimated by sight rather than measured with an inclinometer |
| Cross-slope, minor trip hazards, how much of segment at steepest level | Gates/walls/tall fences around properties | Modified sidewalk or pedestrian zone obstructions to isolate cars; slope estimated by sight rather than measured with an inclinometer |
Global microscale environmental data were collected for the purpose of this reliability study from November 2014 – June 2015 as part of the IPEN Adolescent study, and included five cities: Melbourne (Australia), Ghent (Belgium), Curitiba (Brazil), Hong Kong (China), and Valencia (Spain). Following IPEN protocol, all cities used a GIS-derived macro-level walkability index to select neighborhoods defined as high versus low walkability, based on: net residential density, intersection density, and mixed land use [27, 28]. Neighborhoods in these cities were selected to represent four neighborhood types categorized as high/low-walkability by high/low-median socio-economic status (SES), to ensure the inclusion of a wide range of demographic and built environment attributes.

The IPEN Adolescent study was approved for research with human subjects by the Institutional Review Boards at Deakin University, Ghent University, Pontifical Catholic University of Parana, University of Hong Kong, and University of Valencia.

Route selection
To identify routes for MAPS-Global assessment, each country randomly selected 65 IPEN Adolescent study participants, or randomly selected residences within potential study areas, (total n = 325) stratified by the four walkability-by-SES neighborhood types. The IPEN Coordinating Center identified each route’s destination as the nearest commercial block. Routes were manually created (0.25–0.45 mile (400–724 m) in distance) from each residence toward a commercial block using Google Earth. The routes were drawn along the road network, providing the most direct route from the residence toward a non-residential destination. Alleys, non-motorized, and informal paths adjacent to the street network were not easily identifiable using online images and were therefore not used to create routes. However, these pedestrian facilities were coded within MAPS-Global when they were observed. MAPS-Global data were also collected along a single road segment at the nearest commercial block to enhance the variety of environmental features assessed, as the 0.25–0.45 mile routes did not always reach the end destination, due to a cap on the maximum surveyed distance (based on time and budget considerations).

Training
A research staff manager from the IPEN Coordinating Center was responsible for training, route creation, and quality control. Details about length of training and certification can be found elsewhere [14]. Multiple raters at each study site were instructed to use MAPS-Global through an online webinar and were provided training materials including a manual with item definitions and photos (see training manual online [26]). After the online training, each country’s team practiced rating streets in the field and communicated with the IPEN Coordinating Center to clarify site-specific issues. To be certified to rate independently, raters were required to complete observations of at least five routes with inter-rater reliability at 95% agreement or higher.

Data collection
Data were collected along a 0.25–0.45 mile route (n = 325 residential routes) starting at a study participant’s home or a randomly selected residence and walking toward the nearest commercial destination. Data were also collected along 82 commercial blocks. Table 2 describes data collection areas and sample sizes per country.

Two raters in each country completed each MAPS-Global route independently. Residential routes took on average 26.1 min to complete (range = 2–100 min) and commercial segments were completed in 15.8 min on average (range = 3–110 min). Raters and coordinators reviewed each tool for missing and discrepant items. If more than 5% of items were missing, raters returned to the route and completed the missing items.

Table 2 Reliability pair sample sizes by country

| Country   | City      | Routes | Segments | Crossings | Cul-de-sacs |
|-----------|-----------|--------|----------|-----------|-------------|
| Australia | Melbourne | 65     | 218      | 108       | 10          |
| Belgium   | Ghent     | 65     | 236      | 156       | 6           |
| Brazil    | Curitiba  | 65     | 319      | 213       | 0           |
| China     | Hong Kong | 65     | 224      | 145       | 9           |
| Spain     | Valencia  | 65     | 350      | 266       | 0           |
| Total     |           | 325    | 1347     | 888       | 25          |

*aresidential only, commercial blocks not included
*bsegment defined as the area between crossings
*cboth residential and commercial included
Scoring and creating subscales
The scoring of MAPS-Global largely followed the original MAPS scoring structure which has been described elsewhere [6, 14]. Briefly, the tool has six sections: destinations and land use (DLU), streetscapes, aesthetics and social, street segments (defined as the area between street crossings), street crossings, and cul-de-sacs/dead-ends. DLU, streetscape, and aesthetics/social items were captured at the route level, and these characteristics were generally consistent throughout the route (e.g., speed limit, aesthetics and social environment). Street segment variables, such as sidewalks, buffers between streets and walking spaces, trees, and building setbacks were collected on each segment on the route. Street-crossing variables were measured at every intersection or crossing on the route (e.g., crosswalks, signals). Cul-de-sac variables (e.g., size, amenities) were collected when one or more cul-de-sacs or dead-ends were present within 400 ft (122 m) of the residential address. When multiple segments and crossings occurred along a route, the respective segment and crossing variables were averaged.

This tiered scoring system summarized items into subscales at multiple levels of aggregation. Most sections included positive and negative valence scores based on the expected effect on physical activity. Some items were excluded from subscales due to being transitory (e.g., presence of anyone walking), capturing a particularly important element of the environment (e.g., pedestrian street), or an unclear expected association with physical activity (e.g., segment type). These became single-item indicators.

A modification from the original MAPS was made to adapt to the more destination-dense environments found internationally by increasing the upper range of land use frequency response options to five or more for each type of destination (only “two or more” was used in original MAPS). Land use items were scored as 0, 1, 2, 3, 4, or 5+. Other continuous and descriptive items were dichotomized or trichotomized based on their distributions, theoretical relevance, and compatibility with other scale items’ scoring. In several instances, related items needed to be combined into single variables to be meaningful components of their respective subscales. For example, shortest and tallest building heights were collected as two separate items, but for scoring they were averaged into one variable for the subscale. In such cases, the new variable was computed and then recoded for scoring (e.g., di- or trichotomized) consistently with theoretically related items to match scoring of other items within a subscale.

After items were rescored as necessary, subscale scores were computed by summing the items’ scores. Valence scores were created by summing subscales that were expected to have a positive or negative impact on physical activity based on the consensus of authors familiar with interdisciplinary research, conceptual models, and guidelines. For instance, the sum of the positive destinations and land uses was thought to be positively associated with physical activity, and the presence of social disorder was thought to be negatively associated. All of the positive subscales within a section were summed to create the positive valence score, and the negative subscales were summed for the negative valence score. The streetscape and cul-de-sac sections only contained positively related items. Finally, an overall section score (positive-minus-negative valence scores) was calculated for each main section that contained both of these valence scores. Overall valence scores were calculated by summing the six main sections’ positive and negative scores. The overall grand score was calculated by subtracting overall negative from overall positive scores. The cul-de-sac score was not included in overall valence scores due to an unclear expected association with physical activity.

In addition to section-derived subscales, three new subscales were created from items that were conceptually related but collected within different sections of the tool (e.g., route and segment items). The three new subscales were pedestrian infrastructure, pedestrian design, and bicycle facilities. Detailed information about item recodes, transformations, and subscale creation can be downloaded [26].

Analysis
The purpose of MAPS-Global was to represent the full international variability in environments, so reliability results were computed on the pooled international dataset. Country-specific reliability estimates would be misleading because different attributes would be rare in each country, leading to reduced variability and low frequency of occurrence of variables that would underestimate reliability. To assess inter-rater reliability, the intraclass correlation coefficient (ICC) was calculated for the MAPS-Global computed scales and several single-item indicators (e.g., place of worship, crossing overpass, etc.). IBM SPSS Version 21 Scale/Reliability procedure was used to compute ICCs using the one-way random model for average measures.

A variety of numeric definitions and adjectival descriptors have been used to classify measures of inter-rater agreement using Cohen’s kappa coefficients for categorical variables and the ICC for test-retest of continuous measures [29–31]. For this study, Cicchetti’s [30] numeric ranges and descriptors were used. The ICC was classified to indicate test-retest reliability that was: ‘excellent’ (ICC ≥ 0.75), ‘good’ (0.60–0.74), ‘fair’ (0.40–0.59), and ‘poor’ (< 0.40). Items with insufficient variability but percentage agreement equal or higher than 75% were considered to have good agreement [21].
Results

Results presented here were based on pooled analyses for all five study sites. Table 3 summarizes reliability classification levels for individual items that went into scales, single-item indicators, subscales, and overall scores. Using Cicchetti’s criteria [30], 100% of the subscales and overall scores showed “excellent” agreement. Of the 112 individual items and single item indicators for which ICCs or Kappa’s could be computed, 97 (86.6%) had “excellent” reliability, and 15 (13.4%) had “good” reliability. Six of the tool’s 123 items (unanticipated mid-segment crossing, bicycle locker or compound, basketball hoop in cul-de-sac, skateboard feature in cul-de-sac, soccer goal in cul-de-sac, and outdoor fitness equipment in cul-de-sac) were so rare that no ICC or Kappa could be calculated, yet all were retained in the instrument due to their theoretical importance. Two of the “good” agreement individual items (private outdoor recreation and raised crosswalk) and two of the “good” agreement single item indicators (liquor/alcohol store and presence of people walking) had relatively low Kappa’s (0.50–0.59) due to insufficient variability, but had inter-rater agreements from 94.1%–99.9% so were categorized as having “good” agreement [21].

Table 4 provides more detailed results for the key MAPS-Global constructs, including the number of items in subscales, range of scores, items and overall subscale descriptions, and ICC’s/Kappa’s for single-item indicators, subscale, valence, and overall scores. The median ICC was 0.92, with a range of 0.50–1.0. Aesthetics and social characteristics showed lower ICC values than other sections. Liquor/alcohol stores had the lowest ICC, and crosswalk amenities had the highest. The ICC for the overall grand score was 0.99.

Discussion

To facilitate international comparison of microscale environments relevant to physical activity, a new observational measure (MAPS-Global) was developed by drawing on the previously validated MAPS tool and eight other instruments developed in and for a diverse set of countries. Evaluation of inter-observer reliability of MAPS-Global in five countries indicated all items and scales had “good” or “excellent” agreement. All of the summary scores had “excellent” reliability, with an ICC of > 0.75, and the ICC for the overall grand score was 0.99. The lowest reliabilities for multi-item scales were for the three aesthetics and social characteristics subscales (ICCs = 0.78 to 0.81), though they were still in the “excellent” category. Items dealing with landscaping, water features, dog excrement, and highway nearby may be more difficult to define and require more subjective judgment than other types of items. In general, the results demonstrated that trained observers from multiple countries were able to reliably conduct observations of both residential and commercial areas with the new MAPS-Global instrument.

The development process of MAPS-Global was guided by two considerations. The first was to ensure international applicability by including items relevant to physical activity on every inhabited continent. This was accomplished by including items from environmental measures developed in Africa, the Americas, Asia, Australia, and Europe, as well as adding a bicycling environment subscale. Modifications were also made to existing MAPS items and response scales to capture a wider range of environments. Table 1 summarizes these modifications. IPEN investigators from 15 countries then reviewed, pilot tested, and provided feedback to ensure MAPS-Global would be applicable in their countries. The second consideration was to ensure comparability of measurement across countries. This was accomplished by producing a single instrument supported by a detailed and illustrated instruction manual, delivering training from a central site, and requiring observers to complete an in-field certification process. Although MAPS-Global does not include all possible activity-relevant streetscape features, the included items were deemed most important by consensus of the IPEN Adolescent investigators. Though the

| ICC/Kappa Classifications | “Excellent” agreement (ICCs ≥0.75) | “Good” agreement (ICC = 0.60 to 0.74) |
|---------------------------|-------------------------------|-------------------------------|
| Individual items that make up scales | Median (range) 0.91 (0.50–1.0) | N (%) 80 (87.0) | N (%) 12 (13.0) | Total N (%) 92 a (100.0) |
| Single-item indicators     | 0.88 (0.54–0.99) | 17 (85.0) | 3 (15.0) | 20 b (100.0) |
| Subscales (sums of items)  | 0.94 (0.79–0.99) | 21 (100.0) | 0 (0.0) | 21 (100.0) |
| Overalls (sums of subscales)| 0.96 (0.78–0.99) | 13 (100.0) | 0 (0.0) | 13 (100.0) |
| Total (items + single item indicators + subscales + overalls) | 0.92 (0.50–1.0) | 131 (89.7) | 15 (10.3) | 146 (100.0) |

a96 total individual items, but 4 items were too rare to compute Kappa’s
b22 total single item indicators, but 2 items were too rare to compute Kappa’s
### Table 4 Inter-rater Reliability for MAPS-Global Single Item Indicators, Subscales and Overall Summary Scores

|                        | # items | Sample items and overall subscale description | ICC/Kappa, Confidence Interval |
|------------------------|---------|-----------------------------------------------|-------------------------------|
| **Destinations & Land Use (DLU)** |         |                                               |                               |
| Positive Destinations & Land Use |         |                                               |                               |
| Residential Mix        | 4 (0–3) | Single family, multi-family, mixed, apartment over retail | .83 (.79, .85)                |
| Shops                  | 8 (0–28)| Grocery, convenience store, bakery, drugstore, other retail, shopping mall, strip mall, open air market | .97 (.96, .97)                |
| Restaurant-Entertainment | 4 (0–20)| Fast food, sit-down, café, entertainment      | .90 (.88, .92)                |
| Institutional-Service  | 3 (0–15)| Bank, health-related professional, other service | .94 (.92, .95)                |
| Worship                | 1 (0–5) | Place of worship                              | .91 (.89, .92)                |
| School                 | 1 (0–5) | School land use                                | .98 (.97, .98)                |
| Public Recreation      | 4 (0–20)| Public indoor, public outdoor facility, park, trail | .83 (.80, .86)                |
| Private Recreation     | 2 (0–10)| Private indoor, private outdoor facility       | .84 (.81, .87)                |
| Pedestrian Street      | 1 (0–5) | Pedestrian street/zone                         | .89 (.87, .91)                |
| Negative Destinations & Land Use |         |                                               |                               |
| Age-restricted bar or nightclub | 1 (0–5) | Age-restricted bar/nightclub                  | .93 (.91, .94)                |
| Liquor or alcohol store | 1 (0–5) | Liquor or alcohol store                       | .54 (.47, .61)                |
| Positive DLU           | 27 (0–111) | Sum of the positive DLU subscales            | .96 (.95, .97)                |
| Negative DLU           | 2 (0–10) | Sum of the negative DLU subscales             | .92 (.90, .93)                |
| Overall DLU            | 29       | Positive DLU - Negative DLU                   | .96 (.96, .97)                |
| **Streetscape Characteristics** |         |                                               |                               |
| Transit                | 9 (0–13) | Number of stops, transit type and amenities (bench, shelter, and timetable) | .90 (.89, .92)                |
| Traffic calming        | 1 (0–5) | Signs, circles, speed tables, speed humps, curb extension | .90 (.88, .91)                |
| Roll-over curb         | 1 (0–1) | Roll-over curbs                               | .84 (.81, .87)                |
| Trash bins             | 1 (0–1) | Public trash bins                             | .89 (.87, .91)                |
| Benches                | 1 (0–1) | Benches or other places to sit                 | .81 (.78, .84)                |
| Bicycle racks          | 1 (0–1) | Bicycle racks                                 | .83 (.80, .86)                |
| Bicycle lockers        | 1 (0–1) | Secure bicycle access lockers or compounds    | Too rare to calculate Kappa  |
| Bicycle sharing        | 1 (0–1) | Bicycle docking station for bike sharing      | .97 (.96, .98)                |
| Kiosks                 | 1 (0–1) | Kiosks or information booths                   | .97 (.96, .98)                |
| Hawkers                | 1 (0–1) | Hawkers/shops/carts                           | .97 (.96, .97)                |
| Positive Streetscape   | 17* (0–25) | Sum of positive streetscape             | .93 (.91, .94)                |
| **Aesthetics & Social Characteristics** |         |                                               |                               |
| Presence of anyone walking* | 1 (0–1) | Presence of anyone walking                    | .59 (.53, .65)                |
| Positive Aesthetics/Social | 4 (0–4) | Hardscape, water, softscape, landscaping       | .78 (.74, .82)                |
| Negative Aesthetics/Social | 6 (0–6) | Buildings not maintained, graffiti, litter, dog fouling, physical disorder, highway near | .80 (.76, .83)                |
| Overall Aesthetics/Social | 10*   | Positive Aesthetics/Social - Negative Aesthetics/Social | .81 (.77, .84)                |
| **Crossings/Intersections** |         |                                               |                               |
| Positive Crossing Subscales |         |                                               |                               |
| Crosswalk Amenities    | 7 (0–7) | Crossing aids, marked crosswalk, high visibility striping, different material, curb extension, raised crosswalk, refuge islands | .99 (.99, .99)                |
| Curb Quality & Presence | 3 (0–6) | Curb presence, curb ramps lined up, tactile paving | .95 (.94, .95)                |
| Intersection Control & Signage | 7 (0–7) | Yield signs, stop signs, traffic signal, traffic circle, pedestrian walk signals, push buttons, countdown signal | .97 (.96, .97)                |
| Bicycle Features       | 3 (0–3) | Waiting area, bike lane crossing the crossing, bike signal | .94 (.93, .95)                |
| Overpass               | 1 (0–1) | Crossing on pedestrian overpass, bridge       | .80 (.77, .82)                |
| Mid-segment crossing*  | 1 (0–1) | Unanticipated mid-segment crossing            | Too rare to calculate Kappa  |
Table 4 Inter-rater Reliability for MAPS-Global Single Item Indicators, Subscales and Overall Summary Scores (Continued)

| Subscale                           | # items (range of scores) | Sample items and overall subscale description                  | ICC/Kappa, Confidence Interval |
|------------------------------------|---------------------------|----------------------------------------------------------------|-----------------------------------------|
| Negative Crossing Subscales        |                           |                                                                  |                           |
| Road Width                         | 1 (0–2)                   | Distance of crossing leg                                        | .99 (.98, .99)             |
| Positive Crossing                  | 21 (0–24)                 | Sum of the positive crossing subscales                         | .98 (.98, .98)             |
| Negative Crossing                  | 1 (0–2)                   | Sum of the negative crossing subscales                         | .99 (.98, .98)             |
| Overall Crossing                   | 22*                      | Positive Crossing - Negative Crossing                          | .98 (.97, .98)             |
| Street Segments                    |                           |                                                                  |                           |
| Positive Segment Subscales         |                           |                                                                  |                           |
| Building Height-Setback            | 4 (0–10)                  | Building height, smallest and largest setback                  | .97 (.97, .97)             |
| Segment type*                     | 1 (0–1)                   | Segment type: residential or commercial                        | .96 (.96, .97)             |
| Building Height-Road Width Ratio   | 5 (0–3)                   | Building height, setback and road width                        | .90 (.78, .82)             |
| Buffer                             | 2 (0–5)                   | Parking along street, buffer                                   | .92 (.91, .92)             |
| Bike Infrastructure                 | 3 (0–5)                   | Bike lane presence, quality, signage                           | .95 (.94, .96)             |
| Shade                              | 3 (0–6)                   | Number of trees, sidewalk coverage, shade                      | .93 (.93, .94)             |
| Sidewalk                           | 2 (0–6)                   | Sidewalk presence and width                                    | .93 (.92, .94)             |
| Pedestrian infrastructure           | 5 (0–5)                   | Mid-segment crossing, pedestrian bridge, covered place to walk, street lights | .93 (.92, .93)            |
| Building Aesthetics and Design     | 1 (0–2)                   | Street windows                                                 | .84 (.82, .85)             |
| Informal Path or Shortcut          | 1 (0–1)                   | Informal path connecting to something else                     | .86 (.84, .87)             |
| Hawkers/Shops                      | 1 (0–2)                   | Hawkers/shops on sidewalk/ped zone                             | .73 (.71, .76)             |
| Negative Segment Subscales         |                           |                                                                  |                           |
| Sidewalk                           | 7 (0–13)                  | Non-continuous sidewalk, trip hazards, obstructions, cars blocking walkway, slope, gates, driveways | .96 (.95, .96)             |
| Positive Segment                   | 27 (0–45)                 | Sum of the positive segment subscales                          | .97 (.97, .98)             |
| Negative Segment                   | 7 (0–13)                  | Sum of the negative segment subscales                          | .96 (.95, .96)             |
| Overall Segment                    | 34*                      | Positive Segment - Negative Segment                            | .98 (.98, .98)             |
| Overall Summary and Grand Scores   |                           |                                                                  |                           |
| Overall Positive                   | 102 (0–210)               | Positive DLU, positive streetscape, positive aesthetics/social, positive segment (mean of all segments), positive crossing (mean of all segments). | .96 (.95, .97)             |
| Overall Negative                   | 16 (0–22)                 | Negative DLU, negative aesthetics/social, negative segment (mean of all segments), negative crossing (mean of all crossings). | .92 (.90, .93)             |
| Overall Grand Score                | 118                      | Overall Positive - Overall Negative                            | .99 (.99, .99)             |
| Cross-Domain Subscales             |                           |                                                                  |                           |
| Pedestrian Infrastructure           | 13 (0–27)                 | Trail, pedestrian zone, sidewalk presence/width, buffer, shortcut, mid-segment crossing, pedestrian bridge, air conditioned place to walk, low lights, overpass, crosswalk, refuge island | .96 (.95–.97)             |
| Pedestrian Design                  | 13 (0–21)                 | Open-air market, trash cans, benches, kiosks, hawkers and shops, setback, visibility, pedestrian walk signals, push buttons, countdown signals, ramps, crossing aids | .98 (.97–.98)             |
| Bicycle Facilities                 | 9 (0–11)                  | Bike racks, docking stations, lockers, bike lane, bike lane quality, signs, bike signal, bike box, bike lane crossing the crossing | .97 (.96–.98)             |
| Cul-de-sacs/Dead-ends              |                           |                                                                  |                           |
| Overall Cul-de-sac*                | 6 (0–6)                   | Closeness to participant’s home, total amenities, visibility   | .94 (.88, .97)             |

*not included in subscales
*31 items in section, bicycle shops added to tool later, pedestrian zone not included in subscales
*22 items in this section, 4 new informal transit items added roll over curbs not included in subscales
*11 items in this section, presence of people walking not included in subscales
*23 items in this section, mid- segment crossing not included in subscales
*30 unique items used in subscales, but 5 items (setback × 2, building height × 2, and sidewalk) were scored in more than one way for different subscales, segment type not included in subscales
*Score reported is based on 2 items as 4 items were too rare to calculate Kappa
instrument was developed as part of a study of adolescents, MAPS-Global was designed to be relevant to all ages.

Strengths of the study were the wide variety of constructs, clear scoring guidelines and training procedures, conceptually meaningful summary variables to use in analyses, and good evidence of inter-observer reliability documented in the present paper. Weaknesses of the measure and the study included the large number of items and need for training and ongoing supervision of observers that add to the costs and investigator burden of data collection. Although MAPS-Global is conceptualized as a measure of microscale attributes, it also includes variables such as land use that can be considered macroscale. The present method of assessing routes from residences toward destinations is not applicable for all purposes, such as evaluating microscale features for an entire neighborhood. However, a protocol has been developed [7] for using MAPS-Global on all or selected street segments by coding “route” items for each segment. Although MAPS-Global was tested in five diverse countries, it has not been examined in low-income countries that may have distinct environmental features or rural areas where MAPS-Global may not be applicable. Future studies using the MAPS-Global tool should include study sites from even more diverse locations, especially low-income countries, to further assess international comparability. Variability in frequency of occurrence of items within countries reduced sample sizes and precluded the presentation of country-specific reliability analyses. Additional refinements may be needed to improve the reliability performance among some of the items that require subjective judgment in future iterations.

Conclusion

It is important to improve understanding of how cities can be built to support sufficient physical activity and other health indicators [32]. Microscale environment data are lacking internationally, so MAPS-Global promises to fill a critical gap by providing measures of features such as sidewalks, safety of street crossings, and landscaping that are more feasible and affordable to modify than the macroscale layout of cities. Next steps in the evaluation and application of MAPS-Global include examining associations with physical activity (i.e., construct validity), evaluating use of online imagery to facilitate more efficient and cost effective data acquisition, constructing more comprehensive observer training programs, and eventually creating a shorter version of the instrument to encourage more widespread international use. If MAPS-Global is shown to be valid and comparable across countries, it could also be applied to provide evidence for practice and policy, such as identifying strengths and weaknesses of activity-supportive environments within and across cities to inform planning decisions, and evaluating changes in built environments, especially those designed to improve physical activity and health.

Abbreviations

ALPHA: Assessing Levels of Physical Activity and fitness; DLU: Destinations and land use; EAST: Environment in Asia Scan Tool; FASTVIEW: Forty Area Study Street View; GIS: Geographic Information Systems; ICC: Intraclass correlations; IPE: International Physical Activity and the Environment Network; ISCOLE: International Study of Childhood Obesity, Lifestyle and the Environment; MAPS: Microscale Audit of Pedestrian Streetscapes; REAT: Residential Environment Assessment Tool; tool; SES: Socio-economic status; SPACES: Systematic Pedestrian and Cycling Environmental Scan; SPEEDY: Sport, Physical activity and Eating behavior: Environmental Determinants in Young people.

Acknowledgements

We would like to acknowledge Casper Zhang, Kiko Leung, Ryan Lip, Jo Salmon, Billie Giles-Corti and Karen Villeneuve who provided feedback on the development of the MAPS Global tool.

Funding

Funding for this study was made possible by a grant from National Institutes of Health (NIH) R01 HL111378. EC is supported by an Australian Research Council Future Fellowship (FT 140100885). AT was supported by a National Heart Foundation of Australia Future Leader Fellowship (Award 100046). JV was supported by a National Health and Medical Research Council Early Career Fellowship (ID 1053426).

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Authors’ contributions

KLC conceived of study, participated in study design and coordination, drafted the manuscript and approved the final manuscript as submitted. CMG participated in study design and coordination, conducted analyses, drafted the manuscript and approved the final manuscript as submitted. TLC conceived of study, participated in study design, drafted the manuscript and approved the final manuscript as submitted. LDF participated in study design, contributed to the manuscript review and approved the final manuscript as submitted. JEC participated in study design, contributed to the manuscript review and approved the final manuscript as submitted. EHF participated in study design, contributed to the manuscript review and approved the final manuscript as submitted. AT contributed to data collection, reviewed and provided feedback to manuscript, and approved the final manuscript as submitted. JV contributed to data collection, reviewed and provided feedback to manuscript, and approved the final manuscript as submitted. DV contributed to data collection, reviewed and provided feedback to manuscript, and approved the final manuscript as submitted. HV contributed to data collection, reviewed and provided feedback to manuscript, and approved the final manuscript as submitted. AA contributed to data collection, reviewed and provided feedback to manuscript, and approved the final manuscript as submitted. EC contributed to data collection, reviewed and provided feedback to manuscript, and approved the final manuscript as submitted. RR contributed to data collection, reviewed and provided feedback to manuscript, and approved the final manuscript as submitted. AQ contributed to data collection, reviewed and provided feedback to manuscript, and approved the final manuscript as submitted.

Ethics approval and consent to participate

All investigators completed the San Diego State University Institutional Review Board training, the National Institutes of Health (NIH) Fogarty International Center ethical requirements, and their own country’s ethics
requirements. All participants provided informed consent for participation in their country-level study.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

Publisher’s Note
Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Author details
1. Department of Family Medicine and Public Health, University of California San Diego, San Diego, CA, USA.
2. Health and Community Design Lab, Schools of Population and Public Health and Community and Regional Planning, University of British Columbia, Vancouver, BC, Canada.
3. Urban Design 4 Health, Inc, Rochester, NY, USA.
4. Institute for Physical Activity & Nutrition, School of Exercise & Nutrition Sciences, Deakin University, Geelong, Australia.
5. Department of Movement and Sports Sciences, Ghent University, Ghent, Belgium.
6. Research Foundation Flanders (FWO), Brussels, Belgium.
7. Prevention Research Center, Brown School, Washington University in St. Louis, St. Louis, USA.
8. Research Group on Physical Activity and Quality of Life, Pontificia Universidade Catolica do Parana, Curitiba, Brazil.
9. School of Public Health, University of Hong Kong, Hong Kong, China.
10. Department of Nursing, University of Valencia, Valencia, Spain.
11. Department of Teaching of Musical, Visual and Corporal Expression, University of Valencia, Valencia, Spain.
12. Mary MacKillop Institute for Health Research, Australian Catholic University, Melbourne, Australia.

Received: 19 September 2017 Accepted: 29 January 2018
Published online: 26 February 2018

References
1. Bauman AE, Reis RS, Sallis JF, Wells JC, Loos RJ, Martin BW. Correlates of physical activity: why are some people physically active and others not? Lancet. 2012;380(9838):258–71.
2. Brennan Ramirez LK, Hoehner CM, Brownson RC, et al. Indicators of activity-friendly communities: an evidence-based consensus process. Am J Prev Med. 2006;31(6):S15–24.
3. Brownson RC, Hoehner CM, Day K, Forsyth A, Measuring SJF. The built environment for physical activity: state of the science. Am J Prev Med. 2009;36(Suppl 4):S99–123.
4. Frank LD, Schmid TL, Sallis JF, Chapman JE, Saelens BE. Linking objective and validating an abbreviated version of the microscale audit for pedestrian streetscapes (MAPS-abbreviated). J Transp Health. 2017;5:84–96.
5. Kealey M, Kruger J, Hunter R, Ivey S, Satariano W, Bayles C, Ramirez B, Bryant L, Johnson C, Lee C, Levinger D, Mctigue K, Moni C, Moudon AV, Plato D, Prohaska T, Sible C, Tindal S, Wilcox S, Winters K, Engaging WK. Older adults to be more active where they live: audit tool development. Prev Chronic Dis. 2005;2(22) http://www.cdc.gov/pcd/issues/2005/apr/04_0142q.htm. Accessed 28 August 2017.
6. Millstein RA, Cain KL, Sallis JF, Conway TL, Geremia C, Frank LD, Chapman J, Van Dyck D, Dipzinski L, Kerr J, Glanz K, Saelens BE. Development, scoring, and reliability of the microscale audit of pedestrian streetscapes (MAPS). BMC Public Health. 2013;13:403.
7. Oyeyemi AL, Kasoma SS, Onywera VO, Assah F, Adedoyin RA, Akinrare AK, Ayeyei A, Chau SK, Chin E, Davis H, Dhillon M, Foster C, Oppert JM, Gavand KA, Cain KL, Frank LD, Saelens BE, Chapman J, Adams MA, Conway TL, Sallis JF, Bourdeaudhuij I, Geremia CM, Millstein RA, Lambert EV, Aryeetey R, Bartels C, Cribb T, Crisp J, Davey R, Dieli FN, Diercke D, Dinan M, Dinan PF, Dobson A, Doherty J, Doherty J, Dunstan F, Weber N, Araya R, Belt T, Lannom S, Lewis G, Patterson J, Thomas H, Jones P, Palmer S. An observation tool to assist with the assessment of urban residential environments. J Environ Psychol. 2005;25(3):293–305.
8. The Bicycle Federation of Australia (BFA) for the Australian Government and the Australian Bicycle Council. http://www.healthsmart.gov.au/bikeability/index.html. Accessed 10 August 2017.
9. Pirruccello R, Verloigne M, Gadlow C, Giovan A, Titze S, Foster C, Oppert JM, Rutter H, Ola P, Sjôström M, De Bourdeaudhuij I. Measuring physical activity-related environmental factors: reliability and predictive validity of the European environmental questionnaire ALPHA. Int J Behav Nutr Phys Act. 2010;7:48.
10. Cain KL, Gavand KA, Conway TL, Geremia CM, Millstein RA, Frank LD, Adams MA, Conway TL, Cain KL, Van Dyck D, Dipzinski L, Kerr J, Glanz K, Saelens BE. Development, scoring, and reliability of the microscale audit of pedestrian streetscapes (MAPS). BMC Public Health. 2013;13:403.
11. United Nations. Sixty-seventh session Political Declaration of the High Level meeting of the General Assembly on the Prevention and control of non-communicable diseases. http://www.un.org/ga/search/view_doc.asp?symbol=A/66/L.1. Accessed 28 August 2017.
12. Cain KL, Gavand KA, Conway TL, Geremia CM, Millstein RA, Frank LD, Saelens BE, Adams MA, Glanz K, King AC, Sallis JF. Developing and validating an abbreviated version of the microscale audit for pedestrian streetscapes (MAPS-abbreviated). J Transp Health. 2017;5:84–96.
13. Kealey M, Kruger J, Hunter R, Ivey S, Satariano W, Bayles C, Ramirez B, Bryant L, Johnson C, Lee C, Levinger D, Mctigue K, Moni C, Moudon AV, Plato D, Prohaska T, Sible C, Tindal S, Wilcox S, Winters K, Engaging WK. Older adults to be more active where they live: audit tool development. Prev Chronic Dis. 2005;2(22) http://www.cdc.gov/pcd/issues/2005/apr/04_0142q.htm. Accessed 28 August 2017.
14. Millstein RA, Cain KL, Sallis JF, Conway TL, Geremia C, Frank LD, Chapman J, Van Dyck D, Dipzinski L, Kerr J, Glanz K, Saelens BE. Development, scoring, and reliability of the microscale audit of pedestrian streetscapes (MAPS). BMC Public Health. 2013;13:403.
15. International Physical Activity and Environment Network. http://www.ipenproject.org. Accessed 28 August 2017.
16. Brownson RC, Hoehner CM, Day K, Forsyth A, Measuring SJF. The built environment for physical activity: state of the science. Am J Prev Med. 2009;36(Suppl 4):S99–123.
17. Frank LD, Schmid TL, Sallis JF, Chapman JE, Saelens BE. Linking objective physical activity data with objective measures of urban form. Am J Prev Med. 2009;36(Suppl 4):S99–123.
18. Cain KL, Millerstein RA, Sallis JF, Conway TL, Gavand KA, Frank LD, Saelens BE, Geremia CM, Chapman J, Adams MA, Glanz K, King AC. Contribution of streetscape audits to explanation of physical activity in four age groups based on the microscale audit of pedestrian streetscapes (MAPS). Soc Sci Med. 2014;116:82–92.
19. Sallis JF, Cain KL, Conway TL, Gavand KA, Millstein RA, Geremia CM, Frank LD, Saelens BE, Glanz K, King AC. Is your neighborhood designed to support physical activity? A Brief Streetscape Audit Tool Prev Chronic Dis. 2015;12:E141.
20. Brownson RC, Hoehner CM, Brennan LK, Cook RA, Elliott MB, McMullen KM. Reliability of two instruments for auditing the environment for physical activity. J Phys Act Health. 2004;1:189–207.
21. Sallis JF, Bull FC, Guthold R, Heath GW, Inoue S, Oyeyemi AL, Perez LG, Richards J, Hallall P. For the lancet physical activity series 2 executive committee. Progress in physical activity over the Olympic quadrennium. Lancet. 2016;388:1325–36.
22. Sallis JF, Cenin E, Conway TL, Adams MA, Frank LD, Pratt M, Salvo D, Schippinger J, Smith G, Cain KL, Davey R, Kerr J, Lai P-C, Mitas J, Reis R, Sarmiento OL, Schofield G, Troeslen J, Van Dyck D, De Bourdeaudhuij I, Owen N. Urban environments in 14 cities worldwide are related to physical activity. Lancet. 2016;387(10034):2207–17.
23. Katzmarzyk PT, Barreira TV, Broyles ST, Champagne CM, Chaput J-P, Larouche R, Gavand KA, Cain KL, Lambert EV, Aryeetey R, Bartels C, Tremblay MS, Sallis JF. Construct Validity of the neighborhood environment walkability scale for Africa. Med Sci Sports Exerc. 2017;49(3):482–91.
24. Oyeyemi AL, Kasoma SS, Onywera VO, Assah F, Akinrare AK, Ayeyei A, Chau SK, Chin E, Davis H, Dhillon M, Foster C, Oppert JM, Gavand KA, Cain KL, Lambert EV, Ayeyei A, Bartels C, Tremblay MS, Sallis JF. NISCOLE. For Africa: adaptation and reliability of a built environment questionnaire for physical activity in seven African countries. Int J Behav Nutr Phys Act. 2013;10:33.
25. Oyeyemi AL, Kasoma SS, Onywera VO, Assah F, Akinrare AK, Ayeyei A, Chau SK, Chin E, Davis H, Dhillon M, Foster C, Oppert JM, Gavand KA, Cain KL, Lambert EV, Ayeyei A, Bartels C, Tremblay MS, Sallis JF. ISNCPA. For Africa: adaptation and reliability of a built environment questionnaire for physical activity in seven African countries. Int J Behav Nutr Phys Act. 2013;10:33.
26. MMAPS-Global webpage for document downloads: http://www.randproject.org. Accessed 28 August 2017.
27. Frank LD, Sallis JF, Saelens BE, Leary L, Cain K, Conway T, Hess P. The development of a walkability index: application to the neighborhood quality of life study. Br J Sports Med. 2010;44:924–33.
28. Kerr J, Sallis JF, Owen N, Bourdeaudhuij I, Cerin E, Reis R, Sarmiento Q, Frömöl K, Mitaks J, Troeslen J, Christiansen LB, Macfarlane M, Salvo D, Schofield G, Badland H, Guillon-Grima F, Aguina-Ontoso I, Davey R, Bauman A, Saelens B, Riddoch C, Ainsworth B, Pratt M, Schmid T, Frank LD, Adams MA, Conway TL, Cain KL, Van Dyck D, Bracy NL. Advancing science
and policy through a coordinated international study of physical activity 
and built environments: IPEN methods. J Phys Act Health. 2013;10:581–601.
29. Cohen JA. Coefficient of agreement for nominal scales. Ed psych. 
Measurement. 1960;20:37–46.
30. Cicchetti DV. The precision of reliability and validity estimates re-visited: 
distinguishing between clinical and statistical significance of sample size 
requirements. J Clin Exp Neuropsychol. 2001;23:695–700.
31. Landis JR, Koch GG. The measurement of observer agreement for 
categorical data. Biometrics. 1977;33:159–74.
32. Giles-Corti B, Vernez-Moudon A, Reis R, Turrell G, Dannenberg AL, Badland 
H, Foster S, Lowie M, Sallis JF, Stevenson M, Owen N. City planning and 
population health: a global challenge. Lancet. 2016;388:2912–24.