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Promoting Active Urban Aging: A Measurement Approach to Neighborhood Walkability for Older Adults

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Understanding the role of the built environment on physical activity behavior among older adults is an important public health goal, but evaluating these relationships remains complicated due to the difficulty of measuring specific attributes of the environment. As a result, there is conflicting evidence regarding the association between perceived and objectively measured walkability and physical activity among urban-dwelling older adults. This suggests that both actual environmental features and perceptions of these attributes influence walking behavior. The purpose of this pilot project is to create an Objective Walkability Index (OWI) by census block using a Geographic Information System (GIS) and supplement the results with resident perceptions thus more accurately characterizing the context of walkability. Computerized Neighborhood Environment Tracking (ComNET) was used to systematically assess environmental risks impacting activity patterns of older adults in two New York City neighborhoods. In addition, the Senior Center Evaluation of the Neighborhood Environment (SCENE) survey was administered to older adults attending two senior centers located within the target neighborhoods. The results indicate that there is substantial variation in OWI score both between and within the neighborhoods suggesting that residence in some communities may increase the risk of inactivity among older adults. Also, low walkability census blocks were clustered within each neighborhood providing an opportunity for targeted investigation into localized threats to walkability. A lack of consensus regarding the association between the built environment and physical activity among older adults is a consequence of the problems inherent in measuring these determinants. Further empirical evidence evaluating the complex relationships between the built environment and physical activity is an essential step towards creating active communities.

Keywords

Walkability, built environment, physical activity, older adults, objective measures, subjective measures, active aging, GIS, neighborhood, urban health

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Abstract
Understanding the role of the built environment on physical activity behavior among older adults is an important public health goal, but evaluating these relationships remains complicated due to the difficulty of measuring specific attributes of the environment. As a result, there is conflicting evidence regarding the association between perceived and objectively measured walkability and physical activity among urban-dwelling older adults. This suggests that both actual environmental features *and* perceptions of these attributes influence walking behavior. The purpose of this pilot project is to create an Objective Walkability Index (OWI) by census block using a Geographic Information System (GIS) and supplement the results with resident perceptions thus more accurately characterizing the context of walkability. Computerized Neighborhood Environment Tracking (ComNET) was used to systematically assess environmental risks impacting activity patterns of older adults in two New York City neighborhoods. In addition, the Senior Center Evaluation of the Neighborhood Environment (SCENE) survey was administered to older adults attending two senior centers located within the target neighborhoods. The results indicate that there is substantial variation in OWI score both between and within the neighborhoods suggesting that residence in some communities may increase the risk of inactivity among older adults. Also, low walkability census blocks were clustered within each neighborhood providing an opportunity for targeted investigation into localized threats to walkability. A lack of consensus regarding the association between the built environment and physical activity among older adults is a consequence of the problems inherent in measuring these determinants. Further empirical evidence evaluating the complex relationships between the built environment and physical activity is an essential step towards creating active communities.

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INTRODUCTION

The Built Environment and Physical Activity

Past research has shown that remaining active into old age has numerous public health benefits. Physically active older adults are more likely to avoid functional limitations, prevent disease and disability, and improve survival (Wagner et al. 1992; US Department of Health and Human Services 1996; Clark and Nothwehr 1999; Satariano and McAuley 2003). Despite the numerous benefits of physical activity, adults age 60 and over represent the most inactive segment of the adult population. According to the National Health Interview Survey, inactivity increases with age; by age 75, over 80% of adults do not engage in regular leisure-time physical activity (Schoenborn and Adams 2010). Promoting physical activity among seniors is a national health objective (Satariano and McAuley 2003). However, most research efforts have focused on individual-level determinants of, and barriers to, physical activity, which fail to consider the broader environment in which physical activity occurs (Li et al. 2005b).

Remaining active into old age is achieved when physical activity is integrated into daily routines such as walking for transport, leisure, or exercise. Walking is one of the most common forms of exercise among seniors because it is versatile, inexpensive, and generally low-impact (US Department of Health and Human Services 1996; Michael et al. 2006a). Older adults are particularly vulnerable to the effects of their environment and thus, neighborhoods are an important place to study physical activity and walking behavior (Pastalan and Pawlson 1985; Glass and Balfour 2003). First, as adults grow older, their spatial area shrinks to the vicinity of their home or immediate neighborhood and resources within the community become increasingly important (Lawton 1978; Glass and Balfour 2003). Second, age-related diseases, as well as cognitive and physical changes, may decrease the ability of older adults to cope with environmental stress (Glass and Balfour 2003). Factors associated with the aging process such as physical vulnerability, visual impairment, mobility limitations, and cognitive disorders reduce the ability of seniors to handle person-environment interaction as they once did. However, small modifications to the physical environment may help to maintain levels of independent functioning among senior residents (Pastalan and Pawlson 1985). Thus, understanding the role of the built environment on physical activity and walking behavior among older adults is an important goal in promoting active aging.

Measuring the Built Environment

The built environment is a multidimensional concept, defined by the United States Center for Disease Control and Prevention as "human-formed, developed, or structured areas." For the purposes of measurement, the built environment can be partitioned into three distinct dimensions: land development patterns, microscale urban design, and transportation systems (Handy et al. 2002). Land development patterns reflect the juxtaposition of different types of land-use (i.e., residential, office, commercial, industrial, and open/green space) and activities in a neighborhood (Handy et al. 2002). They also describe the distance between trip origin and destinations such as shops, entertainment venues, recreation facilities, and parks (Cunningham and Michael 2004). Microscale urban design refers to the organization of the city and microelements (e.g., sidewalks, crosswalks, streetlights, etc.) within it (Handy et al. 2002; Cunningham and Michael 2004). Urban design also characterizes the arrangement, complexity, and appeal of urban space (Cunningham and Michael 2004). Transportation systems are comprised of the physical infrastructure that provides connections between people, places, and activities. In addition to public transportation, traffic levels and pedestrian safety are also key components of this system (Handy et al. 2002). Neighborhood walkability is a broad concept designed to evaluate a range of built environment features using a composite index or scale which facilitates area-based comparisons.

Today, the study of the built environment and its influence on physical activity is experiencing academic growing pains caused by the emergence of a plethora of different measurement approaches from different fields of study. Many of these approaches lack a clear conceptual framework and supportive theory to guide methodology, which has mainly been driven by the availability of datasets (Dietz 2002; Macintyre et al. 2002; Diez Roux 2003; Brownson et al. 2004; Diez Roux et al. 2007; Messer 2007; Mujahid et al. 2007). As a result, there is conflicting evidence regarding the association between different features of the built environment and physical activity among urban-dwelling older adults. One of the greatest challenges facing researchers in the field is choosing an appropriate method for evaluating the specific features of the built environment hypothesized to be related to physical activity among older adults. The following sections will discuss a few current trends of data measurement, which include two main categories of built environment measures- subjective surveys measures and objective data audit measures.

Subjective survey measures are designed to assess an individual's perception of their neighborhood environment and are usually obtained via interviews or self-reported questionnaires (Brownson et al. 2004; Araya et al. 2006). Indirect measurement of the built environment by subjective survey evaluates how residents perceive the quality of their physical environment including opportunities for physical activity. Participant responses are then aggregated to selected geographical/spatial areas (and sometimes by population subgroup) to represent the subjective context of different neighborhoods. This category of measure is typically resource light (i.e., expense and time), but has potential limitations in other areas. Only a few subjective survey instruments report reliability (test-retest) and validity (content and construct) and those that do vary substantially both between studies and within specific features of the built environment (Moudon and Lee 2003; Brownson et al. 2009). Reporting bias may overstate associations between the built environment and physical activity if the same individuals are reporting both exposure (built environment) and outcome (physical activity) (Dunstan et al. 2005; Araya et al. 2006; Mujahid et al. 2007; Brownson et al. 2009). The subjective nature of these measures also brings into question whether the findings actually represent the context of a neighborhood or are simply the aggregate of resident perceptions and/or individual characteristics (compositional confounding) (Dunstan et al. 2005; Araya et al. 2006; Brownson et al. 2009). It is important to control for individual characteristics to ensure that the variance is explained by place-based, rather than by individual effects (Araya et al. 2006).

The most commonly used survey to assess walkability is the Neighborhood Environment Walkability Scale (NEWS), a 68 item questionnaire developed by Sallis et al. (Brownson et al. 2004; Brownson et al. 2009). NEWS was created from a conceptual model which sought to obtain information on residents' perceptions of certain built environment characteristics found in urban planning and transportation fields, and how those features are related to walking and bicycling behavior (Cerin et al. 2006). Subscales were comprised from sets of questions to include residential density, proximity to stores and facilities, perceived access to these destinations, street connectivity, facilities for walking and cycling, aesthetics, and safety from traffic and crime. Unlike many other subjective survey instruments, NEWS has strong test-retest reliability and construct validity (Saelens et al. 2003; Brownson et al. 2004).

Objective data audit measures use systematic observation to collect primary data regarding features of the built environment. This method measures attributes in a neighborhood as they are directly observed, attempting to remove subjective evaluations. The intent is to gather information on the presence and quality of specific items that are not included in existing Geographical Information Systems (GIS) or urban planning databases (Brownson et al. 2009). Audit tools typically involve direct in-person observation by trained individuals who walk or drive through neighborhoods using a standardized form to code built environment characteristics (Araya et al. 2006; Brownson et al. 2009). The forms are either in pencil and paper format, or contained within hand-held electronic devices and include close-ended questions such as quantifiable check boxes or Likert scales (Brownson et al. 2009). The unit of analysis for most audit tools is a street segment or block, and due to the amount of time needed to observe, many of the studies sample only segments of neighborhoods.

Direct observation is resource-intensive; particularly when the time needed to select sites and sample segments, train observers, collect and enter data, and analyze raw data is considered (Araya et al. 2006; Brownson et al. 2009). However, the cost and time needed for objective data audits depends on the number of items measured and the size of the geographical area (Brownson et al. 2009). The use of portable electronic devices will speed up the process and also minimize data entry and collection errors. The use of objective data audits tends to be contextually valid, especially compared to methods that employ aggregated individual-level data (Araya et al. 2006). However, some items may not be readily observable or may require subjective inference by the observer. Inter-observer reliability is the most frequently tested measure of reliability and tends to be strongest for objective items relating to land-use mix and street characteristics (Brownson et al. 2009). Test-retest reliability is usually only evaluated to see how features of the built environment have changed over time.

Brownson et al. (2009), reviewed 20 objective audit tools and found that they varied significantly in content, detail, and how they characterized various features (i.e., some items represented by a single question and others by a series of questions). The most commonly assessed variables include land-use mix, streets and traffic, sidewalks, bicycling facilities, public space and amenities, building characteristics, parking and driveways, maintenance, and indicators of safety (Brownson et al. 2009). Several environmental audit tools have been developed specifically for older adults, including the Senior Walking Environmental Audit Tool (SWEAT) and the Healthy Aging Research Network Environmental Audit Tool (Cunningham et al. 2005; Center for Disease Control and Prevention's Healthy Aging Research Network 2009).

Inconsistencies Among Associations

As discussed above, some studies of neighborhood walkability are based upon resident perceptions whereas others use environmental audits as an objective measure. However, associations between the built environment and walking behavior differ according to which type of measure was employed. A review of the literature identified two studies that assessed built environment attributes, using both resident perceptions and environmental data audits, and their impact on physical activity (Hoehner et al. 2005; Michael et al. 2006b). However, only one of these articles focused on older adults (Michael et al. 2006b). Michael et al. sought to determine the degree of concordance between resident perceptions and environmental audit data, and the relationship between these elements and neighborhood walking among older adults. Results indicated poor agreement between objective and perceived measurements of trails, graffiti and vandalism, sidewalk existence, and sidewalk obstruction. In addition, after adjusting for covariates, the only significant attributes remaining in the walking models were objective and perceived presence of a mall, and the objective existence of graffiti and vandalism (Michael et al. 2006b).

Hoehner et al. 2005 evaluated the impact of the built environment on transportation and recreational physical activity among adults by using a subjective survey and an environmental audit in four urban settings. Results indicated that participants with greater access to nonresidential destinations (measured both objectively and subjectively) were more likely to walk for transportation. Other neighborhood attributes that demonstrated consistent associations with transportation or recreational activity across measurement type were access to public transportation (e.g., bus stops) and neighborhood quality as assessed by the quantity of garbage, litter, or broken glass and physical disorder. However, the effect of perceived safety from traffic and objectively measured quantities of trees, benches, and other comfort amenities were both found to be related to transportation activity, but their corresponding measures were not.

Conclusions varied depending on the method of measurement, which suggests that both the actual environmental factors and perceptions of these attributes influence walking behavior (Hoehner et al. 2005; Michael et al. 2006b; McGinn et al. 2007; Nagel et al. 2008; Adams et al. 2009; Gebel et al. 2009; Maddison et al. 2009; Frank et al. 2010; Gómez et al. 2010). However, there is a dearth of research investigating the differences between features of the built environment measured via resident perceptions *and* environmental data audits specifically for older adults. The purpose of this pilot project was to calculate an Objective Walkability Index (OWI) for older adults using data from an environmental audit of two New York City (NYC) neighborhoods in a Geographic Information System (GIS). The OWI is based on an objective data inventory utilizing Computerized Neighborhood Environmental Tracking (ComNET), a tool developed by the Fund for the City of New York's Center on Municipal Government Performance. The OWI will then be compared to resident perceptions, obtained from the Senior Center Evaluation of the Neighborhood Environment (SCENE), a subjective survey instrument.

METHODS

This study uses primary data collected in 2008-2009 by the author and secondary data downloaded in the form of spatial data layers or shapefiles. Shapefile sources include the United States Census Bureau (2000 Census), the NYC Department of City Planning (DCP)– Bytes of the Big Apple, and the NYC Department of Information Technology and Telecommunications (DoITT). The following sections will discuss primary data sources and the methodology of the OWI.

Objective Data Audit

ComNET was developed by the Fund for the City of New York's Center on Municipal Government Performance (CMGP) to assist residents in collecting built environment data for community needs assessments (Fund for the City of New York 2009a; Fund for the City of New York 2009b). ComNET is fully customizable; it allows the user to select any size geographical area and to choose items from the CMGP's core feature list or to create their own (Fund for the City of New York 2009b). The selected areas are then turned into routes and uploaded into a hand-held personal digital assistant (PDA). The innovative software guides the observer to follow a direct pre-determined route, which ensures that all street segments will be covered. Unlike other data audit tools, ComNET assesses built environment characteristics by creating a systematic inventory of all features on each block segment complete with address coordinates. For example, to evaluate land-use mix, observers note the presence and exact location of specific types of commercial, residential, recreational, and industrial facilities in a community. It also evaluates the quality of the physical environment by creating a record of where there is litter, graffiti, drug paraphernalia, etc. Trained observers record conditions in a uniform, verifiable, and replicable manner and are able to take photos and link them directly to the specific feature in the database (Fund for the City of New York 2009b). Once a route is finished, the raw data are uploaded via the internet to a holding database where edits can be made. The dataset can then be exported in a variety of formats (MS Access, MS Excel, Text file, etc.) and is ready for validation and analysis using GIS or other methods.

The pilot study targeted two socioeconomically, racially, and ethnically different neighborhoods in NYC: Crotona Park East in the Bronx and Lenox Hill in Manhattan (See Figure 1). Features of the built environment were determined through a comprehensive literature review and included those associated with walking behavior among older adults (See Table 1 for a list of ComNET attributes). In the fall of 2008, trained observers worked in the field collecting data in pairs to increase rater reliability and objectivity, and to ensure safety. ComNET was developed for community needs assessments and this was the first time the tool was used in a research capacity, so validity estimates are not available. However, the purpose of ComNET was to systematically inventory specific attributes of the built environment and represents a count of different features of the neighborhood. It is therefore not purporting to measure an unobservable latent construct. Data were recorded at the block-face level and contained in an Excel spreadsheet, where each row represented an inventory item.

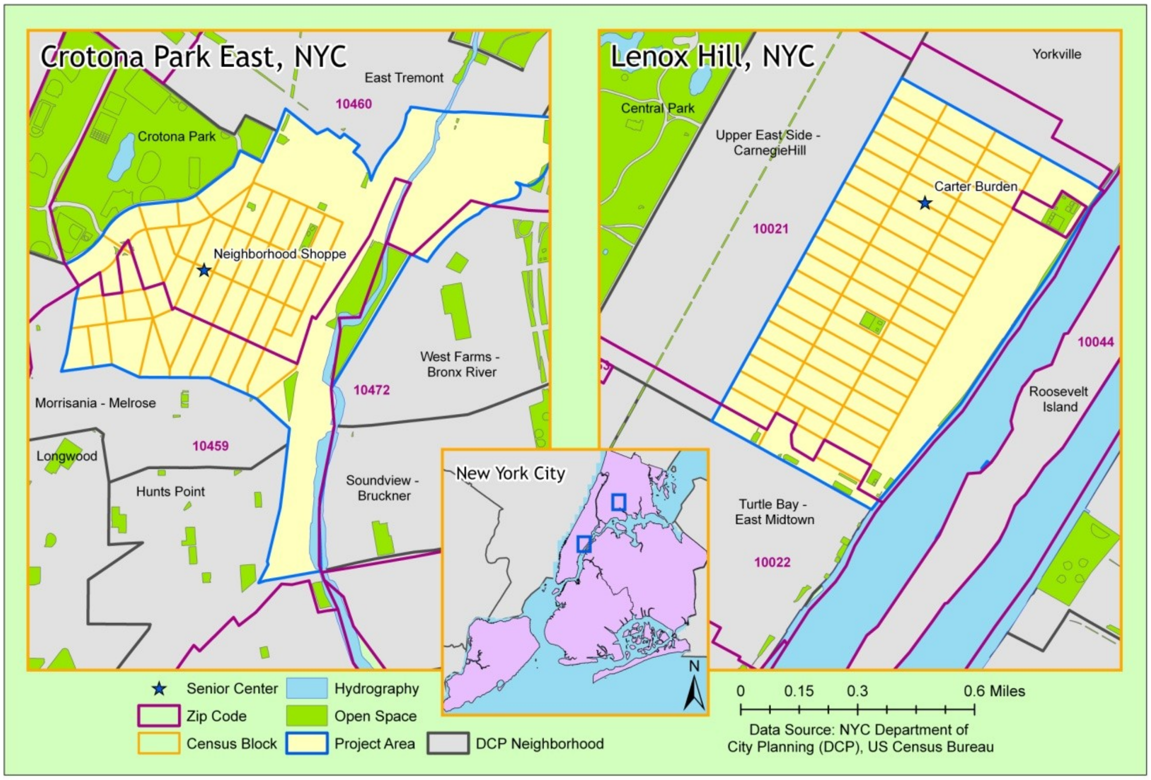

Figure 1: Pilot study target areas- Lenox Hill & Crotona Park East, NYC.
The target study areas of Crotona Park East and Lenox Hill are shown above with census blocks outlined. Also included are proximate zip codes and NYC Department of City Planning neighborhoods. The middle map shows the location of the two neighborhoods with respect to NYC using extent rectangles.

Subjective Survey Data

The SCENE survey was developed by the author to assess physical activity levels and perceptions of the built environment among older adults attending senior centers in NYC. The structured instrument was designed to evaluate which features of the physical and social environment residents perceive to impact physical activity and walking behavior. The physical activity section was based on the Neighborhood Physical Activity Questionnaire, which evaluates physical activity and walking behavior within and outside of residents' local area (Giles-Corti et al. 2006). Perceptions of walkability were assessed using several items from the Neighborhood Environment Walkability Survey (NEWS) (Saelens et al. 2003), along with some original questions. A demographic section includes items on respondent's age, sex, socioeconomic status, marital status, length at present residence, and residential zip code.

Interviews were conducted in the summer of 2009 in two senior centers located within the target neighborhoods: Neighborhood Shoppe in Crotona Park East and Carter Burden in Lenox Hill (See Figure 1). Trained interviewers conducted face-to-face interviews with randomly selected seniors in the participant's language of choice (English or Spanish). A total of 103 questionnaires were completed- 50 at Carter Burden and 53 at Neighborhood Shoppe. Response rates were 76% for Carter Burden in Lenox Hill and 98% for Neighborhood Shoppe in Crotona Park East. Data was entered into a spreadsheet and the walkability score for each respondent was calculated by subscale (see Table 1) using SPSS version 15. The score for each subscale was then averaged by zip code within the targeted study areas. Walkability scores ranged from 1-4, with higher scores representing greater walkability.

Objective Walkability Index (OWI)

The ComNET data was geocoded using the DCPLion address locator and added to the map layout as a point layer file. The census block shapefile was overlaid, and spatially joined to the ComNET point layer to create a new combined ComNET shapefile by census block layer. The Objective Walkability Index (OWI) was calculated by summing the number of points (i.e., inventory items) within each census block and then added as a new field in the attribute table. More specifically, each item from subscale 1 was assigned a value of '-1' since this subscale represents positive features of neighborhood walkability. Conversely, subscales 2-5 were given a value of '1' to demonstrate negative attributes of walkability (see Table 1). An OWI score was calculated for each census block, which was then ranked into quartiles (bottom quartile- low OWI, top quartile- high OWI) by ArcGIS. Table 1 demonstrates the comparability of the objective (ComNET) and subjective measures by subscale.

RESULTS

Objective Walkability

A total of 104 census blocks were inventoried using ComNET- 59 in Lenox Hill and 45 in Crotona Park East. The mean OWI score was 3.36 for Lenox Hill and 11.87 for Crotona Park East. Mean OWI score between neighborhoods was statistically different at the $p<0.05$ level suggesting that objective walkability in Lenox Hill is significantly greater than in Crotona Park East. The same trend was observed when the OWI score was divided into quartiles by census blocks, with Quartile 1 representing low walkability and Quartile 4 indicating very high walkability (see Table 2). Over 55% (n=33) of census blocks in Lenox Hill scored in the 75th percentile (very high walkability) as compared with approximately 2% (n=1) of blocks in Crotona Park East. Conversely, over 37% (n=17) of blocks in Crotona Park East scored in the 25th percentile (low walkability) versus slightly over 3% (n=2) of Lenox Hill census blocks.

Figure 2 is a graphic representation on the OWI by census block for Crotona Park East and Lenox Hill. Darker colored census blocks depict areas of greater walkability as compared with lighter colors. The low walkability census blocks appear to be clustered in the southwestern corner of Lenox Hill and in the southwestern and eastern areas in Crotona Park East.

Table 1. Comparison of perceived and objective measures of walkability by subscale.
Each subscale represents a different dimension of neighborhood walkability. The objective measures (ComNET data) were evaluated by taking an inventory of the items listed in the table whereas the perceived measures (SCENE data) were administered via a survey with responses ranging from strongly agree to strongly disagree for each question.

Subscale	Objective Measure (ComNET)	Perceived Measure (SCENE)
1. Land-use Mix	• Food store/vendor • Retail/commercial store • Open spaces • Outdoor fitness/amenities • Benches on block • Public transportation	• I can do most of my shopping at local stores • Stores are within easy walking distance of my home • There are many places to go within easy walking distance of my home • It is easy to walk to a transit stop (bus, train) from my home • The streets in my neighborhood are hilly, making my neighborhood difficult to walk in*
2. Street Connectivity/ Maintenance	• Trip hazards/ponding • Curb cut missing • Sidewalk blocked	• The distance to cross streets in my neighborhood is usually short • There are many four-way intersections in my neighborhood • There are many alternative routes for getting from place to place in my neighborhood • There are sidewalks on most of the streets in my neighborhood • The sidewalks in my neighborhood are well maintained (paved, even, and not a lot of cracks) • Sidewalks are separated from the road/traffic in my neighborhood by parked cars • There is a grass/dirt strip that separates the streets from the sidewalks in my neighborhood
3. Neighborhood Aesthetics	• Tree missing • Graffiti/scratchiti • Litter/dumping/broken glass/weeds • Dumpster/waste basket overflowing or leaking • Vacant lots/abandoned vehicles	• There are trees along the streets in my neighborhood • Trees give shade for the sidewalks in my neighborhood • There are many interesting things to look at while walking in my neighborhood • My neighborhood is generally free from litter • There are many attractive natural sights in my neighborhood (such as landscaping, views) • There are attractive buildings/homes in my neighborhood
4. Pedestrian Safety	• Crosswalk/pedestrian light missing • Crosswalk lines fading or missing	• There is so much traffic along the street I live on that it makes it difficult or unpleasant to walk in my neighborhood* • There is so much traffic along nearby streets that it makes it difficult or unpleasant to walk in my neighborhood* • The speed of traffic on the street I live on is usually slow (30 mph or less) • The speed of traffic on most nearby streets is usually slow (30 mph or less) • Most drivers exceed the posted speed limits while driving in my Neighborhood* • There are crosswalks and pedestrian signals to help walkers cross busy streets in my neighborhood • The crosswalks in my neighborhood help walkers feel safe crossing busy streets • When walking in my neighborhood, there are a lot of exhaust fumes (such as from cars, buses)*
5. Neighborhood Safety	• Empty alcohol containers • Drug paraphernalia • Persons in need • Subway entrance or sidewalk shed not lit	• My neighborhood streets are well lit at night • Walkers and bikers on the streets in my neighborhood can be easily seen by people in their homes • I see and speak to other people when I am walking in my neighborhood • There is a high crime rate in my neighborhood* • The crime rate in my neighborhood makes it unsafe to go on walks during the day* • The crime rate in my neighborhood makes it unsafe to go on walks at night*

*Indicates a reverse coding item

Table 2. OWI quartile rank and mean score by target neighborhood.
Each Census block was assigned a quartile rank based on its OWI score and the number of census blocks within each quartile was computed for each target neighborhood. In addition the mean OWI score was also calculated for Lenox Hill and Crotona Park East.

	Quartile 1: Low Walkability	Quartile 2: Medium Walkability	Quartile 3: High Walkability	Quartile 4: Very High Walkability	**OWI Score Mean (SD)**
Lenox Hill (n=59)	3.39% (n=2)	18.64% (n=11)	22.03% (n=13)	55.93% (n=33)	**3.36*** **(5.02)**
Crotona Park East (n=45)	37.78% (n=17)	35.56% (n=16)	24.44% (n=11)	2.22% (n=1)	**11.87*** **(6.57)**

*Means significantly different from each other ($p<0.05$)

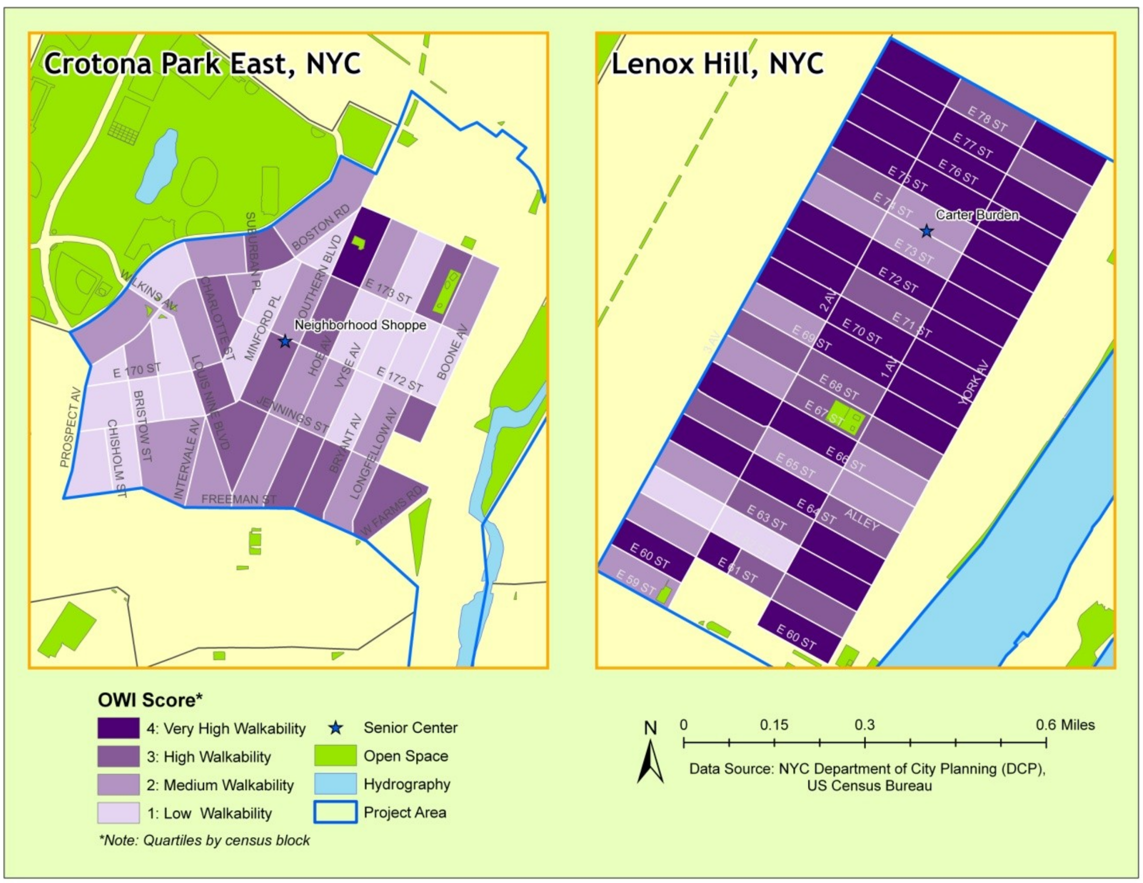

Figure 2. OWI Score by Quartile Rank, Crotona Park East & Lenox Hill, NYC.
Using a GIS, the OWI scores for each census block were mapped according to their quartile rank (1-4). Census blocks of greater walkability are represented by darker colors.

Differences in objective walkability both between and within the neighborhoods can be further evaluated by subscale to provide a more nuanced view of the built environment. Table 3 displays total inventory counts and average count per census block by subscale dimension for each target area. The most striking difference was land-use mix where Lenox Hill has an average of 7.32 destinations (i.e., retail, commercial, recreation, open space, etc.) per block as compared with only 1.91 in Crotona Park East. In addition, Crotona Park East residents are more likely to encounter poor street connectivity and trip hazards (7.67 versus 5.15 per block) than their Lenox Hill counterparts. In terms of both pedestrian and overall neighborhood safety, fewer problems per census block were recorded in Lenox Hill than in Crotona Park East (0.31 versus 2.62 for pedestrian safety and 0.19 versus 0.71 for neighborhood safety). Interestingly, Crotona Park East scored higher on neighborhood aesthetics, indicating a greater presence of graffiti/scratchiti, litter, dumping, and other factors in Lenox Hill.

Table 3. Objective walkability subscale total and mean counts per census block.
Total counts represent the number of inventory items found in each neighborhood by subscale. Mean counts were calculated by dividing total counts by the number of census blocks surveyed within Crotona Park East and Lenox Hill.

Neighborhood	Objective Walkability Subscales				
	1. Land-use Mix	2. Street Connectivity/ Maintenance	3. Neighborhood Aesthetics	4. Pedestrian Safety	5. Neighborhood Safety
Total Counts					
Lenox Hill	432	304	297	18	11
Crotona Park East	86	345	125	118	32
Mean Count per Census Block*					
Lenox Hill	7.32	5.15	5.03	0.31	0.19
Crotona Park East	1.91	7.67	2.78	2.62	0.71

*59 Census block in Lenox Hill, 45 census blocks in Crotona Park East

Subjective Walkability

Data from the SCENE survey represents perceptions of neighborhood walkability and thus can provide additional context for the OWI. A total of 103 surveys were administered in two senior centers located within the target neighborhoods. However, only 42 of the respondents resided within a zip code targeted by the study (14 in Lenox Hill, 28 in Crotona Park East). Surprisingly, this suggests that instead of attending a senior center in their immediate residential vicinity, older adults may travel to outside centers. For this analysis, the responses were limited to participants residing in one of the three study zip codes (i.e., 10021, 10459, and 10460, see Figure 1).

Table 4 demonstrates the mean perceived walkability scores for each subscale and for the total walkability score by zip code. Interestingly, the Lenox Hill zip code had the lowest mean walkability score (3.11) as compared to mean scores for the two Crotona Park East zip codes (3.29 and 3.21). However, the mean total walkability scores stratified by zip code were not statistically different from each other. Mean subscales scores demonstrate that the Lenox Hill zip code scored lower in land-use mix, street connectivity/maintenance, and pedestrian safety than either of the two zip codes representing Crotona Park East. Despite the appearance of neighborhood walkability trends, none of the mean perceived subscale scores were significantly different from each other. The lack of variation between neighborhoods may be due to the small sample size for each zip code.

Table 4. Perceived Walkability Subscales by Zip Code.
Mean scores and their standard deviations were calculated for individual subscales and the total walkability score by study area zip code.

Zip Code	Perceived Walkability Subscales (Mean (SD))					Total Walkability Score
	1. Land-use Mix	2. Street Connectivity/ Maintenance	3. Neighborhood Aesthetics	4. Pedestrian Safety	5. Neighborhood Safety	
10021* (n=14)	2.96 (0.40)	3.10 (0.32)	3.05 (0.67)	2.99 (0.42)	3.48 (0.65)	3.11 (0.31)
10459† (n=14)	3.30 (0.30)	3.18 (0.52)	3.12 (0.43)	3.45 (0.66)	3.39 (0.79)	3.29 (0.34)
10460† (n=14)	3.07 (0.56)	3.21 (0.40)	2.90 (0.70)	3.25 (0.64)	3.63 (0.55)	3.21 (0.32)

*Lenox Hill Zip Code
†Crotona Park East Zip Code

DISCUSSION

This study aimed to supplement the results from an objective data audit with resident perceptions to more accurately define neighborhood walkability. The results from the OWI indicate significant differences in both between and within neighborhood walkability scores. Approximately 78% of the census blocks in Lenox Hill are characterized by high or very high walkability as compared with only 27% of blocks in Crotona Park East. In addition, the mean OWI score for Lenox Hill was significantly greater than that of Crotona Park East. Low walkability census blocks appear to cluster in both of the neighborhoods, suggesting that local effects, although larger than a single block, may be appropriately identified by analysis at the census block level.

In this analysis, results from the SCENE survey were less informative than the ComNET data for several reasons. First, the unit of analysis for SCENE was the zip code, which is ultimately too large a unit to appropriately measure between-group differences in perceived walkability. Second, the majority of the survey respondents were excluded from the analysis due to residence outside of the study area. This unforeseen situation led to a significant reduction in sample size and power that may help to explain the lack of variation in perceived walkability across zip codes. Despite the absence of statistical differences, it is surprising that the zip codes characterizing Crotona Park East scored higher on mean total walkability and several of the subscale-specific scores than the Lenox Hill zip code. Although small sample size may explain this finding, it is also possible that older adult residents of Lenox Hill have a greater expectation of neighborhood walkability than their Crotona Park East counterparts. This may be due to differences in income level and thus have implications for the validity of self-reported measures, particularly in low-income neighborhoods. More research is needed to elucidate variation in perceptions of neighborhood attributes among older adult subpopulations with differing socio-demographic characteristics.

Lenox Hill scored particularly low on the perceived subscale of pedestrian safety with a mean score of 2.99 as compared to 3.45 and 3.25 for Crotona Park East which is most likely due to the heavy volume of traffic experienced in Lenox Hill. However, Lenox Hill had on average fewer pedestrian safety inventory items per block than Crotona Park East (0.31 versus 2.62). This suggests that pedestrian safety is perceived to be a greater problem in Lenox Hill despite having fewer missing pedestrian cross lights and crosswalks at intersections. Hoehner et al. (2005) found the same discrepancy between pedestrian safety measured via resident perceptions and through an environmental audit. Contrasting results were also found for the subscales of land-use mix and street connectivity/maintenance, where resident perceptions indicated poorer scores for Lenox Hill, but objective measures demonstrated the opposite. Despite fewer food or retail venues, open space/recreational facilities, benches, and public transportation stops per census block in Crotona Park East as compared with Lenox Hill, participants from Crotona Park East were more satisfied with land-use mix in their neighborhood. Similarly, Lenox Hill had fewer trip hazards, missing curb cuts, and blocked sidewalks per census block than Crotona Park East, yet Lenox Hill residents scored lower on perceived street connectivity. Michael et al. (2006b) also found a lack of agreement between resident perceptions of sidewalk obstruction and measures obtained using systematic observation suggesting the importance of understanding how residential perceptions may differ from objective measures.

These results suggest that the comparability of perceived and objective measures will differ depending on what aspect of walkability is being evaluated. Further research is needed to elucidate these distinctions, as well as to explore the associations of both perceived and objective measures with socioeconomic status and health outcomes. In addition, although a comprehensive comparison of measures encompassing the construct of walkability (i.e., subscales) is beyond the scope of this paper, it is important to acknowledge the relative importance of these different components. Not all features of the built environment will be relevant for all types of physical activity and not all aspects of physical activity are appropriate for all populations (Diez Roux 2003; Story et al. 2009). This ambiguity points to the importance of specificity and operationalization in defining research questions which should be based on the *a priori* hypotheses of potential pathways to be tested (Macintyre et al. 2002; Diez Roux 2003; Brownson et al. 2004).

Calculating the OWI score for small units of analysis (i.e., census blocks) allows for a targeted approach to understanding and improving neighborhood walkability. Clusters of low-walkability census blocks provide a unique opportunity to further investigate threats to specific dimensions of walkability on a smaller, and thus a less resource-intensive scale. For example, as shown in Figure 2, Crotona Park East contains two clusters of low-walkability blocks in the southwestern and eastern areas of the neighborhood. Figure 3 displays subscale inventory items for the low-walkability cluster along the eastern border of Crotona Park East. As demonstrated in the figure, the majority of the inventory items fall under the 'Street Connectivity/Maintenance' subscale indicating the considerable presence of trip hazards. Past research has revealed that poor sidewalk quality (which leads to trip hazards) influences walking behavior among older adults (King 2008). Improving sidewalk quality within these six blocks would greatly increase neighborhood walkability for senior residents. Additional case-study examination of walkability including both quantitative and qualitative data sources would help to provide detailed context of the local neighborhood environment within these clusters. In addition, structural changes made on a small scale (such as census block clusters) are more likely to be implemented than changes to larger areas (i.e., zip codes) due to greater feasibility.

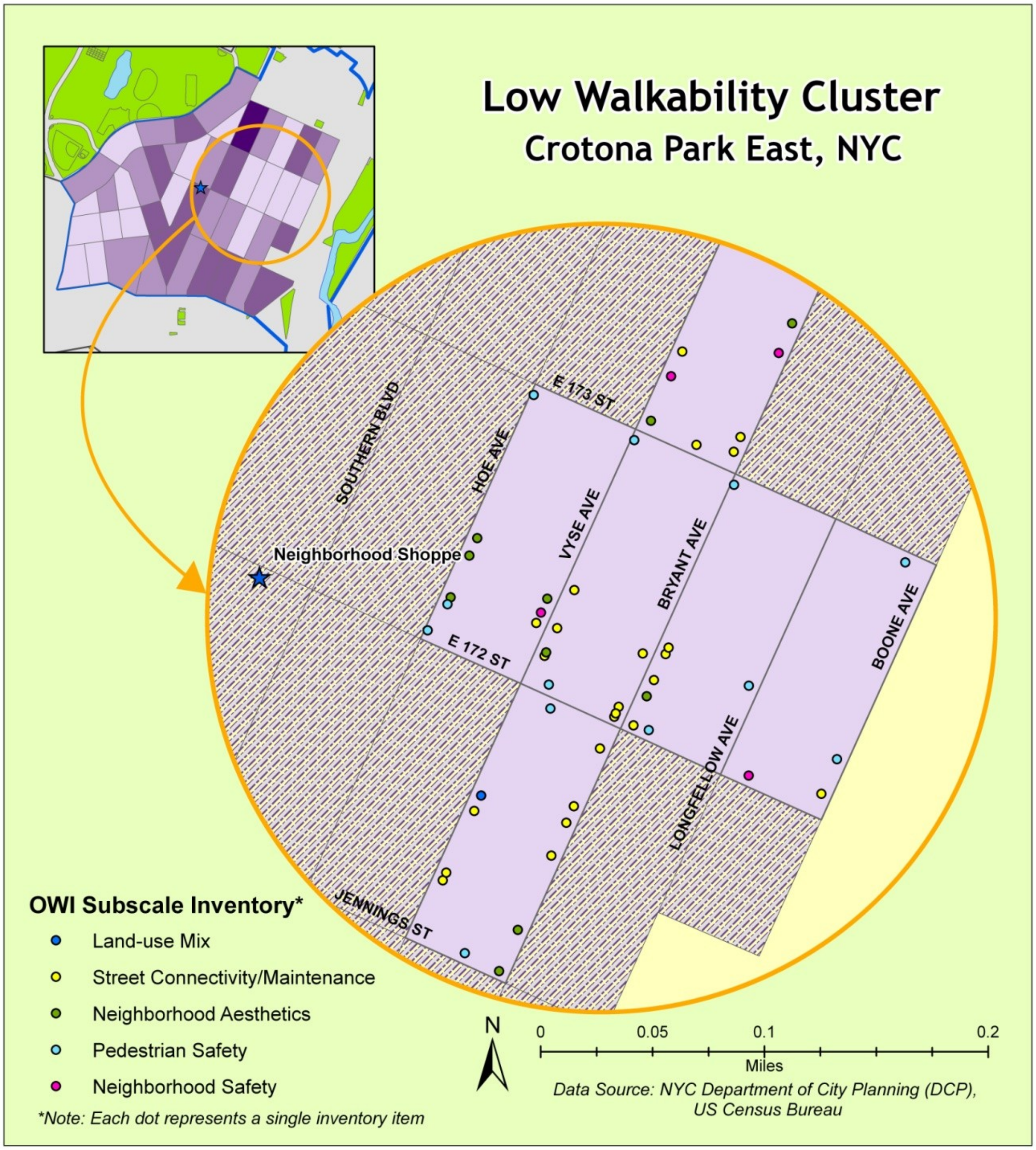

Figure 3. Potential intervention site- low walkability cluster, Crotona Park East, NYC.
The low walkability cluster represents an area of six census block groups where each dot on the map represents a recorded inventory item geocoded to its exact location within the block. The five subscales are represented by different colored dots.

Ultimately, the conceptual framework and research questions should guide the definition of appropriate spatial scale; multiple scales may be needed for different built environment measures (Diez Roux 2003). Older adults are particularly vulnerable to their immediate local environment (Lawton 1978; Glass and Balfour 2003), which means that physical activity behavior and walkability should be measured using a small geographic scale or buffer (Macintyre et al. 2002). Unfortunately, most researchers are constrained by the availability of data and must rely on imperfect spatial units. This study, which relies on census block boundaries for the objective measure and zip codes for the survey data is no exception.

Ideally, both objective and subjective walkability indices would have the same spatial scale based on the smallest possible geographical area. In addition, relying on census-defined or administrative boundaries as a proxy for neighborhoods without taking into account how residents perceive or define their local community is problematic (Macintyre et al. 2002; Diez Roux 2003). Arbitrarily defined neighborhood boundaries often use street segments to delineate a spatial border, which assumes no spillover effect from residents on either side of the boundary. However, residents in close proximity to this border do not view it as a boundary and will freely cross the border, thus raising concerns regarding the validity of results. It is important to make these limitations clear and to evaluate how the scale of the neighborhood may impact the results. These measurement issues must be taken into account when evaluating the impact of neighborhood walkability (using the OWI) on walking behavior among older adults.

CONCLUSION

A lack of consensus regarding the association between the built environment and physical activity among older adults is a consequence of the problems inherent in measuring these determinants (Hoehner et al. 2005; Michael et al. 2006; McGinn et al. 2007; Nagel et al. 2008; Adams et al. 2009; Gebel et al. 2009; Maddison et al. 2009; Gómez et al. 2010; Frank et al. 2010). The challenge remains to link built environment constructs to suitable measures taking into account the target population, outcome, and location. After determining the specific built environment features to be tested, researchers must then decide which measures operationalize those features most appropriately. Due to conflicting evidence regarding whether perceived or objectively measured data has more explanatory power for certain features, both types of measures should be used (i.e., triangulation) whenever possible to more accurately capture the built environment (Messer 2007; Brownson et al. 2004). The tradeoffs intrinsic to each of the categories of data measures must be considered along with resources (such as time frame and funding) available for the study (Brownson et al. 2004). Additionally, direct observation and other objective data audit measures may be unnecessary if archival data on the specific feature already exists (Brownson et al. 2009); thus it is important to have a good understanding of the type and quality of available data. Directions for future research include a comprehensive correlation analysis that evaluates the similarities and differences between resident perceptions and environmental audit measures for each component of walkability (land-use mix, street connectivity/maintenance, neighborhood aesthetics, pedestrian safety, and neighborhood safety). Ultimately, measurement tools are in their infancy and continued investment in improving both theoretical frameworks and measures will ensure future progress in the field.

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