The Irvine–Minnesota Inventory to Measure Built Environments

Development

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Background: Researchers and policymakers increasingly identify active living—including walking and bicycling for travel and recreation—as a potential strategy to increase rates of physical activity in the United States. Understanding the impact of the built environment on physical activity levels requires reliable methods to measure potentially relevant built environment features. This paper presents an audit tool—the Irvine Minnesota Inventory—that was designed to measure a wide range of built environment features that are potentially linked to active living, especially walking.

Methods: The inventory was created through a literature review, focus group interviews, a panel of experts, and field testing in 27 settings. The inventory was developed in 2003–2004.

Results: The Irvine Minnesota Inventory includes 162 items, organized into four domains: accessibility (62 items), pleasurability (56 items), perceived safety from traffic (31 items), and perceived safety from crime (15 items). (Some items are in multiple domains.) The inventory includes both a paper version and a version in Microsoft Access, to allow data to be input directly into the computer.

Conclusions: Limitations of methods used to develop the inventory are discussed. Strategies are offered for using the Irvine Minnesota Inventory to systematically and reliably measure characteristics of the built environment that are potentially linked to active living.
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Introduction

Insufficient physical activity is a major health problem in the United States. A broad literature[1–6] has led public health officials to identify an association between total caloric expenditure and all-cause mortality.[7,8] Yet leisure-time physical activity levels in the United States remain low. In recent national surveys, 60% of adults report little or no leisure-time physical activity.[9]

Recent scientific recommendations suggest that 30 daily minutes of moderate-intensity physical activity of the sort associated with walking or bicycling, accumulated throughout the day, can produce health benefits.[8,10] The results suggest an intriguing link between public health and urban planning that supports active living—primarily walking and bicycling for travel and recreation. Researchers and public health and urban planning advocates now hypothesize that changes in U.S. urban forms may reverse the decades-long trend toward sedentary lifestyles.[11–18] If true, this link can be a vital path to improved public health in the U.S. and elsewhere. This paper advances research on active living, by discussing the development of an audit tool to measure built environment features that are potentially linked to active living, and especially walking.

Research on links between urban form and active living has increased substantially in recent years, linked to broad interest among policymakers and spurred by major national research initiatives by the National Institutes of Health, the Centers for Disease Control and Prevention, and the Robert Wood Johnson Foundation.[19,20] A wide range of built environment features, both objective and perceived, may potentially support active living. These include characteristics that increase the pleasantness of pedestrian environments (e.g., street trees, attractive architecture)[21] as well as the convenience of walking for travel or recreation (e.g., directness of paths, presence of nearby destinations).[22] Also important are features linked to the safety of the environment from traffic and crime (e.g., appropriate traffic signals, absence of graffiti).[23,24]

Researchers face challenges in measuring features of the built environment that may support active living. Often, researchers investigate those features that can be easily measured using existing data, especially

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through the use of geographic information systems (GIS) data or by review of aerial maps (e.g., block length, number of intersections).[15,25–32] These methods circumvent the more labor-intensive, in-person observations of neighborhood built environment characteristics. Yet many built environment features that are potentially linked to active living have not yet been incorporated into local GIS databases (e.g., street trees, sidewalks). Others are best measured through direct observation (e.g., architectural character or maintenance).

This paper discusses an audit tool, the Irvine Minnesota Inventory, which can be used to systematically measure built environment features through in-person observation. Development of the inventory was funded by a grant from Active Living Research, a national program of the Robert Wood Johnson Foundation.

Background: Research on the Built Environment and Physical Activity

Research on the built environment and physical activity has been fragmented across several fields, including urban planning, architecture, environmental psychology, recreation/leisure studies, and public health. Historically, communication among these fields has been limited. Scholars in each field have often focused on isolated elements of physical activity or the built environment.

Urban design and planning researchers have tended to focus on accessibility, and on walking and bicycling as forms of travel.[33–36] Many studies have focused on what Cervero and Kockelman[25] called the three D's: density, diversity, and design. Broadly speaking, the following measures of built environment are common in past studies: population density, employment density, land-use mix, street grid pattern, public spaces such as parks or plazas, and the presence and quality of infrastructure to support nonmotorized travel.[15,25,28–30,37–43]

Researchers from public health and allied fields, in contrast, have regarded walking and bicycling as forms of physical activity and strategies to curb obesity. Studies have addressed a wide range of features, such as walking and bicycling infrastructure; parks, open space, and recreational facilities; features tied to perceived crime safety; traffic calming devices; destinations; aesthetics; and the weather.[17,18,21,44–60]

A wide range of built environment features have been hypothesized to affect active living, as indicated above. Measures are needed to support studies examining behaviors that range from purposeful, nonmotorized travel to leisure-time activity, and that capture a wide range of built environment features that may support these behaviors. Moudon and Lee[61] offer a comprehensive analysis of 31 existing audit tools for characterizing walking and bicycling environments. Together, these tools identify nearly 200 built environment features that may be linked to active living.[62]

Many existing audit tools are not designed for research purposes.[61] For example, audit tools are designed to rank roadway design for suitability for walking and bicycling.[63,64] The most widely known audit tool that is intended for research purposes is the systematic pedestrian and cycling environmental scan (SPACES) tool developed by Pikora et al.[65] The SPACES tool is simple to use. Data are collected on a single page of paper for each street segment (two facing sides of a block). The tool has high intra- and inter-rater reliability (>75% agreement among three observers for inter-rater reliability). The SPACES tool includes many characteristics related to walking and bicycling paths (slope, path obstructions). It also provides general information about land uses, street characteristics, and perceived attractiveness and difficulty for walking and bicycling.

The brevity of the SPACES tool may impede its use in some studies. The SPACES tool measures a moderate number (37) of built environment features. It does not include many features that planning and design researchers may want to measure for studies of planning and design "interventions" and active living. Such features would include elements such as street type (alley, pedestrianized streets where cars have been removed), the presence of vertical mixed use or front porches, or the prominence of garage doors or historic architecture. In addition, the SPACES tool measures some built environment features, such as land use, in fairly broad categories. Researchers may require more detailed information about these features. For example, the SPACES tool includes eight categories of land use, including one category (each) for housing and nature features. Researchers may want to compare environments that include single versus multifamily housing, or housing that is attached versus detached. They may need to know whether nature features comprise woods, ponds, or agricultural land.

Also, the SPACES tool is available in paper format only. After observing features and marking them on paper, researchers separately enter responses to a computer program for analysis, which requires additional time for data entry and introduces an opportunity for error in transferring data. An audit tool that allows observational data to be entered directly into computer software would increase efficiency and could reduce error.

Brownson et al.[62] at St. Louis University also recently developed two versions of an audit tool, including a checklist tool that includes dichotomous responses that is intended for use by community groups, and an "analytic" tool (with Likert scale and ordinal responses) designed for research purposes. The analytic tool is hereafter referred to as the "St. Louis tool." Positive aspects of the St. Louis tool include its incorporation of a hand-held personal digital assistant (PDA) device for

collecting data. The St. Louis tool also measures a wide range of features linked to transportation, land uses, recreational facilities, physical disorder, signage, and social environment. This tool measures only a small number of features related to the architectural environment, however. One question (for each feature) asks whether there are "attractive" features (attractive architecture, building variety, open space), and whether there are "comfort" features (shade trees, benches). Detailed measures of individual "attractive" or "comfort" features are not included.

Researchers tested the St. Louis tool for reliability in both low- and high-income areas. The tool was most reliable in measuring transportation and land-use items. Its questions on physical disorder, signage, and social environment tended to have lower reliability.[62] A more comprehensive measure of built environment features is needed to test the wide range of hypotheses about relationships between the built environment and active living. The Irvine Minnesota Inventory was developed to fill this gap.

Conceptual Framework: Built Environment and Physical Activity

Factors that may influence physical activity include the following characteristics of the built environment: accessibility, pleasurability, perceived safety from traffic, and perceived safety from crime.

Accessibility is the perceived ease with which destinations can be reached and terrain can be traversed during physical activity for travel and/or recreation. Built environment features linked to accessibility include land-use mix; density of origins; density of destinations, including places for exercise and activity, such as recreational facilities; integration of uses; accommodations for public transportation; street pattern; slope of streets and walkways; and physical barriers and amenities for walking or bicycling.[15,22,25,46,49–52,62,66,67] Of course, individual built environment features may influence more than one characteristic. For example, the presence of street trees may influence pleasurability and perceived traffic safety. Land use is included as part of accessibility, since a finely integrated mix of land uses (residential, retail, civic) may provide destinations near home or work that can be reached by walking or bicycling.

Pleasurability is the perceived attractiveness of the setting for physical activity for travel and/or recreation. Pleasurability includes aesthetic appeal, the presence of attractive destinations (places that contribute visually to the environment, such as farmers' markets and parks), and comfort. Other researchers have differentiated pleasurability into subdomains, such as functionality and aesthetics.[65] Often, however, built environment features that enhance pleasurability do so by addressing function and aesthetics simultaneously—that is, by accommodating human needs in ways that increase attractiveness. For example, the presence of street vendors or the availability of outdoor dining addresses the need to eat while also increasing urban vitality. Thus, issues of function and aesthetics are not separated in this model.

The fields of urban design and environment–behavior studies include considerable literature on the qualities of pleasurable urban environments. Built environment features linked to pleasurability include architectural character; aesthetic quality; contextual compatibility (the visual cohesiveness of nearby buildings and spaces); desirable views; features linked to attractive human environments (e.g., active façades, public spaces); features that accommodate human needs and comfort (e.g., street furnishings, sidewalks); and the presence of other users to create a lively setting.[68–77] A limited number of pleasurability features have been examined in existing research on active living.

Perceived safety from traffic involves individuals' beliefs that limited opportunities exist in the setting for injury from autos or other vehicles. Perceived traffic safety is not the same as actual traffic safety, although one can assume that they are closely related. In making decisions regarding physical activity, perceived traffic safety may influence individual behavior, more so than actual traffic safety. Built environment features linked to perceived traffic safety include features that create physical and/or psychological barriers to high traffic speeds (e.g., low speed limits, angled parking); features that divert vehicle traffic from a setting (e.g., cul de sacs, neighborhood entry monuments that discourage through traffic in residential areas); features that allow safe street crossing for pedestrians and bicyclists (e.g., stop and yield signs, curb bulb-outs); features that separate pedestrians and bicyclists from vehicles (e.g., bike lanes, sidewalks); and features that increase the interaction of pedestrians and bicyclists with drivers, thereby encouraging drivers to pay greater attention (e.g., woonerven or shared streets).[23,46,55,57,70,78]

Perceived safety from crime involves individuals' beliefs that limited opportunities exist in the setting for crime victimization or harassment during physical activity for travel and/or recreation. Perceived crime safety is only indirectly related to actual crime safety, that is, the number of crimes that occur.[79] Both actual and perceived crime safety are important.[67] Perceived crime safety may have the greatest influence on individuals' decision to walk or bicycle, since individuals rarely possess accurate or specific information on actual crime rates. Examples of built environment features linked to perceived crime safety include maintenance (e.g., absence of graffiti); street lighting; features that provide "eyes on the street" for surveillance (e.g., front porches); the absence of land uses and individuals that are perceived as threatening (e.g., adult clubs, intoxi-

cated persons).[24,53,59,62,79–81] As with pleasurability, not all aspects of perceived crime safety can be reliably measured. The inventory focuses on those aspects that can be reliably measured using quantitative measures.

Methods

This section describes the development of the Irvine–Minnesota Inventory for measuring built environment features linked to active living. Development of the inventory involved a literature review, focus group interviews, a field survey, and a panel of experts. The inventory was developed in 2003–2004. Methods were intended to identify built environment features that may support active living for inclusion in the inventory. The research team tried to identify a wide range of such features so that the resulting inventory could be used to explore numerous hypotheses about active living. Researchers identified built environment features in the current literature that were hypothesized to support physical activity (e.g., presence of sidewalks, block length). Researchers also identified novel physical features that are not commonly included in existing literature, but that might in fact impact walking or bicycling (e.g., impassable land uses, such as gated communities or major industrial complexes, that could present barriers to through travel).

Developing the Inventory: Identifying Built Environment Features

Literature review. We reviewed current multidisciplinary literature on active living to identify built environment features linked with active living. The literature reviewed included published empirical reports of research and also "advocacy" pieces. We also reviewed seven existing audit tools for measuring built environment features linked to active living, including the SPACES tool and an earlier version of an audit tool that we developed.[23,65] (The St. Louis audit tool was not reviewed at this stage, as it was not yet available.) We focused on identifying features that could be measured objectively, though some subjective features were also identified (e.g., architectural character). The conceptual framework was used to help guide the literatures that were reviewed and the types of features that were identified.

Based on the literature review, a list was created of built environment features that were hypothesized to affect active living. Items on the list were operationalized, and a draft inventory was created. The draft inventory contained measures that could be observed "in person" by a researcher walking through a setting (this process is described later). A few items were included from the SPACES tool, which were reliably measured in tests of that tool.

Focus groups. The research team next conducted three focus group interviews with specific groups who might be overlooked in existing literature on active living, including low-income persons, teens, and nonwhite college students. The focus group interviews were intended to identify additional built environment features that might impact active living for these groups. Focus groups were not intended to be universal or representative of all members of these groups. Focus group participants were recruited through various methods, including posters placed in public settings (for teens and low-income individuals) and convenience sampling (for nonwhite college students). Each interviews included from five to seven participants.

During focus group interviews, participants were asked to consider aspects of their local environments that might support or impede walking or bicycling for travel and recreation. Questions asked participants to describe built environment features in the neighborhoods where they lived, worked, or attended school. Participants were asked to describe physical features of those places that might impede or support walking or bicycling there. They were also asked to consider how the design of these or other places could be improved to facilitate walking or bicycling. Finally, participants were asked to consider different kinds of people (in terms of income, race/ethnicity, age) and how neighborhood design could make it easier for different groups to walk or bicycle. Focus group interviews lasted approximately 1 hour. Interviews were tape recorded, and notes were made of any built environment features that were mentioned.

Initially, the research team had planned to conduct additional focus group interviews, including interviews with seniors and with middle- and upper-income individuals. The first three focus group interviews did not, however, identify many additional built environment features that were not already included in the draft inventory. It may have been that this topic (i.e., links between built environment features and walking and bicycling) was one that most individuals had not previously considered. Participants' responses tended to identify only the more obvious built environment characteristics (e.g., presence of sidewalks and nearby destinations). Since the purpose of the focus group interviews was to identify additional built environment features to add to the inventory, and not to assess the relative importance of different features to diverse groups, a decision was made to halt focus groups and to concentrate instead on other methods that might prove more fruitful in this regard.

Field survey. A field survey of 27 different settings was conducted to identify additional built environment features that might be linked to active living. The field survey was conducted primarily in Southern California; 2 of the 27 settings were located in Northern California. Settings were located in 5 counties and in 15 different cities.

Settings were selected through purposive sampling aimed at maximum variation of environments.[82] The sample included representatives of settings that are hypothesized to support active living, such as "new urbanist" developments and older urban neighborhoods. The sample also included representatives of settings that are hypothesized to impede active living, such as suburban residential neighborhoods. Some novel types of settings were included, such as transit-oriented developments and suburban entertainment centers. These novel settings were seen as of potential interest to future researchers, and so their physical features were included in the inventory. Additionally, the sample included several "nonlinear" settings (i.e., settings that are not organized by a network of streets, face inward, and are not regularly intersected by streets, such as some outdoor shopping malls or campuses). Nonlinear settings were included so that a version of the instrument could be developed to be used in such places. (This version of the inventory is included in the code book.) Settings were selected to vary in age,

Table 1. Settings observed to identify built environment features potentially linked to active living

Urban form	Urban/suburban
Residential neighborhood	Suburban (2) Older urban (2) Dense urban (2)
Residential neighborhood, inwardly oriented development	Suburban (2)
Small town (2)	—
Rural	—
Mixed use	New urban development (3)
Mixed use	Urban
Mixed use, nonlinear setting	Suburban
Employment center	Suburban Urban
Employment center, nonlinear setting	Suburban (2)
Entertainment center	Suburban Urban
Entertainment center, inwardly oriented development	Suburban Urban
Transit-oriented development	Suburban (2) Urban

physical features, and, in the case of residential areas, in income level. Table 1 characterizes the settings that were observed in the field survey.

To conduct the field survey, one of the authors walked through each setting, searching for built environment features that might impact active living in that setting and that were not already included in the draft inventory. As additional features were identified, we carefully deliberated whether to include each new feature in the inventory. We considered how common the feature might be and its potential importance for active living. The value that would be added by including the feature in the inventory was weighed, versus the difficulty of reliably measuring that feature and the added time that would be required for observing the feature. For example, in one setting, permanent play equipment—a swing set—was observed in front of a home. This feature was considered for possible inclusion in the inventory, since permanent play equipment might increase active play by children. After consideration, the research team decided not to include this feature, reasoning that permanent play equipment might be more typically located behind homes, where it would be difficult to reliably observe. As features were selected for inclusion, they were operationalized and added to the draft inventory.

Panel of experts. Midway through the field survey, a panel of five experts was convened to review the draft inventory and the proposed procedures for using it. Experts represented the fields of urban planning, health, GIS, and environmental psychology. Experts participated in a 2-hour conference call. In advance, experts received a description of the project, the draft inventory, a list of questions (described below), and the draft codebook, which outlined procedures for using the inventory. During the panel review, experts were asked whether the inventory was missing any key built environment features. They were asked whether the inventory could be improved to enhance clarity or ease of use. Experts were asked to suggest improvements for the proposed data collection procedures for using the inventory. They were also asked to suggest ways to make sure that data collected with the inventory would lend itself to fruitful analysis.

Experts' feedback dealt mostly with detailed aspects of the inventory and data collection procedure. Feedback included suggestions for clarifying, modifying, and adding specific items. For example, experts suggested that "settings" and "segments" be defined more clearly (see below). They recommended rewording some terms so as not to convey value judgments about specific features (e.g., change an item measuring "threatening land uses"—liquor stores and adult-oriented uses—to instead refer to "other uses"). Experts also identified items to add to the inventory (e.g., vertical mixed use, additional traffic-calming features.) Additionally, experts recommended that the research team develop a list of common research questions that future researchers might want to use the inventory to investigate, and then assess whether the inventory included the appropriate items to examine those questions.

The research team modified the draft inventory and data collection procedures in light of experts' recommendations. Items were clarified as suggested. Several features were added to the instrument (e.g., more traffic-calming features). Some suggested features were not added because these items might require design training to assess (e.g., architectural coherence). Other features were not added because they were judged to be too indirectly linked to active living to warrant additional time for data collection (e.g., amount of historical ornamentation on buildings). As suggested, the research team generated several research questions that the inventory might be used to test, including the following:

- Are new urbanist neighborhoods associated with more physical activity, compared to traditional suburban developments?
- Are more pleasurable settings associated with more physical activity?
- Which built environment features are associated with walking for travel versus walking for recreation?
- Are there differences in the associations between built environment features and physical activity for different groups (e.g., by gender, age)?

Several features were added to the instrument based on consideration of these questions (e.g., garage doors, front porches).

Pilot testing. The research team pilot tested the draft inventory in two settings. The inventory was refined to eliminate or revise confusing items. The order of items in the instrument was modified, and data collection procedures were refined to increase ease of data collection and to enhance reliability.

At this point, the University of California-Irvine research team was approached by researchers at the University of Minnesota. The Minnesota researchers were interested in using the draft inventory as part of an ongoing study to collect data on built environment features associated with active living. These researchers further pilot tested and refined the paper version of the draft inventory to increase the ease and efficiency of data collection. They changed its format to reduce the number of pages, standardized rating scales,

clarified some items in the instrument, and clarified instructions to reduce potential error in data collection.

The final inventory (after reliability testing) included 162 items.[83] Items were associated with the four domains as follows: accessibility (62 items); pleasurability (56 items); perceived safety from traffic (31 items); and perceived safety from crime (15 items). Some items pertained to more than one domain. Items were associated with domains based on the researchers' expertise and on associations in the existing literature. (The instrument, code book, and training protocol are available at www.ajpm-online.net.) The following section describes procedures for collecting data with the Irvine–Minnesota Inventory.

Using the Irvine Minnesota Inventory

The Irvine–Minnesota Inventory is designed for in-person ("field") observations of built environment features. The inventory is available in both a paper and a tablet PC survey (the latter uses a version of the instrument in ACCESS software). (Both versions are available at www.ajpm-online.net.) In the tablet PC version, data can be entered directly into the computer during observations. Also, the tablet PC version limits allowable responses so that the observer cannot enter "incorrect" responses.

The inventory was designed to be used by a team of two observers for each setting. Settings were conceptualized as discrete (non-overlapping) places that are roughly as large as residential neighborhoods or commercial districts. Settings included residential and also nonresidential places (commercial district, central city). Settings varied in size. As noted earlier, the instrument focuses mainly on characteristics potentially linked to walking and on settings that are of a "walkable" size. Research that focuses primarily on biking may require a larger scale and additional features that are not included in this inventory. To identify settings, researchers considered criteria such as legal jurisdictions, place names, consistency of architectural character, and census geography. (The latter definition allowed researchers to also incorporate GIS and other data that are organized by census block.)

In testing the instrument for reliability, two or three persons observed each setting (results of reliability testing are reported elsewhere).[83] Observers were undergraduate student research assistants. They varied in terms of age, education level, and other characteristics. Qualifications for observers included being able to read the inventory and the code book, participate in training, travel (walking or driving) through the setting to conduct observations, and collect and input data according to instructions. Observers were trained in a series of classroom and field training meetings.[83] (The code book and the training protocol are available at www.ajpm-online.net.)

Sampling Segments

Each setting to be observed was identified on a map before data collection. Maps were printed at a level of resolution that showed all segments in a setting. (MapQuest produced reasonable-quality maps for this use.) Each segment in the setting was numbered on a map (a segment includes two facing block fronts). Before beginning observation, the lead graduate student research assistant surveyed the entire setting in person to identify a sample of segments to be observed. (It was determined that all sampling should be conducted by a member of the research team with expertise in active living, which the graduate student research assistant possessed. Observers did not select the sample of segments themselves.) The sampling procedure was intended to reduce the number of segments to be observed, while retaining all segments with important unique features that could impact active living in that setting.

Beginning with the first segment in the setting, the research assistant included segments in the sample if the current segment differed from the previously observed segment in terms of any of four key features: type of land uses, presence of a sidewalk network, presence of barriers, and whether the segment looks like a "nice" place to walk. These four features were intended to differentiate various types of segments in a setting, such that the full range of types of segments in a setting would be included in the sample. The first three criteria were objective. They were designed to capture major differences between a segment and the previous segment, such that novel segments would be included. The last criterion, which was intentionally subjective, provided some leeway in including in the sample those segments that were believed to be different in some other significant way that was not captured by more objective criteria (e.g., a segment with a large number of abandoned buildings, where previous segments had none).

In sampling segments, a maximum of three adjacent segments were skipped. At that point, the following segment was included in the sample, even if it was similar to the last observed segment in these four features. This sampling scheme was adaptive, in the sense of altering the probability that a given segment was sampled depending on the previous segment. To state this notion more formally, the probability of an element, n, being sampled depended on the differences between its characteristics and those of the previous element, $n - 1$. Such an approach is often used when elements are extremely difficult to find, such as homeless people or the "infected."[84]

The Minnesota team did not use this sampling approach, but instead chose a simple random sample that yielded a representative sample with known probabilities of selection to enable better calculation of sampling weights and proper sample survey inferences.

What This Study Adds . . .

Researchers and policymakers have identified the design of the physical environment as a potentially important part of strategies to promote physical activity by making it easier for individuals to walk and bicycle as part of their everyday activities.

This article presents a reliable research instrument for measuring built environment features that may be linked to physical activity.

Collecting Data

Items were arranged in the inventory in the most sensible order for data collection. The inventory also included instructions for measuring an additional five features using GIS, where these measurements are more reliable and easier to obtain (e.g., block length, street width). All items in the inventory itself were measured through in-person observation (i.e., an observer in the field with a paper or computer audit tool, physically noting the presence or absence of each feature). The instrument included eight items that pertained to the overall setting (including predominant land use in the setting, major barriers to walking or bicycling, and the presence of alleys or greenbelts). All other features were measured at the segment level. To observe a segment, the observer stood at the first point on the segment and answered as many questions as possible. The observer then walked the segment, observed remaining features, and completed the inventory for that segment. Sixteen items pertaining to street intersections (curb cuts, crosswalks) were measured at both the beginning and end of each segment. After completing observations for the segment, the observer then began again at the next segment in the sample, until all segments in the sample were observed.

Conclusions

Several limitations in the research methods and in the final inventory warrant discussion. One limitation involved the small number of focus groups that were conducted in developing the inventory. As noted, focus group interviews generated few new built environment features outside of those identified in the literature review. Focus group interviews might have been more productive if more interviews had been conducted for each group. Also, focus group questions might have generated more novel responses if participants had been questioned about how their own identities (as teens, low-income individuals) influenced their opportunities for active living. Additionally, the group of nonwhite college students may have been too similar to the research team (in terms of education background, income) to adequately represent a range of experiences in terms of race/ethnicity.

The inventory itself includes a large number of items for data collection and analysis (162 items). The inventory may be too time consuming to use in its entirety in settings with many segments, when sampling of segments is not employed. Future researchers may elect to shorten the instrument by including only items in particular domains of interest. For instance, to examine the impact of neighborhood accessibility on walking, researchers could measure only those items in the instrument that are part of the accessibility domain. Alternately, researchers could measure a subset of items in each domain, perhaps selecting only those items that have been found to be associated with walking or bicycling in existing research. This latter strategy is somewhat limiting, in that research on built environments and active living is still in the early stages. It is not yet possible to report on the validity of many items in the inventory. Testing the items in the inventory for validity is an important ongoing agenda for research.

Although the inventory is lengthy, it is not exhaustive of all built environment features that might be linked to active living. The inventory includes numerous features that are part of the architectural environment or "streetscape" (porches, building facades, historical architecture). It includes few items that measure the characteristics of parks or playgrounds, beyond noting the presence of these places. Other researchers are developing measures that are more appropriate for the detailed examination of parks and playgrounds.[67] Also, the inventory does not include all possible features related to sidewalks and streets (e.g., distance of sidewalk from curb, sidewalk material). The existing SPACES tool measures these features in considerable detail, and may be more useful than the inventory for studies that focus on these features.[65] Additionally, the Irvine–Minnesota Inventory does not measure weather. In developing the instrument, researchers concentrated especially on those built environment features that might be modified to promote active living; hence, weather was omitted. On reflection, including a measure of weather in the inventory would have been useful for some future applications of the inventory.

Although the Irvine–Minnesota Inventory is designed for measuring built environment features linked to active living, researchers may elect to use the instrument to examine other issues. For example, researchers might modify the inventory to include only those items linked to certain place types (residential suburbs, new urbanist developments), or other issues (e.g., sense of community, fear of crime). In all such cases, researchers would need to review the existing literature on the pertinent issue or place type, identify built environment features that are linked to that issue or place type (such as bars on windows, graffiti, and poor mainte-

nance, for fear of crime), and identify the items in the inventory that measure those features. Researchers are encouraged to adapt the instrument to suit their specific research questions and interests.

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References

1. Blair SN, Kohl HW, Paffenbarger RS, Clark DG, Cooper KH, Gibbons LW. Physical fitness and all-cause mortality: a prospective study of healthy men and women. JAMA 1989;17:2395–401.
2. Ekelund L, Haskell WL, Johnson JL, Whaley FS, Criqui MH, Sheps DS. Physical fitness as a predictor of cardiovascular mortality in asymptomatic North American men: the Lipid Research Clinics Mortality follow-up study. N Engl J Med 1988;319:1379–85.
3. Leon AS, Connett J, Jacobs DR, Rauramaa R. Leisure-time physical activity levels and risk of coronary heart disease and death: The Multiple Risk Factor Intervention Trial. JAMA 1987;258:2388–95.
4. Morris JN, Clayton DG, Everitt MG, Semmence AM, Burgess EH. Exercise in leisure time: coronary attack and death rates. Br Heart J 1990;63:325–34.
5. Paffenbarger RS, Hyde RT, Wing AL, Hsieh CC. Physical activity, all-cause mortality, and longevity of college alumni. N Engl J Med 1986;314:605–13.
6. Sandvik L, Erikssen J, Thaulow E, Erikssen G, Mundal R, Rodahl K. Physical fitness as a predictor of mortality among healthy, middle-aged Norwegian men. N Engl J Med 1993;328:533–7.
7. Pate R, Pratt M, Blair S, et al. Physical activity and public health: a recommendation from the Centers for Disease Control and Prevention and the American College of Sports Medicine. JAMA 1995;273:402–7.
8. U.S. Department of Health and Human Services. Physical activity and health: a report of the Surgeon General. Atlanta GA: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, 1996.
9. Caspersen CJ, Merritt RK. Physical activity trends among 26 states, 1986–1990. Med Sci Sports Exerc 1995;27:713–20.
10. Office of the Surgeon General. Overweight and obesity: what you can do, 2005. Available at: www.surgeongeneral.gov/topics/obesity/calltoaction/fact_whatyoucando.htm. Accessed March 10, 2005.
11. Burden D. Streets and sidewalks, people and cars: the citizens' guide to traffic calming. Sacramento CA: Local Government Commission Center for Livable Communities, 2000.
12. Fizgibbons ML, Stolley MR. Environmental changes may be needed for prevention of overweight in minority children. Pediatr Ann 2004;33:45–9.
13. Frank LD, Engelke PO, Schmid TL. Health and community design: the impact of the built environment on physical activity. Washington DC: Island Press, 2003.
14. Frumkin H, Frank L, Jackson R. Urban sprawl and public health. Designing, planning, and building for healthy communities. Washington DC: Island Press, 2004.
15. Handy S, Boarnet MG, Ewing R, Killingsworth RE. How the built environment affects physical activity: Views from urban planning. Am J Prev Med 2002;23(suppl 2):64–79.
16. Local Government Commission. New thinking for a new transportation age. Focus on Liveable Communities. Sacramento CA: Center for Liveable Communities, no date (fact sheet).
17. Owen N, Leslie E, Salmon J, Fotheringham MJ. Environmental determinants of physical activity and sedentary behavior. Exerc Sports Sci Rev 2000;28:153–8.
18. Sallis JF, Bauman A, Pratt M. Environmental and policy interventions to promote physical activity. Am J Prev Med 1998;15:379–97.
19. Centers for Disease Control and Prevention. Active community environments. Available at: www.cdc.gov/nccdphp/dnpa/aces.htm. Accessed February 21, 2005.
20. Robert Wood Johnson Foundation. Active living research. Available at: www.activelivingresearch.org. Accessed February 21, 2005.
21. Ball K, Bauman, A, Leslie E, Owen N. Perceived environmental aesthetics and convenience and company are associated with walking for exercise among Australian adults. Prev Med 2001;33:434–40.
22. Frank LD, Schmid TL, Sallis JF, Chapman J, Saelens BE. Linking objectively measured physical activity with objectively measured urban form. Am J Prev Med 2005;28(suppl 2):117–25.
23. Boarnet MG, Day M, Anderson C, McMillan T, Alfonzo M. Safe routes to school, vols. 1 and 2. California Department of Transportation, 2003. Available at: www.dot.ca.gov/hq/LocalPrograms/SafeRTS2School/SR2SVol_1_final11-05-03.pdfandwww.dot.ca.gov/hq/LocalPrograms/SafeRTS2School/SR2SVol_2_final11-05-03.pdf. Accessed May 13, 2005.
24. Centers for Disease Control and Prevention. Neighborhood safety and prevalence of physical inactivity in selected states, 1996. MMWR Morb Mortal Wkly Rep 1999;48:143–6.
25. Cervero R, Kockelman K. Travel demand and the 3Ds: density, diversity, and design. Transp Res D Transp Environ 1997;2:199–219.
26. Dill J. Measuring network connectivity for bicycling and walking. Presented at the Joint Congress of ACSP-AESOP, Leuven, Belgium, 2003 (draft).
27. Forsyth A. Environment and physical activity: GIS protocols, version 2.0. Minneapolis: Metropolitan Design Center, 2005. Available at: www.designcenter.mn.edu/projects/current/current_research_areas/walkability/twin_cities_walking/epaGISprotocols.html. Accessed March 15, 2005.
28. Greenwald M, Boarnet M. The built environment as a determinant of walking behavior: analyzing non-work pedestrian travel in Portland, Oregon. Transp Res Rec 2002;1780:33–42.
29. Krizek K. Residential relocation and changes in urban travel: does neighborhood-scale urban form matter? J Am Plann Assoc 2003;69:265–81.
30. Krizek K. Operationalizing neighborhood accessibility for land use-travel behavior research and regional modeling. J Plann Educ Res 2003;22:270–87.
31. McCann BA, Ewing R. Measuring the health effects of sprawl: a national analysis of physical activity, obesity and chronic disease. Smart Growth America Surface Transportation Policy Project. Washington DC: , 2003.
32. Moudon AV, Lee C, Cheadle A, et al. Walkable and Bikable Communities Project: a draft report on findings from the walking models. Seattle: University of Washington Urban Form Lab, 2004.
33. Handy S, Neimeier D. Measuring accessibility: an exploration of issues and alternatives. Environ Plann A 1997;29:1175–94.
34. Mitchell RB, Rapkin C. Urban traffic: a function of land use. New York: Columbia University Press, 1954.
35. Vickerman R. The demand for nonwork travel. J Transp Econ Policy 1972;6:176–210.
36. Wachs M, Kumagai TG. Physical accessibility as a social indicator. Socioecon Plann Sci 1973;7:437–56.
37. Boarnet M, Crane R. Travel by design: the influence of urban form on travel. New York: Oxford University Press, 2001.
38. Boarnet MG, Crane R. The influence of land use on travel behavior: empirical strategies. Transp Res A 2001;35:823–45.
39. Handy S. Regional versus local accessibility: implications for nonwork travel. Transp Res Rec 1993;1400:58–66.
40. Handy S, Clifton K. Local shopping as a strategy for reducing automobile travel. Transportation 2001;28:317–46.
41. Handy S, Clifton K, Fisher J. The effectiveness of land use policies as a strategy for reducing automobile dependence: a study of Austin neighborhoods. College Station TX: Texas A & M University, Southwest Region University Transportation Center, 1998.
42. Hess PM, Moudon AV, Snyder MC, Stanilov K. Site design and pedestrian travel. Transp Res Rec 1999;1674:9–19.
43. Saelens B, Sallis J, Frank L. Environmental correlates of walking and cycling: findings from the transportation, urban design, and planning literatures. Ann Behav Med 2003;25:80–91.
44. Baker EA, Brennan LK, Brownson R, Houseman RA. Measuring the determinants of physical activity in the community: current and future directions. Res Q Exerc Sport 2000;71:146–58.
45. Berrigan D, Troiano RP. The association between urban form and physical activity in U.S. adults Am J Prev Med 2002;23(suppl 2):74–9.
46. Craig CL, Brownson RC, Cragg SE, Dunn AL. Exploring the effect of the environment on physical activity. A study examining walking to work Am J Prev Med 2002;23(suppl 2):36–43.

47. de Bourdeaudhuij I, Sallis JF, Saelens BE. Environmental correlates of physical activity in a sample of Belgian adults. Am J Health Promot 2003;18:83–92.
48. Gauvin L, Richard L, Craig CL, Spivock M, Riva M, Forster M, et al. From walkability to active living potential: an "econometric" validation study. Am J Prev Med 2005;28(suppl 2):126–33.
49. Giles-Corti B, Donovan RJ. Socioeconomic status differences in recreational physical activity levels and real and perceived access to a supportive physical environment. Prev Med 2002;35:601–11.
50. Giles-Corti B, Broomhall MH, Knuiman M, Collins C, Douglas K, Ng K, et al. Increasing walking: how important is distance to, attractiveness, and size of public open space? Am J Prev Med 2005;28(suppl 2):169–76.
51. Hoehner CM, Ramirez LKB, Elliott MB, Handy SL, Brownson RC. Perceived and objective environmental measures and physical activity among urban adults. Am J Prev Med 2005;28(suppl 2):105–16.
52. Humpel N, Owen N, Leslie E. Environmental factors associated with adults' participation in physical activity. Am J Prev Med 2002;22:188–99.
53. Huston SL, Evenson KR, Bors P, Gizlice Z. Neighborhood environment: access to places for activity, and leisure-time physical activity in a diverse North Carolina population. Am J Health Promot 2003;18:58–69.
54. King WC, Brach JS, Belle S, Killingsworth R, Fenton M, Kriska AM. The relationships between convenience of destinations and walking levels in older women. Am J Health Promot 2003;18:74–82.
55. Merom D, Bauman A, Vita P, Close G. An environmental intervention to promote walking and cycling—the impact of a newly constructed Rail Trail in Western Sydney. Prev Med 2003;36:235–42.
56. Molnar BE, Gortmaker SL, Bull FC, Buka SL. Unsafe to play? Neighborhood disorder and lack of safety predict reduced physical activity among urban children and adolescents. Am J Health Promotion 2004;18:378–86.
57. Morrison D, Thomson H, Petticrew M. Evaluation of the health effects of a neighbourhood traffic calming scheme. J Epidemiol Community Health 2004;58:837–40.
58. Sallis JF, Hovell MF, Hofstetter CR, et al. Distance between homes and exercise facilities related to frequency of exercise among San Diego residents. Public Health Rep 1990;105:179–85.
59. Sallis JF, Johnson MF, Calfas KJ, Saparosa S, Nichols JF. Assessing perceived physical environmental variables that may influence physical activity. Res Q Exerc Sport 1997;68:345–51.
60. Wilcox S, Bopp M, Oberrecht L, Kammermann SK, McElmurray CT. Psychosocial and perceived environmental correlates of physical activity in rural and older African American and white women. J Gerontol 2003;58:P329–37.
61. Moudon AV, Lee C. Walking and bicycling: an evaluation of environmental audit instruments. Am J Health Promot 2003;18:21–37.
62. Brownson, RC, Hoehner CM, Brennan LK, Cook RA, Elliot MB, McMullen KM. Reliability of 2 instruments for auditing the environment for physical activity. J Phys Activ Health 2004;1:191–208.
63. Dixon L. Bicycle and pedestrian level of service performance measures and standards for congestion management systems. Trans Res Rec 1996; 1538:1–9.
64. Khisty CJ. Evaluation of pedestrian facilities: beyond the level of service concept. Transp Res Rec 1994;1438:45–50.
65. Pikora TJ, Bull FC, Jamrozik K, Knuiman M, Giles-Corti B, Donovan RJ. Developing a reliable method to measure the physical environment for physical activity. Am J Prev Med 2002;23:187–94.
66. Bauman AE, Sallis JF, Dzewaltowski DA, Owen N. Toward a better understanding of the influences on physical activity. The role of determinants, correlates, causal variables, mediators, moderators, and confounders Am J Prev Med 2002;23(suppl 2):5–14.
67. Bedimo-Rung AL, Mowen AJ, Cohen DA. The significance of parks to physical activity and public health. A conceptual model Am J Prev Med 2005;28(suppl 2):159–68.
68. Altman A, Zube E. Public places and spaces. New York: Plenum Press, 1989.
69. Bacon EN. Design of cities. New York: Viking Press, 1974.
70. Carr S, Rivlin L, Francis M, Stone A. Public space. New York: Cambridge University Press, 1992.
71. Gehl J. Life between buildings: using public space. New York: Van Nostrand Reinhold, 1987.
72. Jacobs A. Great streets. Cambridge MA: MIT Press, 1993.
73. Leccese M, McCormick K, Charter of the new urbanism. New York: McGraw Hill, 2000.
74. Loukaitou-Sideris A, Banerjee T. Urban design downtown: poetics and politics of form. Berkeley: University of California Press, 1998.
75. Nasar JL. Environmental aesthetics: theory, research, and applications. Cambridge: Cambridge University Press, 1988.
76. Nasar JL. The evaluative image of the city. Thousand Oaks CA: Sage, 1998.
77. Whyte WH. The social life of small urban spaces. New York: Conservation Foundation, 1980.
78. Agran PF, Winn DG, Anderson CL, Tran C, Del Valle CP. The role of the physical and traffic environment in child pedestrian injuries. Pediatrics 1996;98:1096–103.
79. Day K. Strangers in the night? Women's fear of sexual assault on urban college campuses. J Architec Plann Res 2000;16:289–312.
80. Lee RE, Cubbin C. Neighborhood context and youth cardiovascular health behaviors. Am J Public Health 2002;92:428–36.
81. Loukaitou-Sideris A. Hot spots of bus stop crime: the importance of environmental attributes. J Am Plann Assoc 1999;65:395–411.
82. Miles MB, Huberman AM. Qualitative data analysis. A sourcebook of new methods. Beverly Hills CA: Sage, 1984.
83. Boarnet MG, Day K, Alfonzo M, Forsyth A. The Irvine–Minnesota Inventory to measure built environments—reliability testing. Am J Prev Med 2006; 30:144–52.
84. Thompson WD, Seeber SD. A reappraisal of the kappa coefficient. J Clin Epidemiol 1988;41:949–58.