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Neighborhood Influences on Physical Activity in Middle-Aged and Older Adults: A Multilevel Perspective

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Over the past few years, attention has been drawn to the importance of neighborhood influences on physical activity behavior and the need to consider a multilevel analysis involving not only individual-level variables but also social- and physical-environment variables at the neighborhood level in explaining individual differences in physical activity outcomes. This new paradigm raises a series of issues concerning systems of influence observed at different hierarchical levels (e.g., individuals, neighborhoods) and variables that can be defined at each level. This article reviews research literature and discusses substantive, operational, and statistical issues in studies involving multilevel influences on middle-aged and older adults' physical activity. To encourage multilevel research, the authors propose a model that focuses attention on multiple levels of influence and the interaction among variables characterizing individuals, among variables characterizing neighborhoods, and across both levels. They conclude that a multilevel perspective is needed to increase understanding of the multiple influences on physical activity.

Key Words: aging, multilevel analysis, neighborhood

Physical activity, defined as “bodily movement produced by the contraction of skeletal muscle that increases energy expenditure above the basal level” (U.S. Department of Health and Human Services [USDHHS], 1996, p. 20), is becoming recognized as a key health behavior linked to optimal healthy aging (USDHHS, 2000). Accumulating research-based evidence suggests that physical activity positively influences a broad range of health conditions, both physiological and psychological (USDHHS, 1996, 2000, 2002a). Health benefits, however,
do not require vigorous levels of physical activity; spending at least 30 min in moderate activity such as a brisk walk or raking leaves on all or most days of the week is considered sufficient for older adults to obtain significant health benefits (USDHHS, 1996). In light of a substantial body of scientific evidence on the health and functional benefits of physical activity, there is a growing consensus that regular physical activity is associated with significant improvements in the quality of life for adults of all ages (American College of Sports Medicine, 1998; Carbonell, 2003; Chodzko-Zajko, 2001; Sheppard et al., 2003; USDHHS, 1996, 2000a; World Health Organization, 1997).

Sedentary Lifestyles
Among Middle-Aged and Older Adults

There is persuasive and compelling epidemiological and intervention research evidence of the benefits of regular physical activity for older adults (Bauman, 2004; Conn, Marian, Burks, Rantz, & Pomeroy, 2003; King, Rejeski, & Buchner, 1998; van der Bij, Laurant, & Wensing, 2002). Despite this, most Americans are not physically active enough to achieve these health benefits. Overall, government-sponsored, population-based surveillance data suggest little, if any, meaningful change in physical activity levels during the past few decades, and the participation rates of middle-aged and older adults in physical activity are especially low relative to those of other age groups (Centers for Disease Control and Prevention [CDC], 2001; USDHHS, 1996, 2002b). For example, the 1996 U.S. Surgeon General’s report (USDHHS, 1996) estimates that between one third and one half of Americans over age 50 engage in no leisure-time physical activity at all. Recent national data indicate that few older adults engage in regular physical activity (Agency for Healthcare Research and Quality & Centers for Disease Control [AHRQCDC], 2002; CDC, 2001; USDHHS, 2000, 2002b). For example, only 31% of individuals age 65–74 report participating in 20 min of moderate physical activity on 3 or more days per week, and even fewer (16%) report 30 min of moderate activity 5 or more days per week (USDHHS, 2000). For those age 75 and older, levels of activity are even lower: 23% engage in moderate activity for 20 min 3 or more days per week, and only 12% participate in such activity for 30 min 5 or more days per week. Thus, many older Americans are inactive, and even more do not get enough physical activity to achieve important health benefits. There has been no improvement in the levels of physical activity among older adults over the past decade in the United States (AHRQCDC).

Research on Physical Activity

The sedentary and inactive lifestyle in the general older adult population has spawned considerable research efforts aimed at identifying determinants of and barriers to physical activity participation and examining and predicting variation in levels of physical activity of individuals. Because physical activity is most often
construed as an individual-level behavior, however, variation in physical activity patterns is often explained in terms of individual-level determinants or predictors. In this regard, observational physical activity research has predominantly focused on identifying individual-level demographic and psychosocial determinants of physical activity. These include, but are not limited to, gender, age, health status, level of education, attitudes, motivation, intentions, self-efficacy, perceived exercise benefits and barriers, and social support (from friends/peers, spouse/family). These individual-level characteristics have been well documented and are modest but consistent correlates of physical activity in the adult population (Bauman, Sallis, Dzewaltowski, & Owen, 2002; Chogahara, O’Brien Cousins, & Wankel, 1998; Dishman, 1988, 1994; Dishman & Sallis, 1994; McAuley & Katula, 1998; Sallis & Owen, 1999; Shephard, 1994; Trost, Owen, Bauman, Sallis, & Brown, 2002; USDHHS, 1996).

Current Research Paradigms

The individual-level approach has tended to overlook the broader context in which the physical activity of individuals occurs. More recently, however, attention has focused on the potential impact that social- and physical-environment characteristics, as well as public policies, can have on levels of physical activity (Bauman, Sallis, & Owen, 2002; Humpel, Owen, & Leslie, 2002; King, Stokols, Talen, Brassington, & Killingsworth, 2002; Saelens, Sallis, & Frank, 2003; Sallis & Owen, 2002). Social-environment influences on physical activity might include relatively new concepts such as social cohesion or social capital among individuals living in the same neighborhood and social support from others. Factors related to physical-environment influences include the proximity and availability of physical activity facilities, safety of physical activity settings, population density, street connectivity, and land-use mix. Public policies might include rules, laws, or regulations that shape environmental or policy attributes conducive to physical activity.

Although social-ecological models were proposed more than a decade ago in the public health arena for planning and evaluating effective health-promotion programs (McKinlay, 1995; McLeroy, Bibeau, Steckler, & Glanz, 1988), less attention has been given to such frameworks in the field of physical activity. This ecological paradigm suggested the need to go beyond conventional individual-level approaches and consider multifaceted and multilevel ecological influences on population physical activity levels (Sallis & Owen, 2002). Of particular importance in this multilevel approach is the simultaneous consideration of the relative influences of individual factors and contextual factors (i.e., neighborhood social and physical environments) on physical activity.

Purpose of This Article

This article is intended to stimulate discussion about research on aging and physical activity by extending the current focus on the individual-level research paradigm.
Our goal is to examine the value and importance of a multilevel-analysis paradigm. This paradigm includes consideration of the larger social-environmental system in which physical activity takes place and where levels of physical activity participation are mostly likely to be influenced. In line with the Surgeon General’s report (USDHHS, 1996), we confine our discussion of physical activities primarily to those taking place in natural contexts for social reasons, leisure, transportation, or gardening, involving either individual (e.g., daily walking, bicycling) or structured group activities (e.g., stretching, Tai Chi, low-impact exercises). Although there is no consensus on the definition of “neighborhood” in providing a meaningful discussion, we use either resident-defined or census-defined boundaries as proxies for neighborhoods in urban communities. We also focus our population of interest on adults age 50+ because they are the most physically inactive adult population (USDHHS, 2002b), at higher risk for health problems (AHRQCDC, 2002; National Academy on an Aging Society, 2000), and the primary adult population targeted for physical activity promotion (e.g., National Blueprint; Chodzko-Zajko, 2001; Sheppard et al., 2003). The central thesis of this article is that researchers in aging and physical activity should pay more attention to the community contexts where the physical activity behavior of the older adult population takes place. Following this theme, we first present a case for the need to consider multiple levels of influence on physical activity based on conceptual considerations. We then provide a discussion of issues related to the operationalization of multilevel variables in the study of physical activity and statistical methodologies required for mapping the study hypotheses onto multilevel empirical data. We follow this with a discussion of future research needs and suggestions for when to apply multilevel perspectives to research on physical activity in aging. We focus primarily on the social and neighborhood context but recognize the important influences of intraindividual, interpersonal, organizational, community, environmental, and policy factors on the initiation and maintenance of an active lifestyle for middle-aged and older adults.

**Substantive Considerations of Multilevel Influences**

A key notion for considering a multilevel approach in physical activity research is that physical activity most often takes place in a community or neighborhood context. For example, middle-aged and older adults often participate in physical activity programs that are offered through local community organizations (e.g., parks and recreation agencies, senior service providers, health departments, or private foundations; e.g., Hooker, 2002; Orsega-Smith, Payne, & Godbey, 2003; Stewart et al., 1997). In addition, common activities such as walking and jogging reported in the general adult population are typically done in neighborhoods instead of specific facilities (Bauman, Sallis, & Owen, 2002; Fisher & Li, 2004), making the neighborhood context a unique setting that makes a difference in physical activity. Thus, in addition to numerous individual-level (demographic, psychosocial) influences, it is important to take into account neighborhood social- and
physical-environment characteristics and to emphasize the role that contexts and environments play in shaping and promoting physical activity in this population. Such a conceptual perspective is intrinsically multilevel; that is, factors that influence physical activity need to be viewed as simultaneously operating at the level of individuals and at the neighborhood level.

There has been growing recognition in the social-epidemiological literature that social capital and built-environment conditions in broad community and social settings (e.g., neighborhoods, suburbs, metropolitan areas) are associated with people’s mental and physical health (Kawachi & Berkman, 2003; Shinn & Toohey, 2003), which makes a strong case for considering neighborhood effects in the area of physical activity. There are also important epidemiological reasons for considering contextual (e.g., neighborhood) variations in explaining physical activity outcomes. For example, if particular neighborhoods appear less physically active than others, it might have something to do with the contextual environment of the neighborhood. It might be that strong social cohesive processes of contextual/geographical separation are taking place (i.e., similar types of individuals choose to reside in a given neighborhood). In addition, social and economic conditions in these contextual settings might also be likely to moderate individual physical activity behavior (Estabrooks, Lee, & Gyrus, 2003; Ross, 2000; Yen & Kaplan, 1998). Such an evaluation of the extent to which these contextual variables explain variation in physical activity would require a multilevel approach.

ECOLOGICAL APPROACHES

As indicated previously, the earlier social-ecological framework presented for public health problems (McLeroy et al., 1988) has provided researchers an initial framework for understanding factors that influence physical activity in general (Baranowski, Perry, & Parcel, 2002; Bauman, Sallis, Dziwaltowski, & Owen, 2002; Booth et al., 2001; King et al., 2002; Saelens, Sallis, & Frank, 2003; Sallis & Owen, 2002; Smiley & Syme, 2000; Stokols, 1996). For example, Sallis and Owen’s work (1999, 2002) focused on environment and policy influences. Booth et al. (2001) proposed more specific models that deal with primary settings (e.g., health clubs, senior centers, shopping malls, neighborhoods) where physical activity takes place. King et al. (2002) provided an overall review of theoretical perspectives aimed at different levels of understanding and analysis, from the personal level through broader scale meso- and macroenvironmental perspectives. Saelens et al. (2003) provided insights from a transportation and urban-planning perspective on how the built environment might affect population physical activity levels. These views collectively suggest that physical activity might be best explained by level-specific (i.e., individuals, contexts) psychosocial, built-environment, social, and public-policy variables. Although few studies using the ecological approach have been conducted in the older adult population, new findings and evidence based on general adult populations have emerged to support this approach (e.g., Brennan, Baker, Haie-Joshu, & Brownson, 2003; Estabrooks et al., 2003; Fisher, Li, Michael,
Influences From the Built Environment. A number of studies, mainly based on the general adult population, have shown multifaceted built-environment influences on physical activity. For example, Troped et al. (2001) showed that adults who reported less busy streets and less hilly terrains in the community environment were more likely to report using a community rail-trail. Brownson, Baker, Housemann, Brennan, and Bacak (2001) reported that neighborhood characteristics such as sidewalks, hills, and enjoyable scenery were positively associated with self-reported physical activity among U.S. adults. Saelens, Sallis, Black, and Chen (2003) showed that residents living in high-walkability neighborhoods reported higher residential density, land-use mix, street connectivity, aesthetics, and safety than did those living in low-walkability neighborhoods. Correlates of physical activity appear to vary by demographic, economic, and geographic characteristics in the general U.S. adult population (King, Castro, Wilcox, Eyler, & Sallis, 1998; Parks, Housemann, & Brownson, 2003; Wilcox, Castro, & King, 2000). For example, for rural women, White race, higher educational attainment, and enjoyable scenery in the neighborhood were associated with increased physical activity (Wilcox et al.). A study by Parks et al. showed that although lower income residents in general report being less physically active than higher income residents do, lower income residents in urban areas were more likely to report using neighborhood streets, parks, and shopping malls as places to exercise.

A number of studies conducted in Australia have also shown support for built-environment influences on physical activity (Ball, Bauman, Leslie, & Owen, 2001; Giles-Corti & Donovan, 2002a, 2002b). For example, perceptions of pleasant environments and convenient access to destinations (which is an index of mixed land use) were associated with increased adult walking (Ball et al.). Spatial access to attractive, public open space and perceptions of access to sidewalks and neighborhood attractiveness were associated with adults’ walking and vigorous activity (Giles-Corti & Donovan, 2002a). For the older population, Booth, Owen, Bauman, Clavisi, and Leslie (2000) found that participants who reported the availability of footpaths that were safe for walking and who had access to local facilities were more frequently physically active.

Social Environment Influences. Perceptions of social-environment indicators are also found to be associated with individual-level physical activity, including neighborhood supports such as active neighbors (Brownson et al., 2001) and significant others (Ball et al., 2001; Booth et al., 2000; Giles-Corti & Donovan, 2002a; CDC, 1996). Furthermore, because older adult physical activity often occurs in community settings (e.g., neighborhoods) and entails the likelihood of social networking and personal and social interactions, it is plausible that these social activities and the degree to which older adults engage in social and recreational activities might lead to increased social capital in neighborhood communities. Social capital has been defined as those features of communities that involve levels of interpersonal
trust between citizens, reciprocity, and social bonding that facilitate cooperation for mutual benefit (Kawachi & Berkman, 2000; Putnam, 1995). Social capital is a resource that resides in the relationships that residents have with each other and that residents within a neighborhood can draw on to achieve certain collective actions (Kawachi & Berkman, 2000). The concept of social capital has been an extensive research topic in the fields of epidemiology, criminology, and urban sociology (Baum & Ziersch, 2003; Kawachi & Berkman, 2000; Leyden, 2003; Putnam, 1993; Sampson, 2003) and has been shown to be of great importance for population health. Studies linking social capital to health have examined several indicators including mortality (Kawachi, Kennedy, Lochner, & Prothrow-Stith, 1997; Lochner, Kawachi, Brennan, & Buka, 2003), violent crime (Sampson, Raudenbush, & Earls, 1997), self-rated health status (Kawachi, Kennedy, & Glass, 1999; Veenstra, 2000), and binge drinking (Weitzman & Kawachi, 2000).

Therefore, it is conceivable that social capital, acting as a community resource, might be linked to the physical activity of middle-aged and older adults at the neighborhood level. As a neighborhood-level characteristic, social capital is likely to be associated with physical activity participation because it (a) provides resources and facilities (i.e., access to local health care, social services, amenities), (b) provides opportunities for civic activities and events (e.g., walkathon for a good cause), (c) communicates information and materials about health and active lifestyles (e.g., Healthy People 2010; National Blueprint), (d) creates community social networks that promote a healthier society (e.g., Fun runs, Fun walks), and (e) forges collaborative action and partnerships for health and physical activity promotion (e.g., American Association of Retired Persons, American Heart Association). Research linking elements of social capital to physical activity is sparse, but a small but insightful body of studies suggests that the concept is relevant and appropriate in the domain of physical activity research.

A cross-sectional survey study of adults (Brennan et al., 2003) showed that, after accounting for demographic variables (e.g., age, gender, education, income, and ethnicity), perceptions of social protective factors such as social networks, participation, social cohesion, informal social control, sense of community, reciprocity, trust, and safety were associated with an increased likelihood of meeting general recommendations for physical activity in adults. Nonetheless, because all indicators were parceled into a single construct and the data were analyzed at the individual level, the study was not able to delineate any specific effect or discern community-level impact on individual-level physical activity. In a multilevel cross-sectional analysis, Lindström, Moghaddasi, and Merlo (2003) explored whether social capital (operationalized as social participation of formal and informal groups in neighborhoods) among people age 20–80 years was related to levels of leisure-time physical inactivity in neighborhoods. Their results showed that along with individual-level factors, the social-capital variable was found to partially influence leisure-time physical activity in the neighborhoods. In another multilevel cross-sectional study, Fisher et al. (2004) found a positive association between levels of neighborhood walking activity and perceptions of neighborhood social cohesion (operationalized through an aggregation of participants’ self-report measures to
the neighborhood level) in a sample of neighborhood older residents (age 65 and over). The results indicated that residents in socially cohesive neighborhoods were more likely to report higher levels of neighborhood walking activity than were those living in less cohesive neighborhoods.

**Limitations.** It should be noted that the majority of studies conducted to date focus on the general adult population. Little is known about the influences of the social and physical environment or environmental policy on the aging population. More important, no intervention study is yet available investigating the impact of change in social and physical environments on change in physical activity. Consequently, no causal inference can be made with regard to correlates/predictors or moderator/mediator effects on change in physical activity. Similarly, although the findings from Fisher et al.’s (2004) study extend the individual-level findings linking the association between social capital (more specifically, social cohesion) and physical activity to the level of neighborhoods in the older adult population, much work remains to be carried out before social capital can be widely applied to improve physical activity, including establishing standards of measurement. At the moment, the field remains in its infancy and new methodological and statistical techniques need to be considered and tested (Bauman, Sallis, & Owen, 2002) before the science can move farther forward. These points are briefly discussed below.

**Operational Considerations of Multilevel Influences**

Having recognized relevant sources of influence from a multilevel-system perspective that considers both individual and contextual influences, we recognize the need to conceptualize our model of physical activity behavior so that multilevel system influences, such as those of the social and physical environments, will be appropriately assessed and evaluated. Given the proposed multilevel influences on physical activity in middle-aged and older adults, it is important that studies of individual physical activity behavior take into account differences in the properties of the social and ecological units to which individuals belong (e.g., neighborhoods, communities).

At the operational level, there is a need to consider measures that accurately characterize and assess the ecological contexts that affect physical activity behavior. The measurement of these contextual-level variables is less well defined than that of individual-level characteristics. There are less rigorous definitions of larger social units such as neighborhoods or communities in which individuals reside and in which their physical activity takes place. Specification of level-specific influences is thus critical in delineating characteristics that might be attributable to either neighborhood-level or individual-level domains. In this section, we focus on three issues: sources of data, measurement issues, and defining and selecting the geographic unit.
SOURCES OF DATA

Physical Activity. In studying multilevel influences, outcome-response data are often collected at the individual level. In the field of physical activity, self-reported measures are the primary source of data, including physical activity recall, measured in units (e.g., estimates of energy expenditure; Godin, Jobin, & Bouillon, 1986; Sallis et al., 1985) or nonunits (Washburn, Smith, Jette, & Janney, 1993). Objective measures, however, such as pedometers and accelerometers are receiving increasing attention (see Dale, Welk, & Matthews, 2002).

Information about neighborhood- and individual-level characteristics can be collected from multiple sources, including objective measures (e.g., geographic information systems, census data, direct observations, police records, epidemiological data) or subjective measures (e.g., self-reports). Individual-level measures are well established for examining individual-level characteristics; next we briefly discuss neighborhood-level measures that can be used to link neighborhood environments to physical activity.

Census Data. Census data are considered aggregated (or derived) variables summarizing the characteristics of individuals for the census-defined area in which they reside (e.g., census tract, block group, neighborhood; Diez-Roux, 2003). Census data can readily be used as upper-level social and economic indicators in the study of neighborhood effects. For example, in Fisher et al.’s (2004) study, neighborhood-level data were compiled from census data to describe neighborhood characteristics (e.g., percentage of neighborhoods with low income, number of parks and trails per neighborhood acre, number of senior residents per neighborhood acre) that were linked to neighborhood physical activity in older adults. Although census data are easily available and expedient, they might not represent the current status of change in the units of interest (Shinn & Toohey, 2003) because most census data are collected only once every 10 years.

Other Public-Domain Data. There are other sources of available or established databases to consider when evaluating community or neighborhood features with regard to physical activity. These include, but are not limited to, the following: commercial- and residential-property information (e.g., industrial, commercial, or residential building codes), real-estate data (valuations, lot sizes, sales-history data), economic or fiscal data (unemployment statistics, insurance records, funding and other appropriations for community development), public safety (e.g., crime data from police records), public health information (e.g., vital records, disease and illness prevalence), community-resources provision (e.g., social services and public assistance data, community-agency directories, neighborhood associations), and utilization of physical activity facilities. Many of these data can be collected from state agencies, city and county offices, or private companies. A study by Estabrooks et al. (2003) provided an example of collecting resource availability and accessibility of physical activity in a neighborhood setting.
**Geographic Information Systems.** Researchers have begun to use geographic information systems (GIS) to develop indices for spatial and attribute information of the built environment. For example, size, shape, and amenities of a public park and demographic variables of individuals living near the park can be linked through GIS. GIS can also provide spatial linkage that enables the integration of measures of proximity, street- and travel-related connectivity, topography, urban density, and other environmental factors with systematic assessment of household or individual physical activity behavior (Saelens, Sallis, & Frank, 2003). Others have used more sophisticated global-positioning systems to collect coordinates of public recreational facilities, shopping malls, and walking or bicycling trails (Kirtland et al., 2003; Li, Fisher, Brownson, & Bosworth, in press). There has also been an increased use of GIS environmental measures to quantify the relation between the physical environment and individual physical activity (e.g., Giles-Corti & Donovan, 2002a, 2003; Kirtland et al., 2003; Troped et al., 2001). Nonetheless, data related to individual-level social components (e.g., social cohesion, social support) might still need to rely on self-reported measures to be aggregated to the upper level (e.g., neighborhoods).

**Self-Reported Data.** Self-reported subjective data are commonly used in community research to define either individual- or neighborhood-level measures. In fact, many self-report perception-based measures characterize community settings or assess quality (e.g., perceptions of the living environment, values, attitudes, and neighborhood safety; Ball et al., 2001; Shinn & Toohey, 2003). These measures can be aggregated to create neighborhood-level characteristics or norms. Examples of using self-reported data aggregated to the neighborhood level can be found in physical activity research involving social capital (e.g., social cohesion, Fisher et al., 2004; social participation, Lindström et al., 2003) and individual-level measures of social and environmental factors (Brennan et al., 2003; Leyden, 2003), including neighborhood “walkability” (Saelens, Sallis, Black, & Chen, 2003).

**Observational Measures.** Observational measures involve using trained observers to evaluate features of the built environment, including (a) accessibility to surrounding physical activity facilities, recreational centers, and walking/cycling trails; (b) quality of infrastructure of the facilities, including equipment, lighting, and restrooms; (c) aesthetic features such as attractiveness and pleasantness; and (d) safety from traffic, such as sidewalk width and quality, bike lanes, and signs at intersections. Thus, observational measures can provide objective, quantitative, and qualitative measures of the built environment in neighborhoods. It is crucial, however, that interrater reliability be established before any observational measures can be used with confidence.

**MEASUREMENT ISSUES**

Bauman, Sallis, and Owen (2002) outlined several challenges in studying multiple levels of influence on physical activity, including the lack of reliable and valid measures of social and physical environments. Although there are some measures that are currently available for the general adult population (e.g., Booth et al., 2000;
Brennan et al., 2003; Brownson et al., 2001; Kirtland et al., 2003; Saelens, Sallis, Black, & Chen, 2003), specific instruments relevant to the aging population are virtually nonexistent. Similarly, policy measures relevant to physical activity have been proposed (Bauman, Sallis, & Owen, 2002) but have not been studied in the aging and physical activity area. All this presents a great challenge to the field and calls for more psychometric efforts to be brought to the issues of measurement. Many measures are developed for specific purposes in studies without undergoing a test–retest procedure or confirmatory evaluation. There is a need to develop standardized and context-specific measures assessing multiple levels of influence in neighborhood contexts. On the positive side, however, currently available measures might be used as a foundation for establishing psychometrically sound and valid social- and physical-environment measures for this population.

There are currently both subjective and objective measures of physical activity outcomes. Although objective measures of physical activity are becoming increasingly available (e.g., pedometers, accelerometers) and are more valid, these measures are not without limitations; they are often cost prohibitive, labor intensive, or invasive. In addition, they tend to have greater variability, resulting in nonnormal data distribution caused by outliers (e.g., Saelens, Sallis, Black, & Chen, 2003). Despite this, and given the lack of gold-standard measures in this area, multiple sources of data are encouraged.

Measures of social-capital indicators (e.g., social engagement, social cohesion) are commonly aggregated through individual self-reports. Kawachi and Berkman (2003), however, noted that the extent to which the respondents’ own personality and health status might contaminate the ratings of their neighborhood is unknown and unobserved. From this perspective, independent sources of assessment would be helpful. Self-report measures should be subject to a rigorous validation process in which they are linked with objective measures to establish concurrent validity. In addition, although social capital is often conceived as a neighborhood construct, individuals’ perceptions of neighborhood social capital are often ignored. We cannot rule out the possibility that these self-report measures have individual-level effects on physical activity, suggesting the need to take into account individual differences in modeling neighborhood effects of social capital on physical activity.

DEFINING AND SELECTING THE GEOGRAPHIC UNIT

A key issue to address in selecting sampling units (e.g., census tracts, census-block groups, neighborhoods, counties) in a multilevel study design concerns the meaningfulness and representativeness of the chosen sampling units. Currently, there is no rule of thumb in determining whether the study unit is defined geographically or by residents’ perceived neighborhood boundaries. Most physical activity research to date uses the census-defined boundary (e.g., census tract, block group) as a proxy for neighborhood in urban communities (e.g., Kirtland et al., 2003; Saelens, Sallis, Black, & Chen, 2003). Others use boundaries defined by local communities (e.g., neighborhood associations; Fisher et al., 2004). In either case, there
is doubt that census- or local-community-defined neighborhoods entirely match residents’ perspectives on neighborhood boundaries. Coulton, Korbin, Chan, and Su (2001) found that residents’ self-defined neighborhoods were close in size to actual census tracts but typically included portions of at least two adjacent census tracts and three block groups. Furthermore, rank-order correlations between social indicators calculated for census tracts and for resident-defined neighborhoods were as low as .3. A recent study of physical activity revealed low levels of agreement between individual perceptions of environment and physical activity and objective measures using GIS procedures (Kirtland et al.). These findings suggest that people’s definitions of their neighborhoods do not necessarily conform to census boundaries or other objective measures.

Fundamentally, the choice of geographic unit should be guided by a theory or a conceptual framework. Choosing small geographic units (e.g., block groups, streets) might have the advantage of obtaining within-neighborhood homogeneity (e.g., shared culture values, goals, civic activities). Geographic units or areas where residents spend the most time or from which they travel to work, shopping, and social or recreational activities might be more influential as a proxy for neighborhood (Shinn & Toohey, 2003). On the other hand, selecting larger geographic units might increase within-neighborhood heterogeneity of both the outcome variable and the covariates or predictors. In principle, the geographic unit chosen for investigation should be the smallest unit available to increase variability between units and decrease variability within units (Cook, Shagle, & Degirmencioglu, 1997; Roosa, Jones, Tein, & Cree, 2003; Taylor, 1997). The use of short distances from one’s neighborhood residence (e.g., 0.25-, 0.3-, or 0.5-mile radius) to define geographic areas or neighborhoods has also been used in physical activity research (Giles-Corti & Donovan, 2002a; Kirtland et al., 2003; Li, Fisher, Brownson, & Bosworth, in press). Because most physical activity behavior (e.g., walking, jogging) takes place in immediate neighborhoods or nearby streets, it might be reasonable to consider street blocks ideal units for most studies of physical activity behavior of older adults.

The issue of representativeness of the sampled units should be addressed through a random, multistage sampling process. It is feasible to select larger numbers of neighborhoods while sampling smaller numbers of residents in each neighborhood. This certainly might increase the representativeness of neighborhoods but potentially limits diversity within neighborhoods. Other options involve selecting smaller numbers of neighborhoods but larger numbers of within-neighborhood residents. This might affect diversity among neighborhoods and intraneighborhood correlations common in neighborhood research (an issue that is discussed in the next section). Both scenarios tend to decrease statistical power to detect neighborhood effects. To ensure the representativeness of the sample population in multilevel studies, units within each level need to be randomly sampled with sufficient sample sizes. There are, however, tradeoffs in considering the sampling design, both at the individual and at the neighborhood level. The tradeoffs, with regard to efficiency of model-parameter estimates, depend on three issues: (a) estimates of fixed effects (i.e., significance of the predictor variables) versus random effects
(i.e., variability of means and slopes between neighborhoods) of individual- and neighborhood-level parameters; (b) design effects (Muthén & Satorra, 1995), which are a function of the intraclass correlation (i.e., the within-neighborhood variation relative to total variation) and the average cluster size; and (c) the complexity of the model (i.e., number of predictors at the individual and neighborhood levels). Some of these issues fall under the umbrella of statistical considerations and are discussed in the following section.

**Statistical Considerations**

As we alluded to earlier, a multilevel model of physical activity requires inclusion of level-specific variables in a system hierarchy to accurately explain variation in the physical activity outcome. After level-specific variables are identified and specified at their relevant levels, subsequent modeling of physical activity outcomes should consider analyses that would delineate the specific contribution of level-specific effects or interaction of effects across levels.

Multilevel modeling of influences on physical activity implies that data-measuring variation in outcomes comes in the form of a hierarchical structure, such as individual units nested within clusters or groups. For example, in large-scale survey studies, individuals are observed from a higher level (e.g., neighborhoods), which are, in turn, nested in communities. Communities, in turn, are further nested within geographic areas (e.g., counties, states), and so forth. In such a sampling scheme, individual observations are in general not completely independent. As such, the usual regression assumption of independence of errors is violated, leading to biased coefficients. At the same level, data that contain higher-level information (e.g., neighborhood characteristics) but are analyzed at an individual level (i.e., by appending the neighborhood characteristics to individual observations) might also be inappropriate because the individual variation in relation to neighborhood-level characteristics can only be generalized to individuals. Until relatively recently, common approaches to the analysis of data generated from social-unit levels would be to either disaggregate data to the individual (i.e., resident) level or aggregate data to the social unit (e.g., neighborhood). Neither approach is considered adequate for a more complete understanding of the actual structure of the data.

**UNIT OF ANALYSIS**

The units of analysis can be defined at different levels; however, the level of analysis conducted has implications for inferences to be made. Substantively, limiting analysis to the individual level makes it impossible to separate the influence of individual effects from environmental or contextual effects or to examine interactions between individual and environmental characteristics. As we have discussed previously, this leads to limitations in understanding the results.

Despite the important conceptual considerations of multiple levels of influences on middle-aged and older adults’ physical activity, the vast majority of existing studies involving the examination of social- and physical-environment influences
have been conducted at a single level. As a result, multiple levels of influence on physical activity, although well defined at the conceptual and theoretical level, have not been dealt with operationally. Therefore, this raises the question about the meaningfulness and interpretation of existing reports about social and physical influences on physical activity. The methodological problems inherent in drawing inferences regarding individual-level associations based on group-level data (the ecological fallacy) or group-level associations based on individual-level data (individualistic fallacy) have long been recognized in the epidemiological literature (e.g., Alker, 1969; Diez-Roux, 1998, 2003; Robinson, 1950; Subramanian, Jones, & Duncan, 2003; Susser, 1994). The issue common to both types of fallacy is the failure to recognize unique relationships observable at multiple levels, each being important in its own right (Subramanian et al.). The resulting outcome of this approach might therefore lead to misleading and erroneous conclusions.

From a statistical standpoint, if individual data are aggregated to a contextual level, information is lost and statistical analysis loses power. When physical activity data are collected at the neighborhood level (residents nested within neighborhoods), the data are inherently clustered. It is likely that the residents who reside in a particular geographic area are more similar to each other than a randomly selected group of individuals would be. When modeling data are gathered from these clustered individuals, the within-group homogeneity (indexed by the well-known intraclass correlation, or ICC, to be discussed later) results in potentially shrinking standard errors, thus increasing Type 1 error rates. In such a situation, analyses suffer from the unit-of-analysis problem. Therefore, statistical procedures that account for a multilevel data structure are required. If, on the other hand, contextual data are disaggregated to the individual level but are not independent of one another, the result is fewer independent data values. Ordinary statistical tests demand that data values for individual observations be independent. Failing to recognize the dependent nature of data values, along with the source of the dependency, can lead to finding significant relationships where none exist. A multilevel methodological and statistical perspective provides a comprehensive framework to address these concerns.

**MULTILEVEL ANALYSIS**

Neighborhood research on physical activity often includes data from two levels (e.g., neighborhood, individual) and uses combinations of these data to examine their relations to physical activity outcomes. If data were collected longitudinally on each individual, we would have three levels, with repeated observations nested within individuals, nested within neighborhoods. Such a data structure is commonly referred to as multilevel data. The appropriate approach to a multilevel-data structure is through multilevel analysis (see Diez-Roux, 1998, 2003; Goldstein, 1995; Muthén, 1994; Raudenbush & Bryk, 2002; Subramanian et al., 2003). Multilevel models allow the simultaneous examination of intergroup (e.g., neighborhoods) and interindividu]].
simultaneous analysis of the influences of group- and individual-level variables in explaining variation of physical activity among individuals and among groups. For example, a study might make observations of a sample of neighborhoods and of the individual-level characteristics of a sample of residents within each neighborhood. Researchers might be interested in investigating how neighborhood-level and individual-level factors are related to physical activity outcomes, as well as the extent to which between-neighborhood and between-individual variability in the outcomes are explained by variables defined at both levels. Thus, multilevel analysis enables researchers to deal with individual-oriented characteristics (e.g., health status, psychosocial variables) and neighborhood contextual characteristics or attributes related to physical activity (e.g., availability and accessibility of facilities, neighborhood density, traffic conditions, socioeconomic status, social support). The resulting output from the multilevel analysis can thus be used to draw level-specific inferences regarding the causes of interindividual variation and the extent to which it is explained by individual- or neighborhood-level variables. Inferences can also be made regarding intergroup variation, whether it exists in the data, and to what extent it is accounted for by group- and individual-level characteristics. Li and Harmer (in press) provide an illustrative example of multilevel analysis in the context of physical activity.

Intraclass Correlation. A common way to determine whether a multilevel analysis is warranted is to examine intraclass (or intraneighborhood) correlation (ICC). ICC is often used to determine the degree of similarity (homogeneity) in physical activity outcomes for residents in a neighborhood to make a neighborhood-level attribution meaningful. Individuals living in the same neighborhood might engage in more similar physical activity behaviors that are linked to the environment (e.g., walking for transportation) than do individuals living in other neighborhoods, because they share a similar environment (e.g., service availability, transportation systems), similar norms and values, and other neighborhood characteristics, which therefore results in smaller within-neighborhood variance. In this sense, neighborhoods can be considered “clusters” of individuals sharing similarities with regard to physical activity. In technical terms, ICC is a variance-partition coefficient that indicates the proportion of the total variance (i.e., the sum of lower level [individuals] and higher level [neighborhood] variances in a physical activity outcome) that is accounted for by the higher level variance. The size of ICC ranges from zero (no within-neighborhood variation) to 1 (high within-neighborhood variation). As alluded to earlier, the importance of the size of an ICC depends on the size of the clusters (Muthén & Satorra, 1995). Both cluster size and ICC contribute to the design effect (Kish, 1965). In cluster samples, the design effect is approximately equal to 1 + (average cluster size – 1) × ICC (Kish). Referring to work by Muthén and Satorra, if the design effect is smaller than 2, using single-level analysis on multilevel data does not seem to lead to overly misleading results. Therefore, it is the issue of the design effect in cluster samplings that needs to be taken into account in justifying the application of a multilevel analysis.
Sample Size. Most statistical software that analyzes multilevel data uses maximum likelihood estimation, which has asymptotic properties, that is, properties that hold as the sample size gets large. In addition, estimates and their standard errors become more accurate with increasing sample sizes at all levels (Hox, 2002; Hox & Maas, 2001; Kreft, 1996). Exactly how large the sample size has to be is an empirical question that depends on a number of factors, including estimation of fixed (i.e., means) versus random (variance, covariance) parameters or effects, distribution of outcome variables (normally distributed data vs. proportions or binomial data), number of variables at all levels, and model complexity (i.e., cross-level interactions). Kreft proposed a rule of thumb of a “30/30 rule” (i.e., 30 groups with at least 30 individuals per group). Hox suggested that with complex models such as one involving cross-level interactions, the number of groups might be even larger, which leads to a 50/20 rule (a minimum of 50 groups with about 20 individuals per group). If the researcher is interested in random effects of a multilevel model, a much larger ratio of 100:10 is recommended. Muthén (1991) suggests between 50 and 100 groups for multilevel statistical procedures using structural-equation modeling. An option, noted by Muthén, would be to sample fewer observations within groups and increase the number of between-group clusters. This suggestion is supported by simulation studies (Hox & Maas), which show that large groups are preferable to large numbers of individuals. Another consideration is the magnitude of ICC. As indicated previously, if the ICC is essentially zero, there need be no consideration of a multilevel analysis. If, on the other hand, the ICC is high, a large within-group sample might not be necessary, and it is better to have more groups. Simulation studies show that, in general, the required sample size per group decreases as the ICC increases (Snijders & Bosker, 1999). Obviously, increases in group- and individual-level sample sizes are linked to financial costs. The costs in some cases can be prohibitive if objective physical activity outcome data (e.g., accelerometers) are involved. In this case, decisions should be made based on proper power analysis (Hox; Snijders & Bosker).

Future Research Needs and Directions

The subject of multilevel influences on physical activity in later life offers great potential for future research. Current research efforts have primarily focused on the general adult population and on individuals as units of analysis, with less emphasis on the importance of how individuals are embedded in neighborhoods, communities, and societies. This might be largely because of individualistic theories resulting in individual-level analyses for explanations of physical activity behavior. Broader theoretical frameworks are needed. An individual’s routine daily activities are often nested in larger social units that affect health behavior. Similarly, other researchers have focused on environmental- and policy-level factors, with little concern for individual-level determinants and possible cross-level interaction. To counter these polar extremes, each of which is limiting in its own way, increased application of ecological approaches to the understanding of the physical activity of populations and individuals is warranted. Researchers should think in both
substantive and methodological terms about what is needed to pursue multilevel studies. With this in mind, in the following section we provide a general discussion of further research needs and directions.

Despite the increasing trend toward emphasizing social- and physical-environment factors that influence middle-aged and older adult physical activity, some critical conceptual and methodological issues remain to be resolved. First, although inquiry related to the effects of neighborhoods on health has long been a research agenda in social-science research (see Kawachi & Berkman, 2003), the extent to which variations in physical activity in different contexts (e.g., neighborhood, town, city), above and beyond individual-level variation, has not been investigated in the literature on aging and physical activity. For example, there is evidence that characteristics of the physical environment and, more specifically, characteristics of neighborhoods, defined in a variety of ways, are associated with different health behaviors (Balfour & Kaplan, 2002; Diehr et al., 1993; Diez-Roux et al., 1997; Yen & Kaplan, 1998). With respect to physical activity, the central question to be asked is, Can certain social and physical characteristics of residential neighborhoods make a difference to people’s lifestyle, over and above the characteristics of the individuals who live in them? Answering this question requires a multilevel perspective.

Second, few studies have addressed the issue of change in older adults’ physical activity. Given the increasing impetus to promote physical activity from several levels of society (e.g., Chodzko-Zajko, 2001; Robert Wood Johnson Foundation, 2000; Sheppard et al., 2003; USDHHS, 1996, 2000, 2002a), it is plausible that change needs to occur both at the individual level and the societal level. Information on changes in older adults’ physical activity participation over time are needed in order to provide empirical evidence about general trends in physical activity to determine variation in change (whether at the individual level or at the neighborhood level) and to examine determinants, correlates, and mechanisms of such change. Therefore, we urgently need research examining changes in physical activity over time both at the group level (e.g., neighborhood) and at the individual level (Li, Fisher, & Brownson, in press). Furthermore, it would be unreasonable to assume that all individuals follow the same trajectories of change in physical activity over time. This argument implies heterogeneity of change, ranging from those who are fully active to those who are sedentary. Thus, to effectively capture variation in change, one needs to consider neighborhood-level population heterogeneity, individual-level heterogeneity, and level-specific variables that can explain patterns of heterogeneity in physical activity over time.

Third, little research has been done to focus on neighborhood effects on older-adults’ physical activity behavior and patterns of change. Many routine physical activities such as walking and jogging take place in neighborhood settings rather than in indoor facilities, so neighborhood attributes are of particular relevance. To make inferences about social- and physical-environment influences on physical activity, it is imperative to consider the impact of change in social and physical environments (e.g., increasing neighborhood support for an active lifestyle, improving sidewalks).
Finally, recent consensus in the physical activity literature indicates that influences or determinants of physical activity should be assessed at multiple levels (Bauman, Sallis, & Owen, 2002; Humpel et al., 2002; King et al., 2002; Saelens, Sallis, & Frank, 2003; Satariano & McAuley, 2003), which requires involvement of multidisciplinary research teams (King et al., 2002; Sallis & Owen, 2002). Questions of how to study the complex interaction of individual and contextual factors, however, have never been adequately addressed in the literature on aging and physical activity. These efforts will require a multilevel approach that focuses on neighborhood contexts as determinants of population and individual physical activity. In addition, as physical activity levels change, so do their determinants and causal mechanisms. Therefore, there is a need to integrate longitudinal and multilevel data to identify determinants of change (either time varying or time invariant) in physical activity (Li, Fisher, & Brownson, in press). This effort will have significant public health value with regard to a better understanding of specific predictors or correlates and mechanisms and consequently will assist in the design of appropriately tailored health and physical-activity-promotion strategies for older adult populations.

TOWARD A COMPREHENSIVE MULTICOMPONENT AND MULTILEVEL MODEL OF INFLUENCE ON PHYSICAL ACTIVITY

In line with the preceding literature review and ecologically based theoretical perspectives, we propose a multicomponent and multilevel model of influence on physical activity outcomes (Figure 1) in the middle-aged and older adult population. We acknowledge that this model does not contain every identifiable component related to individual, social, and physical-environment influences, but it is inclusive enough to provide a starting framework for discussion. This model addresses community context in aging and physical activity research by (a) taking into account characteristics at the neighborhood level and at the individual level, (b) allowing for the partition of variation in individual responses on physical activity outcomes into neighborhood-level (interneighborhood variability) and individual-level (interindividual variability) components, (c) simultaneously examining level-specific effects (individual, neighborhood) of influence, and (d) assessing the possible multilevel mediational and interaction effects between individuals and the neighborhoods in which they are embedded.

The large oval in Figure 1 represents individual physical activity outcomes. Physical activity appears here as a latent variable operationalized by multiple observed or measured indicators in a typical application of structural-equation-modeling-based methodology (Bollen, 1989; Li & Harmer, in press). Depending on design, the latent variable can be defined by either cross-sectional data with multiple measures or longitudinal data points, allowing for the examination of change and correlates of change in physical activity. Throughout this article, we have considered physical activity variation at both the neighborhood and the individual level through observation of either cross-sectional or longitudinal data. To make causal
Figure 1. A heuristic multilevel model of influences on physical activity.
inferences about neighborhood and physical activity, however, we argue for the need to consider longitudinal and multilevel analysis of physical activity.

Within the ecological framework described previously, explaining variation in physical activity requires multiple sources of data collected at either the individual or the neighborhood level. These might include, but are not limited to, data collected through geographical information systems (e.g., walkability, bike paths, land-use mix), census (e.g., demographics), public-domain sources (e.g., police data, rules and regulations), self-reported surveys describing social-climate characteristics at the neighborhood level (see top boxes in Figure 1), demographic perceptions of physical activity resources and access, and psychosocial variables at the individual level (see bottom boxes in Figure 1). An additional feature of this model is the consideration of potential mediators or moderators at the neighborhood level (see boxes on left side in Figure 1).

**Direct Effects.** An optimal approach to understanding multiple levels of influence on physical activity is to focus on the specification of direct effects involving demographic and psychosocial factors and social, physical, and policy indicators at either level (individual or neighborhood). Such an approach will help account for independent, additive, or synergistic effects of individual and neighborhood factors in association with physical activity. For example, in line with the physical activity literature (Humpel et al., 2002; Saelens, Sallis, & Frank, 2003), we might hypothesize that levels or rate of change in physical activity in older adults could be explained by a combination of demographics and social- and physical-environment factors specified at the neighborhood level. As indicated earlier, this latter hypothesis of change is a vital, yet unexplored, area of inquiry. In addition to the direct effects, the processes that underlie variation in the level or change in individual differences in physical activity should be recognized. We consider this next, with particular emphasis on the neighborhood level.

**Mediator Effects.** Several researchers have identified potential mediators (intervening causal variables) at the neighborhood level. King et al. (2002) identified environmental mediators that might constrain or decrease levels of physical activity, including population density, traffic congestion, and physical features of residential environments. Along this line of thinking, we argue that certain neighborhood-level characteristics could be mediators of physical activity. For example, the relation between neighborhood-level walking and built-environment neighborhood walkability might be weakened or strengthened by social (e.g., crime rate) or environmental safety (traffic) factors. Walkable neighborhoods might be safer places to walk than less walkable neighborhoods (e.g., neighborhoods with high crime rates or vehicle use). In turn, socially and environmentally safe neighborhoods might stimulate more neighborhood walking activity. Based on results reported by Lindström et al. (2003) and Leyden (2003), one might expect that the effect of neighborhood-level elements of social capital (i.e., levels of neighborhood social engagement, social cohesion) on physical activity would be mediated through neighborhood-level physical-environment measures such as safety, walkability, and
land-use mix (i.e., access and diversity; Saelens, Sallis, & Frank, 2003). In other words, dimensions of social capital could directly stimulate physical activity, but neighborhoods that are walkable, mixed use, and safe in terms of traffic also could mediate the effects of social-capital influences.

**Moderator Effects.** Characteristics of individuals are naturally correlated with characteristics of their social or neighborhood contexts. Because of this, neighborhood- and individual-level characteristics might interact. This issue of cross-level interaction has not been considered or addressed in the physical activity literature. It is therefore also important to recognize and identify neighborhood- and individual-level factors that might moderate the strength between neighborhood influences and physical activity at either level, or across levels. For example, the effects of neighborhood-level factors on physical activity might differ by individual-level attributes, such as older adults’ health or socioeconomic status. Cross-level moderational research might investigate whether effects of neighborhood-level characteristics differ for different types of residents based on their demographic and psychosocial characteristics and personal physical activity resources at the individual level (see left-hand side of Figure 1). Not to be overlooked is the fact that elements reflecting neighborhood social capital might moderate more proximal processes of individual-level variables. For example, the effect of individual-level characteristics (e.g., intentions, motivation) on physical activity participation such as walking or bicycling might differ depending on the extent to which social engagement, supportiveness, and connectivity of the neighborhood operate at the neighborhood level. A recent study showed that the availability and accessibility of physical activity resources in neighborhoods differed by neighborhood socioeconomic status (Estabrooks et al., 2003), suggesting that neighborhood socioeconomic status might affect the extent to which resources are being used for physical activity purposes. Certainly, individual-level factors can also be potential moderators. For example, having a strong psychological sense of neighborhood can also be a moderator at the individual level, affecting the degree to which neighborhood-level factors influence physical activity.

**Summary**

The importance of considering and examining both mediators and moderators in the context of physical activity has been indicated (Bauman, Sallis, Dzewaltowski, & Owen, 2002; King et al., 2002). Little is known empirically, however, about their level-specific influences (i.e., at the neighborhood level or interaction with variables at a lower level). Therefore, we propose examination of direct effects and mechanisms involving mediators and moderators of physical activity at both the neighborhood and the individual level. These efforts can shed important light on the multiple levels of influence on physical activity and lead to the development of more effective physical-activity-promotion strategies. It is important to bear in mind that the proposed relationships in Figure 1 are subject to empirical
verification. A vigorous examination of these relationships, however, requires a multidisciplinary approach, appropriate measurement and sampling, and use of multilevel analyses.

**Concluding Remarks**

Existing evidence suggests that exclusively focusing on individual-level attributes might be of limited utility in advancing our understanding of why variation occurs in the physical activity of middle-aged and older individuals. Certainly, broad, contextually based policy, social-environment, and physical-environment forces are hypothesized to generate differences among existing social units (neighborhoods, metropolitan areas, communities) that shape the distribution of physical activity patterns of aging populations. Within a multilevel perspective, we believe that ecological models that are evaluated through multilevel analyses and that consider factors influencing physical activity behavior hold promise for the evaluation of physical activity in middle-aged and older adult populations. Such an ecological approach that acknowledges these multifaceted, multilevel determinants of physical activity will increase our understanding of the contexts and individual characteristics contributing to the physical activity of middle-aged and older adult populations and will subsequently inform the future design and evaluation of community- and population-based physical activity interventions.

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