ELSEVIER

Available online at www.sciencedirect.com
ScienceDirect

The Social Science Journal xxx (2011) xxx–xxx

The SOCIAL SCIENCE JOURNAL

www.elsevier.com/locate/soscij

The utilization of geographic information systems to create a site selection strategy to disseminate an older adult fall prevention program

Tom Carlson[a,*,1], Sally York[b,2], Janet Primomo[c,3]

[a] *Independent Geographer, Tacoma, WA, USA*
[b] *Trauma Program Manager, TG & Mary Bridge Hospital, 311 S. L St., Tacoma, WA 98405, USA*
[c] *University of Washington, Tacoma, Campus Box 358421, 1900 Commerce Street, Tacoma, WA 98402, USA*

Received 18 January 2010; received in revised form 10 September 2010; accepted 17 September 2010

Abstract

Public health programmatic interventions are increasingly required to address the prevention needs of aging populations. Falls in adults age 65 and older are the leading cause of injury hospitalization in the U.S., and a leading cause of international fatal injuries in older adults. This project used geographic information systems (GIS) to create a site selection strategy for the dissemination and pilot evaluation of a community-based fall prevention program for older adults in Pierce County, Washington. Potential site addresses ($n = 84$), 2000 U.S. census data for adults ≥65 years of age, and local road networks, which were converted into service areas using actual travel time, were entered in a GIS. Potential sites were then ranked by census densities of older adults who lived within 10 min travel time. Nine sites launched the program, with the goal recruiting 20 older adult program participants at each site ($n = 180$). At the end of 12 months, participation exceeded program goals ($n = 331$). GIS can be used to determine actual travel time, and may facilitate the selection of community-based prevention program sites to maximize accessibility and utilization by targeted populations.

* Corresponding author. Tel.: +1 253 225 1839.
E-mail addresses: tcarlson06@gmail.com, tcarlson@usgs.gov (T. Carlson), sallyyork7@gmail.com (S. York), jprimomo@u.washington.edu (J. Primomo).
[1] Independent geographer.
[2] Tel.: +1 253 228 1790.
[3] Tel.: +1 253 692 4475.

0362-3319/$ – see front matter © 2010 Western Social Science Association. Published by Elsevier Inc. All rights reserved.
doi:10.1016/j.soscij.2010.09.002

1. Introduction

Falls pose a significant health problem for older adults. Every year, about one-third of those 65 years and older experience a fall. Falls accounted for over 15,000 deaths in 2005 and are the leading cause of nonfatal injury among older adults in the United States (Centers for Disease Control and Prevention, 2007). Furthermore, falls injuries in older adults are the leading cause of injury hospitalization in the United States (Finkelstein, Corso, & Miller, 2006; Stevens, Ryan, & Kresnow, 2006). Internationally, injuries are a leading cause of death in older adults, and falls represent a high proportion of their injury fatalities (Rubinstein & Josephson, 2002). The resulting U.S. direct medical costs are about $0.2 billion dollars for fatal falls and $19 billion dollars for nonfatal falls (Stevens, Corso, Finkelstein, & Miller, 2006). Falls in older adults are also recognized as an international public health concern that requires population-based prevention strategies (McClure et al., 2006). These preventable injuries create a financial and utilization burden on all segments of health care systems, and threaten the independence and quality of life of our aging population.

Falls in older adults have multifactorial causes and predisposing factors such as lower extremity weakness, balance problems, and a history of falls (Rubenstein & Josephson, 2006). Research shows that many falls in community-dwelling older adults can be prevented through interventions such as multidimensional risk assessment and risk reduction to prevent falls, and exercise that improves balance, strength, flexibility, and endurance (Campbell & Robertson, 2006; Chang et al., 2004; Finkelstein et al., 2006). In order to reduce fall-related injuries, community-dwelling older adults who are aging in place are an important target for evidence-based community fall prevention programs.

A geographic information system (GIS) is a software system and group of procedures that provide data input, storage and retrieval, mapping, and spatial analysis for both spatial (location and shape of geographic features) and attribute (characteristics of the spatial features) data to support the decision-making activities of an organization (O'Sullivan & Unwin, 2003). GIS provides the ability to combine and overlay different data sets together using geography so that spatial analysis and modeling operations can be used to better understand geographic relationships (Cromley & McLafferty, 2002).

Geographic information systems (GIS) are now widely used by local, county, regional and state governmental agencies in the areas of public health, economic development, transportation, and land use planning, and are thus accessible by related community agencies and organizations as a planning tool. GIS is also used in the private sector by business, transportation and environmental consulting firms. Despite this widespread use, GIS are an underused yet powerful tool to guide program planning efforts (Cromley & McLafferty, 2002; Hirshorn & Stewart, 2003). In this article, we describe an application of GIS that was used to analyze and select accessible sites in neighborhoods with high densities of adults 65 and older for an evidence-based public health fall prevention program that targeted independent-living, community-dwelling older adults and utilizes partnerships with existing community-based organizations.

1.1. GIS in health studies

GIS has been used to measure geographic accessibility of hospitals to older adults (Love & Lindquist, 1995), determine geographic access to pharmacies by the elderly (Lin, 2004), and describe the geographic pattern of fall injuries among the elderly based on emergency department reports (Yiannakoulias et al., 2003). GIS can also be used as a decision support tool to allocate health services so that they are geographically accessible to the population they intend to serve (Boulos, Roudsari, & Carson, 2001; Phillips, Kinman, Schnitzer, Lindbloom, & Ewigman, 2000).

Access to health care may be defined as the ability of people to utilize services where and when needed (Aday & Anderson, 1981; Cromley & McLafferty, 2002). Specifically, accessibility includes geographic barriers or impedance such as distance, transportation, travel time, and cost (Penchansky & Thomas, 1981) and is the dimension of health care access relevant to this study. For our purposes, we utilize a working definition of accessibility that is geographically focused by seeking the shortest path and travel time for senior citizens to obtain a specific health service, fall prevention exercise and education.

The most common measurement of accessibility in health care is straight-line or Euclidean distance (Love & Lindquist, 1995; McLafferty, 2003). This distance measurement is typically performed with a 'buffering' operation in the GIS, where buffers at various straight-line distances from a particular point are generated (Longley, Goodchild, Maquire, & Rhind, 2005; O'Sullivan & Unwin, 2003). Buffering operations are relatively simple from a GIS standpoint and thus have frequently been used in health care studies of patient accessibility (Love & Lindquist, 1995; Martin, Roderick, Diamond, Clements, & Stone, 1998; Martin, Wrigley, Barnett, & Roderick, 2002). However, it is well supported that this is not the most effective method of measuring actual travel distance or travel time, and hence accessibility (Longley et al., 2005; Martin et al., 2002; O'Sullivan & Unwin, 2003; Scott, Temovsky, Lawrence, Gudaitis, & Lowell, 1998). As an example, Martin et al. (1998) found that there were significant differences in travel times between models based on Euclidean distance versus actual travel times in a study of patient's access to renal dialysis centers.

There have been a few studies that describe the use of normative models as a tool for healthcare planning within a GIS context. Cromley and McLafferty (2002) provide a brief look into normative models and mathematical programming and Gesler et al. (2006) utilized normative modeling techniques to investigate inequalities in health care coverage in rural North Carolina. In a more detailed example of the application, Walsh, Page, and Gesler (1997) conducted research to assess the role that GIS and network analysis play in defining service where hospitals, patients, and transportation networks were organized within a spatial analytical system that integrated measures of supply, demand, and impedance in the calculation of a normative model of healthcare accessibility. The derived normative model assumes that all patients can be treated at all hospitals and that patient travel time is the primary decision factor in the selection or allocation of patients to hospitals for healthcare. The analysis generated normative service areas; that is, representations of what the service areas "should be" to ensure geographic efficiency through travel time optimization. In this case, efficiency was based on minimization of travel time to care from patient addresses.

Basic to an individual's ability to access health care services is the geographic concept of distance decay (Cromley & McLafferty, 2002). This is described as the tendency for a person's interaction with health services to decline as the distance to services, additional time, cost, and effort increase. Several past studies have demonstrated the effect of distance on the use of a variety of health care services (Fortney, Rost, Zhang, & Warren, 1999; Joseph & Phillips, 1984; Shannon, Bashshur, & Metzner, 1969). Interestingly, required hospitalization and emergency care show little or no distance decay, whereas there is strong distance decay in situations where outpatient care is not urgent (Cromley & McLafferty, 2002; Goodman, Fisher, Stukel, & Chang, 1997; Haynes, Bentham, Lovett, & Gale, 1999; Joseph & Phillips, 1984). Past studies also indicate that patients with poor mobility, such as the elderly, are more sensitive to distance and as a result will likely utilize the closest health services (Bashshur, Shannon, & Metzner, 1971; Haynes & Bentham, 1982; Nemet & Bailey, 2000). Furthermore, studies have shown that patients are more likely to utilize health care services if they are found in their typical activity spaces such as those routes that are traveled to and from work, or in the vicinity of shopping. Thus, co-locating health services with other frequently used services and identifying locations that minimize travel time may provide additional benefits to patients and providers and minimize accessibility issues such as distance decay (Cromley & Shannon, 1986; Kendal, Peterson, Manning, Xu, Neville, & Hogue, 2002; Nemet & Bailey, 2000).

In summary, while GIS has been used in access to health care studies, there are few applications in the literature regarding the use of GIS models to find optimal solutions to the problem of locating health promotion activities for place-bound subpopulations, such as evidence-based fall prevention programs for community-dwelling older adults. Furthermore, the use of actual travel time, rather than distance as a criterion to locate potential sites for health promotion programs, is an approach that is useful in health promotion planning.

1.2. Project background

Over the past decade, successful group exercise and education interventions for older adults that address potentially modifiable risk factors for falling, such as muscle weakness, balance impairment, and use of medications, have been examined through clinical trials, meta-analyses, and systematic reviews. The resulting evidence-based guidelines for falls prevention identify multidimensional falls risk assessment (medication review and home modification) and exercise interventions to improve strength, balance, flexibility and endurance, as effective prevention strategies for older adults living in community settings (Chang et al., 2004; Clemson, Cumming, Kendig, Swann, Heard, & Taylor, 2004; Finkelstein et al., 2006; Gillespie, Gillespie, Robertson, Lamb, Cumming, & Rowe, 2003; Rubenstein, Stevens, & Scott, 2007; Sherrington et al., 2008; Tinetti et al., 1994). Despite this evidence, there remains a gap between research and public health practice. In order to bridge the gap, replicable models are needed that facilitate the dissemination of research into community settings, and that provide guidance on how to establish fall prevention programs that are cost effective, sustainable, and able to reach large numbers of the target population of community-dwelling older adults (Prohaska et al., 2006; Stevens, Corso, et al., 2006; Wilcox et al., 2006).

From 2003 to 2005, the Washington State Department of Health Injury and Violence Prevention Program conducted a Centers for Disease Control-funded randomized controlled trial to evaluate a community-based targeted fall prevention intervention for older adults (Shumway-Cook et al., 2007). A key strategy used in that study was to locate community exercise sites greater than 20 min of driving distance apart to reach the maximum number of community-dwelling older adults in two counties with similar mixes of urban and rural communities, and comparable total population sizes. These community sites included one non-profit fitness organization, two assisted living facilities, two senior centers, one independent living residential facility, and two parks and recreation facilities.

From this study (Shumway-Cook et al., 2007), it was learned that most participants selected a facility15 min or less of travel time from their residences for enrollment and exit interviews, and the exercise and education class intervention sites if randomized to the intervention group. We found that over time, participants reported increasing difficulty in attending classes regularly if their travel time was greater than 10 min to class due to convenience, and transportation costs. Therefore, the goal of this project was to develop a site selection strategy based on travel time and target older adult population census densities by utilizing GIS, which we hoped would maximize access and utilization to the fall prevention program sites by community-dwelling older adults.

2. Methods

2.1. GIS model development

The primary purpose of this research was to utilize the analytical capability of geographic information systems (GIS) to conduct a site selection strategy for fall prevention program sites in Pierce County, Washington (see Fig. 1). According to the U.S. Census, the 2000 population of Pierce County was 751,121, making it the second most populous county in the state of Washington. The 2000 population density was 161 people km^2 (417 per square mile). Pierce County has a senior population of adults 65 and older of 86,511 or 11.8% of the total population (U.S. Census Bureau, 2000). In order to find suitable sites for the fall prevention program, we first had to determine a process and set of criteria that would help drive our analysis and aid in the development of the GIS model that guided the project (see Fig. 2).

The first and most important criterion was to locate sites in close proximity (10 min or less travel time) of adults 65 years of age and older as derived from the 2000 Census. This was deemed important as insights from the Senior Fall Prevention Study (Shumway-Cook et al., 2007) had determined that seniors were most comfortable with an average travel time of approximately 15 min or less when participating in a regularly scheduled exercise class. This finding was confirmed in the focus groups of older adults on exercise program motivators and barriers which were held after the study was completed. Another transportation factor originally considered for analysis in the study was senior access to public transportation and in particular municipal bus service. When this was examined with the GIS it was readily observed that there was a significant coverage of bus stops and routes across the study area and was deemed not a critical variable to include in the analysis. Research on the travel behavior and transportation patterns of older adults has found that about 90% of daily travel trips taken by adults 65 and older are made in private cars (University of California Berkeley Traffic Safety

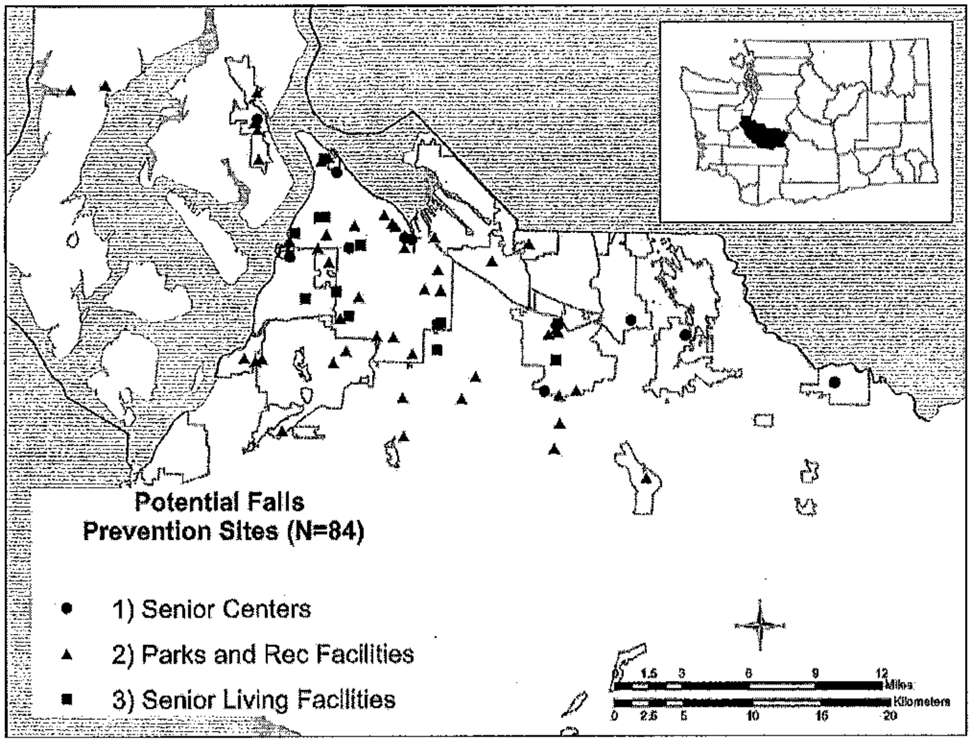

Fig. 1. Location of Pierce County, WA. Inset and potential falls prevention site locations ($n = 84$).

Center, 2002). Therefore, one challenge health planners face is to geographically locate these prevention programs so that they are accessible to the population they are designed to serve, thus maximizing the anticipated demand for services, minimizing overlapping service areas, and promoting sustainability by using existing community-based organizations. The second criterion was that the new sites be located in existing senior centers, if possible, as these facilities often have the greatest organizational capacity and experience in program delivery for community dwelling older adults. Alternate sites following existing senior centers in order of organizational capacity for the program were parks and recreation facilities and senior living facilities, respectively. The third criterion we considered was the overall proximity to other senior fall prevention activity sites.

In order to reduce overlap, increase program reach, and to ensure an adequate geographic coverage, we attempted to maximize the distance between sites, while maintaining a 10 min maximum travel time to each site by high older adult census densities. So in addition to geographic location, the site selection process included the sites' older adult community program capacity characteristics, based on the type of organization (senior center, parks and recreation facility, or older adult residential facilities). This method allowed us to integrate older adults' preferences for types of community program sites, and organizational capacity (appropriate facility space, marketing and staffing resources, adequate parking, and public transportation access) for program sustainability, as learned in the previous study (Shumway-Cook et al., 2007). For example, senior centers have a greater capacity for offering programs to community-dwelling seniors than parks and recreation, and were therefore assigned a higher ranking. So

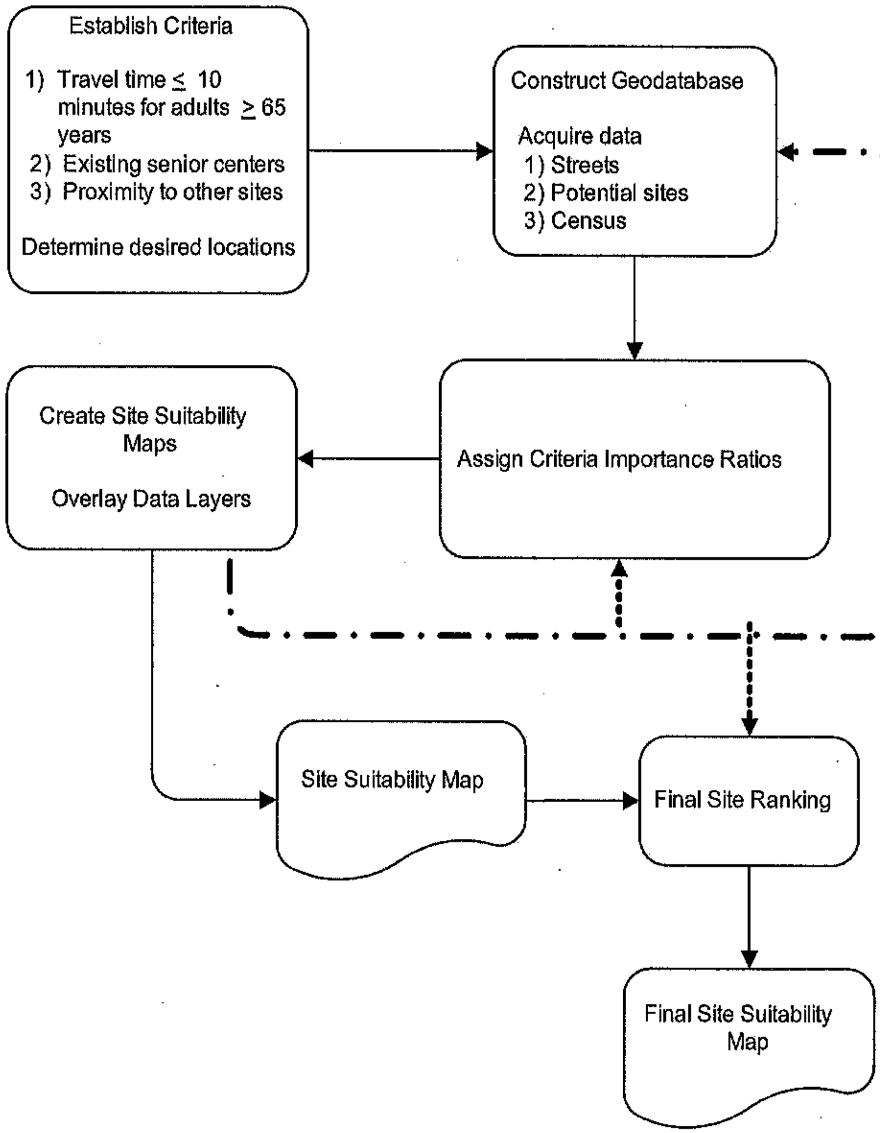

Fig. 2. GIS model for site suitability analysis. (Dotted lines indicate the process of map revisions as the steps of the model are completed.)

in addition to census density and geographic location factors, we took organizational capacity into consideration in selecting sites.

The next step was to disseminate the pilot program for evaluation at up to 10 sites which would be publicly accessible in Pierce County, Washington. In order to maximize community-dwelling older adults' access to the pilot program sites, we needed to identify the geographic distribution of the census density of older adults age 65 and over in Pierce County in relation to potential community organization partners (current exercise program sites, senior centers, parks and recreation facilities, and senior residential facilities) that could be approached for program delivery. A geographic information system (GIS) approach to identify and integrate the geographic distribution of older adult census densities, potential community organization partners (ranked by capacity criteria), and travel time in driving minutes was chosen (see Fig. 2). This goal led to the creation of a campus–community partnership which resulted in a successfully implemented GIS model that can be replicated at the macro (county or regional level) or micro (city or town) level for public health and older adult program planning and analysis.

2.2. Geodatabase creation

In order to manage and store the complex spatial data needed for the project it was deemed necessary to construct a geodatabase. The geodatabase for this site suitability study included a street centerline file for Pierce County, Census 2000 Block Group data, and a table of potential fall prevention site addresses. The street centerline file for Pierce County was obtained from Pierce County GIS Division, and Census 2000 Block Group data were obtained from ESRI (ESRI, 2007). Addresses of the five previous fall prevention study sites and the 84 potential sites (senior centers, parks and recreation centers, and senior living facilities) that NorthWest Orthopaedic Institute had identified through a community assessment (NorthWest Orthopaedic Institute, 2006) were geocoded and added to the geodatabase (see Fig. 1). Geocoding is the process of assigning a location, usually in the form of coordinate values (points/latitude and longitude), to an address by comparing the descriptive location elements in the address table to those present in the reference material such as street file data set. Addresses come in many forms, ranging from the common address format of house number followed by the street name and succeeding information to other location descriptions such as postal zone or census tract (Cromley & McLafferty, 2002). The steps involved in geocoding are translating an address entry, searching for the address in the reference data embedded in an address locator, and delivering the best candidate or candidates. These steps include parsing or splitting the file into parts that can be easily manipulated the address, standardizing abbreviated values, assigning each address element to a category known as a match key, indexing the needed categories, searching the reference data, assigning a score to each potential candidate, filtering the list of candidates based on the minimum match score, and delivering the best match. Often utilized as a means to provide geographic reference for health-related data (Melnick, 2002), the process requires reference files, input address records, address locators, and the GIS software (Longley et al., 2005; Maantay & Zigler, 2006).

2.3. Creating service areas using proximity analysis

Once the geodatabase was created, the geocoded point locations of potential fall prevention sites were used in conjunction with the street layer to calculate service areas that were to be used in determining proximity to high-density populations of older adults. This is a point in which our project deviated from traditional proximity analysis that utilize geographic buffers. Geographic buffers are commonly used to determine the characteristics of an area within close proximity to specific services, as well as a means to measure the accessibility of an area. These buffers are typically defined by circle-shaped polygons which have a radius defined by the maximum distance a person is likely to drive. Another method that has recently gained a lot of attention in the modeling and research communities involves the development of network-

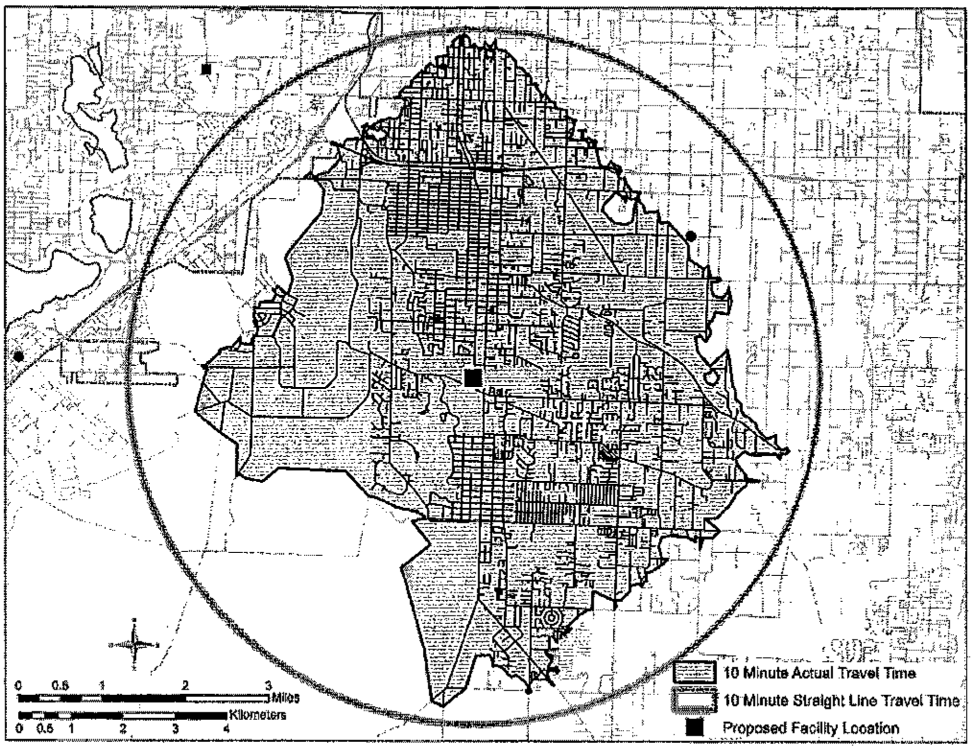

Fig. 3. Comparison of geographic buffer to road network generated service area. The circular buffer depicts an as the crow flies 10 min travel time from the proposed facility location whereas the network generated service area depicts the actual 10 min travel time.

based polygons, or "service areas" that are constructed from the actual street or road network for an area, as opposed to the "as-the-crow-flies" method that defines the circular-polygons. Because of this characteristic, the network-based approach can be used to provide a better understanding of the overall vehicular accessibility of an area, and therefore travel time.

A service area is a zone around a map feature (in this case, a potential exercise program site) measured in units of distance or time (Cromley & McLafferty, 2002). As a means of performing a proximity analysis, we utilized ArcGIS Network Analyst, which allows for a type of network analysis to determine the region that encompasses all accessible streets (streets that lie within a specified impedance). For example, the 10 min service area for a location (such as a senior center) includes all the streets that can be reached within 10 min of driving time from that location.

Compared with simple buffering operations, using the Network Analyst Extension was found to provide a far more accurate representation of actual service areas. A visual example of this difference is provided in Fig. 3. This figure shows that the circular shaped polygon around a location misrepresents actual travel time and distance as compared to the network service area. Generating buffers only provides a Euclidian or straight line distance from selected features, whereas using Network Analysis functions we were able to determine actual travel distance and hence travel times from selected features, which then enabled us to calculate a "service area" around each feature. The service area represents areas of actual travel distance to or from a site. This network-based approach makes more sense in that accessibility should be measured using real roads and networks and travel times as opposed to the fiction of traveling through solid buildings and across blocks of land (as assumed by the traditional polygon approach).

2.4. *Creating network-based service areas*

There are three steps involved in generating network service areas. The first and most crucial step involves building a Network Dataset. Typical components used in a network dataset include: Streets or paths represented as polylines, attributes that can be used to define path connectivity policies, street or path names, elevation of path segments, functional hierarchy of streets, as well as some form of network impedance such as segment length or estimated speed of travel. A necessary sub-step in building the Network Dataset is the modification of a regional street dataset to include network impedances or cost attributes that can be used to model the flow of pedestrian or vehicular traffic. Network impedances determine which roads are accessible to vehicles as well as pedestrians, the speed or time it takes to traverse a particular segment, as well as the length or distance traveled along the segment.

The second step involves locating the facilities or locations from which the service area boundaries will be generated. Facilities must be located within an acceptable distance from the network paths in order to generate the network-based polygons.

The third step is to generate the network-based polygons based on user-defined parameters. Examples of these parameters are the network impedance, the direction of travel, if u-turns are permitted, and the type of polygon generated. The Network Analyst extension contains several tools to facilitate these three steps.

3. Results

We utilized the 10 min drive-time as the final distance criterion and applied it to senior centers, park and recreation facilities and senior living facilities. With the geographic variation in potential site locations and conditions, eliminating overlap of the 10 min drive time was not entirely possible. We also found that there were some gaps between the potential sites, again something that was unavoidable due to the distribution of potential sites in relation to other variables such as type of site, and population density.

From previous work it was determined that the senior centers were preferable to park and recreation facilities and senior living facilities. We then examined population 65 and over for each of these areas, distance to other areas or potential sites, and how many other senior facilities were in the vicinity or service area to reduce the original geocoded number of 84 potential sites down to 20. This was accomplished in the GIS through an overlay process, where Census Block Groups and associated data were captured that fell within or intersected the boundary of the service areas. We provide Fig. 4 to emphasize again the importance of utilizing the network service area over simple geographic buffers and believe that the map demonstrates this utility in capturing Census data as part of this criterion. This then allowed for the ranking by population over 65. This was perhaps the most valuable part of the analysis in order to determine which sites to approach for fall prevention activities. This provided a total

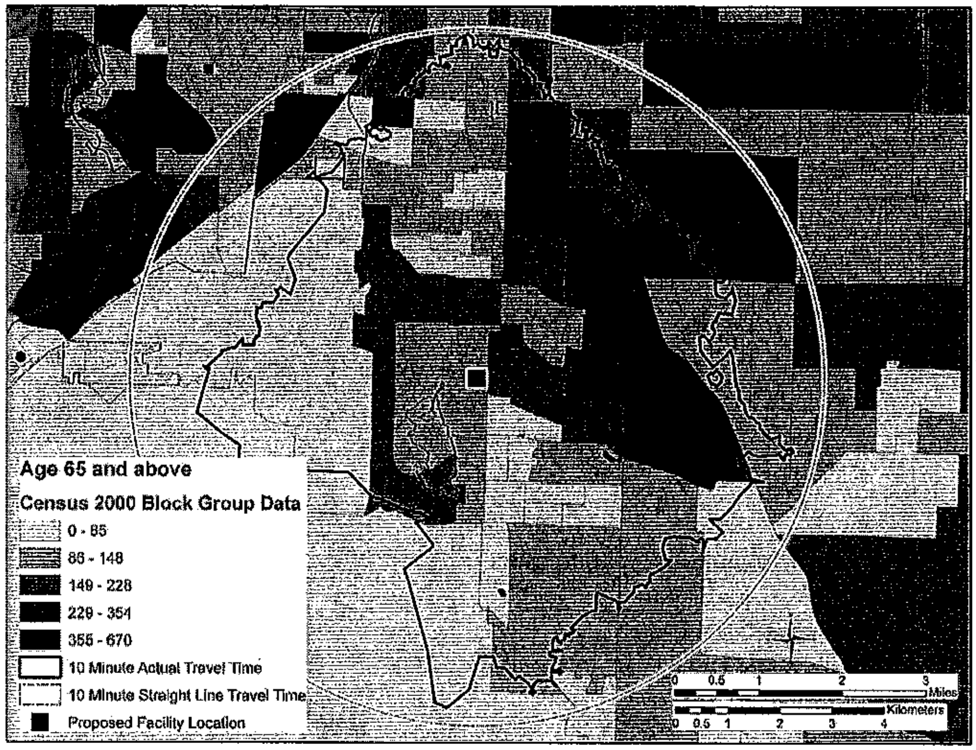

Fig. 4. Comparison of circular buffer vs network service area for capturing Census data.

of 20 service areas and potential locations for fall prevention activities (Fig. 5, due to scale not all sites are visible).

In the next phase, organizations were approached for program partnering based on their GIS model ranking. A total of 17 sites were identified and approached to obtain the final nine sites, which each offered one class designed for up to 20 older adults to attend on a regular basis (1 h, three times a week), for a goal of recruiting 180 older adults. Barriers to site participation were policy-related (organizations did not feel program was of value or did not have senior administrative support to start a new program) or capacity-related (unavailable time, resources, facility space, schedule, or personnel for program).

One year later, six of the nine sites had successfully sustained the program and were offering a total of seven classes, and 331 adults (316 adults 65 and older, and interestingly, 15 adults 48–64 years of age), attended the classes (range of 1–119 classes, mean number of classes attended 24.72, SD 28.51). This recruitment was 83% greater than the original goal of recruiting 180 older adults. To promote long-term sustainability, sites were allowed to set their own class fees for participants; cost per class was free at two sites, and up to a maximum of $2.75 per class at other sites. One site ended their class shortly after 12 months due to a decision by its operating board, despite the objections of the class participants. The five remaining sites successfully embedded the program into their organizations and created long-term sustainability. Four of five sites under one parks and recreation organization were not able to successfully launch the classes, due to inadequately mobilized internal support at several organizational levels. Thus, while it is important for public health program planners to externally assess potential partner

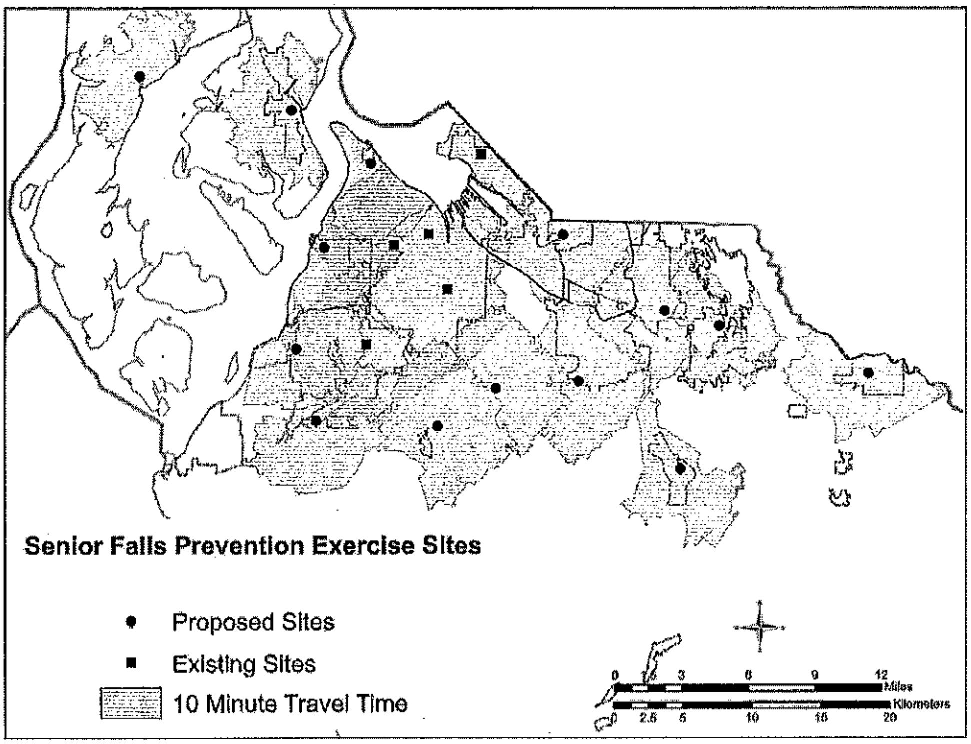

Fig. 5. Senior fall prevention exercise sites.

sites' geographic location and organizational capacity, we found that it is equally important for the partner organizations to internally assess readiness and develop program support at all organizational levels (Frank, 2003) when initially forming public health program partnerships.

4. Discussion

This study demonstrated how GIS can be used to assist health planners in identifying accessible sites for health promotion programs that maximize the efficient utilization of resources. Locating sites and recruiting and retaining older adults for a fall prevention pilot program was aided by the use of GIS. The site suitability analysis model was created by first conducting a community assessment of potential sites that we identified to have program capacity, establishing criteria for site selection, and then creating a geodatabase that included street file data, census data and geocoded addresses of potential sites. Service areas were established and actual travel time using ArcGIS's Network Analyst Extension (instead of traditional buffering operations) was determined. This method was found to provide a more representative assessment of travel time/distance than circular buffers. The use of a network model to generate service areas provided us with actual travel distance in real time, as opposed to straight line distance, and also helped us minimize overlapping service coverage through the visualization of service areas.

GIS offers a feasible and practical method for public health program planning for older adults and other populations. By overlaying layers of spatial data such as street networks and the geographic distribution of the population with attribute data such as the location of services, new information is produced that can be used in program planning. While others have reported the benefits of using the analytic operations of GIS to identify the geographic distribution of the population to be served, locate existing resources or services, and evaluate the spatial relationship between them (Caley, 2004; Cusimano, Chipman, Glazier, Rinner, & Marshall, 2007; Hirshorn & Stewart, 2003; Murad, 2004; Phillips et al., 2000), the network analysis operation in our study used actual travel time to delineate service areas rather than straight-line distance. This paper varies from the afore mentioned studies by Walsh et al. (1997), Cromley and McLafferty (2002), and Gesler et al. (2006) in that although a network analysis is used, we were not seeking the best route to a service, but instead we sought to allocate a service area around each site, which was then utilized to determine travel times, capture Census data and reduce potential overlaps in the defined service. However, very much like the Walsh et al. paper, we sought to demonstrate the use of GIS and Network analysis in the area of healthcare. The process used in this study is replicable in other communities that want to evaluate the suitability of potential program sites for health promotion programs, as it takes into account the geographic distribution of the population to be served, their geographic mobility characteristics, and actual travel time to program locations.

Lessons learned from this phase of the pilot program dissemination were that the GIS approach is highly effective in identifying, prioritizing and targeting potential program sites. Organizational barriers (e.g. conflicting organizational policies, capacity issues) are also program implementation factors. Organizational capacity and willingness factors related to disseminating programs for community-dwelling older adults also need to be analyzed when identifying potential community-based organization program partners (Beilenson, 2005). Community partnerships with academic partners and community-based organizations facilitated the selection of suitable sites for the fall prevention program utilizing GIS.

Several limitations were noted, including the currency of Census data used. Because of potential population mobility, there may be changes in where older adults reside, thereby affecting the models used in the analysis. Another limitation of the approach is the potential to not provide coverage or undercover geographic regions; this might be particularly true in rural communities where population densities may be lower. Therefore, additional program planning or justifications may need to be considered in geographically underserved areas when population density is less of a factor. For some health planners, access to accurate local street data may be difficult. Furthermore, the technological capability (GIS) of public health planners may be limited, and it may be difficult to identify partners with GIS expertise to assist in the analysis. Once potential sites were identified, we found that there was a lack of understanding and some resistance in community-based organizations about fall prevention best practices. This highlights the importance of community education at policy and professional levels. Finally, the number of sites where fall prevention programs could be started was limited by program funding.

It is important to note that this particular intervention model (study) was developed from a solid understanding of the behavior and attitudes of older adults and was based on interview data from the Shumway-Cook et al. (2007) study. As previously mentioned, questions on travel methods and time indicated that older adults prefer travel in private cars over short distance or travel times; which equated with ease of access and was found to foster long-term participation.

For long-term, 2–3 times per week fall prevention exercise program participation, in order to maximize and maintain the benefits of this type of health program, travel factors were found to be of increased importance to participants, whereas in a program that delivers benefits with only short-term participation goals, participants are less sensitive to travel time/distance factors (such as monthly, quarterly or semi-annual physician office visits). It was also noted that there was a preference for co-location of exercise classes with other activities. We realize in future studies it may be beneficial to ask prevention program participants how important distance and time are in comparison with other social and economic factors in their decisions to choose particular falls prevention program locations.

Geographic information systems are an underused yet potent tool that can be used by program planners to locate services so that they are travel accessible to the population they are designed to serve, cost effective, and are sustainable using existing community resources. GIS, when used with organizational assessments, social marketing strategies, and professional education, can facilitate the adoption of effective health promotion programming for older adults in a geographic region.

References

Aday, L. A., & Anderson, R. M. (1981). Equity of access to medical care: A conceptual and empirical overview. *Medical Care*, *19*(Suppl. 12), 4–27.

Bashshur, R. L., Shannon, G. W., & Metzner, C. A. (1971). Some ecological differentials in the use of medical services. *Health Services Research*, *6*(1), 61–75.

Beilenson, J. (2005). Spring diffusion of innovations: How NCOA is developing a better way to disseminate evidence-based health programs. *Innovations: The Publication of the National Council on Aging*.

Boulos, M. N. K., Roudsari, A. V., & Carson, E. R. (2001). Health geomatics: An enabling suite of technologies in health and healthcare. *Journal of Biomedical Informatics*, *34*, 195–219.

Caley, L. (2004). Using geographic information systems to design population-based interventions. *Public Health Nursing*, *21*(6), 547–554.

Campbell, A. J., & Robertson, M. K. (2006). Implementation of multifactorial interventions for fall and fracture prevention. *Age and Ageing*, *35*(S2), ii60–ii64.

Centers for Disease Control and Prevention, National Center for Injury Prevention and Control. (2007). *Web-based Injury Statistics Query and Reporting System (WISQARS) 2007.* Retrieved June 27, 2007 from www.cdc.gov/ncipc/wisqars

Chang, J. T., Morton, S. C., Rubenstein, L. Z., Mojica, W. A., Maglione, M., Suttorp, M. J., et al. (2004). Interventions for the prevention of falls in older adults: Systematic review and meta-analysis of randomized clinical trials. *British Medical Journal*, *328*, 680–683.

Clemson, L., Cumming, R. G., Kendig, H., Swann, M., Heard, R., & Taylor, K. (2004). The effectiveness of a community-based program for reducing the incidence of falls in the elderly: A randomized trial. *Journal of the American Geriatrics Society*, *52*(9), 1487–1494.

Cromley, E. K., & McLafferty, S. L. (2002). *GIS and public health.* New York, London: Guilford Press.

Cromley, E. K., & Shannon, G. (1986). Locating ambulatory medical care facilities for the elderly. *Health Services Research*, *21*, 499–514.

Cusimano, M. D., Chipman, M., Glazier, R. H., Rinner, C., & Marshall, S. P. (2007). Geomatics in injury prevention: The science, the potential and the limitations. *Injury Prevention*, *13*, 51–56.

ESRI (Environmental Systems Research Institute, Inc). 2007. Retrieved June 27, 2007 from http://www.esri.com/

Finkelstein, E. A., Corso, P. S., & Miller, T. R. (2006). *The incidence and economic burden of injuries in the United States*. New York: Oxford University Press.

Fortney, J., Rost, K., Zhang, M., & Warren, J. (1999). The impact of geographic accessibility on the intensity and quality of depression treatment. *Medical Care, 37*, 884–893.

Frank, J. C. (2003). Literature review on community organizations' roles in health promotion and program diffusion. *National Council on Aging: Center for Healthy Aging*, http://healthyagingprograms.org/content.asp?sectionid=32&ElementID=447

Gesler, W., Sherman, J., Spencer, J., Preisser, J., Arcury, T., & Perin, J. (2006). Exploring inequalities and health care coverage by degree of rurality in Western North Carolina. *Southeastern Geographer, 46*, 97–120.

Gillespie, L. D., Gillespie, W. J., Robertson, M. C., Lamb, S. E., Cumming, R. G., & Rowe, B. H. (2003). Interventions for preventing falls in elderly people. *Cochrane Database of Systematic Reviews*, (44) doi:10.1002/14651858.CD000340 [Art. No.: CD000340]

Goodman, D., Fisher, E., Stukel, T., & Chang, C. (1997). The distance to community medical care and the likelihood of hospitalization: Is closer always better? *American Journal of Public Health, 87*, 144–150.

Haynes, R., & Bentham, G. (1982). The effects of accessability on general practitioner consultations, out-patient attendances, and in-patient admissions. *Social Science and Medicine, 16*(5), 561–569.

Haynes, R., Bentham, G., Lovett, A., & Gale, S. (1999). Effects of distances to hospitals and GP surgery on hospital inpatient episodes controlling for needs and provision. *Social Science and Medicine, 49*, 425–433.

Hirshorn, B. A., & Stewart, J. E. (2003). Geographic information systems in community-based gerontological research and practice. *Journal of Applied Gerontology, 22*, 134–151.

Joseph, A., & Phillips, D. (1984). *Accessibility and utilization: Geographical perspectives on health care delivery*. New York: Harper and Row.

Kendal, A., Peterson, A., Manning, C., Xu, F., Neville, L., & Hogue, C. (2002). Improving the health of infants on Medicaid by co-locating special supplemental nutrition clinics with managed care provider sites. *American Journal of Public Health, 92*, 399–401.

Lin, S. (2004). Access to community pharmacies by the elderly in Illinois: A geographic information systems analysis. *Journal of Medical Systems, 28*(3), 301–309.

Longley, P. A., Goodchild, M. F., Maguire, D. J., & Rhind, D. W. (2005). *Geographic information systems and science*. West Sussex, England: John Wiley and Sons Ltd.

Love, D., & Lindquist, P. (1995). Geographical accessibility of hospitals to the aged: A geographic information system analysis within Illinois. *Health Services Research, 29*, 629–651.

Maantay, J., & Zigler, J. (2006). *GIS for the urban environment*. Redlands, CA: ESRI Press.

Martin, D., Roderick, P., Diamond, I., Clements, S., & Stone, N. (1998). Geographical aspects of the uptake of renal replacement therapy in England. *International Journal of Population Geography, 4*, 227–242.

Martin, D., Wrigley, H., Barnett, S., & Roderick, P. (2002). Increasing the sophistication of access measurement in a rural healthcare study. *Health and Place, 8*, 3–13.

McClure, R., Turner, C., Peel, N., Spinks, A., Eakin, E., & Hughes, K. (2006). Population-based interventions for the prevention of fall-related injuries in older people (Review). *The Cochrane Library*, (2).

McLafferty, S. L. (2003). GIS and health care. *Annual Review of Public Health, 24*, 25–42.

Melnick, A. K. (2002). *Introduction to geographic information systems in public health*. Gaithersburg, MD: Aspen Publishers.

Murad, A. A. (2004). Creating a GIS application for local health care planning in Saudi Arabia. *International Journal of Environmental Health Research, 14*(3), 185–199.

Nemet, G. F., & Bailey, A. J. (2000). Distance and health care utilization among the rural elderly. *Social Science and Medicine, 50*, 1197–1208.

O'Sullivan, D., & Unwin, D. J. (2003). *Geographic information analysis*. Hoboken, NJ: John Wiley and Sons, Inc.

Penchansky, R., & Thomas, J. W. (1981). The concept of access: Definition and relationships to consumer satisfaction. *Medical Care, 19*(2), 127–140.

NorthWest Orthopaedic Institute. (2006). *Stay fit!: Physical activity resources for pierce county adults*. Retrieved July 26, 2007 from http://www.nwoi.org/Stay%20Fit%202006%20web%20edition.pdf

Phillips, R. L., Jr., Kinman, E. L., Schnitzer, P. G., Lindbloom, E. J., & Ewigman, B. (2000). Using geographic information systems to understand health care access. *Archives of Family Medicine, 9*, 971–978.

Prohaska, T., Belansky, E., Belza, B., Buchner, D., Marshall, V., McTigue, K., et al. (2006). Physical activity, public health, and aging: Critical issues and research priorities. *Journal of Gerontology, Series B: Psychological Sciences and Social Sciences*, *61*, S267–273.

Rubinstein, L. Z., & Josephson, K. (2002). The epidemiology of falls and syncope. *Clinical Geriatric Medicine*, *18*, 141–158.

Rubenstein, L. Z., & Josephson, K. (2006). Falls and their prevention in elderly people: What does the evidence show? *Medical Clinics of North America*, *90*(5), 807–824.

Rubenstein, L. Z., Stevens, J. A., & Scott, V. (2007). Interventions to prevent falls among older adults. In S. Doll, S. E. Bonzo, D. A. Sleet, J. A. Mercy, & E. N. Haas (Eds.), *Handbook of injury and violence prevention* (pp. 37–53). New York: Springer.

Scott, P., Temovsky, C., Lawrence, K., Gudaitis, E., & Lowell, M. (1998). Analysis of Canadian population with potential geographic access to intravenous thrombolysis for acute ischemic stroke. *Stroke*, *29*, 2304–2310.

Sherrington, C., Whitney, J. C., Lord, S. R., Herbert, R. D., Cumming, R. G., & Close, J. C. T. (2008). Effective exercise for the prevention of falls: A systematic review and meta-analysis. *Journal of the American Geriatrics Society*, *56*, 2234–2243.

Shumway-Cook, A., Silver, I., LeMier, M., York, S., Cummings, P., & Koepsell, T. (2007). The effectiveness of a community-based multifactorial intervention on falls and fall risk factors in community living older adults: A randomized, controlled trial. *Journal of Gerontology: Medical Sciences*, *62A*(12), 1420–1427.

Shannon, G. W., Bashshur, R. L., & Metzner, C. A. (1969). The concept of distance as a factor in accessibility and utilization of health care. *Medical Care Review*, *26*(2), 143–161.

Stevens, J. A., Ryan, G., & Kresnow, M. (2006). Fatalities and injuries from falls among older adults – United States, 1993–2003 and 2001–2005. *Morbidity and Mortality Weekly Report*, *55*(45), 1221–1224.

Stevens, J. A., Corso, P. S., Finkelstein, E. A., & Miller, T. R. (2006). The costs of fatal and nonfatal falls among older adults. *Injury Prevention*, *12*, 290–295.

Tinetti, M. E., Baker, D. I., McAvay, G., Claus, E. B., Garrett, P., Gottschalk, M., et al. (1994). A multifactorial intervention to reduce the risk of falling among elderly people living in the community. *New England Journal of Medicine*, *331*(13), 821–827.

University of California Berkeley Traffic Safety Center Online Newsletter. (2002). How older adults will drive transportation policy: Safe mobility a concern as the nation ages. UC Berkeley Traffic Safety Center Newsletter *1* (1), 3–8. Retrieved July 23, 2007 from http://www.tsc.berkeley.edu/newsletter/Aug02/frontpage.html.

U.S. Census Bureau. (2000). *DP-1. Profile of general demographic characteristics: 2000 Census 2000 Summary File 1 (SF 1) 100-Percent Data*. Retrieved September 20, 2006 from U.S. Census: http://factfinder.census.gov

Walsh, S. S., Page, P. H., & Gesler, W. M. (1997). Normative models and healthcare planning: Network-based simulations within a geographic information system environment. *Health Services Research*, *32*(2), 243–260.

Wilcox, S., Dowda, M., Griffin, S. F., Rheaume, C., Ory, M. G., Leviton, L., et al. (2006). Results of the first year of Active for Life: Translation of 2 evidence-based physical activity programs for older adults into community settings. *American Journal of Public Health*, *96*(7), 1201–1209.

Yiannakoulias, N., Rowe, B. H., Svenson, L. W., Schopflocher, D. P., Kelly, K., & Voaklander, D. C. (2003). Zones of prevention: The geography of fall injuries in the elderly. *Social Science and Medicine*, *57*(11), 2065–2073.