ELSEVIER

Physiology & Behavior 86 (2005) 603 – 613

PHYSIOLOGY & BEHAVIOR

Environmental influences on food choice, physical activity and energy balance

Barry M. Popkin *, Kiyah Duffey, Penny Gordon-Larsen

Department of Nutrition, School of Public Health, University of North Carolina, United States

Received 12 July 2005; accepted 25 August 2005

Abstract

In this paper, the environment is defined as the macro- and community-level factors, including physical, legal and policy factors, that influence household and individual decisions. Thus, environment is conceived as the external context in which household and individual decisions are made. This paper reviews the literature on the ways the environment affects diet, physical activity, and obesity. Other key environmental factors discussed include economic, legal, and policy factors. Behind the major changes in diet and physical activity in the US and globally lie large shifts in food production, processing, and distribution systems as well as food shopping and eating options, resulting in the increase in availability of energy-dense foods. Similarly, the ways we move at home, work, leisure, and travel have shifted markedly, resulting in substantial reductions in energy expenditure. Many small area studies have linked environmental shifts with diet and activity changes. This paper begins with a review of environmental influences on diet and physical activity, and includes the discussion of two case studies on environmental influences on physical activity in a nationally representative sample of US adolescents. The case studies illustrate the important role of physical activity resources and the inequitable distribution of such activity-related facilities and resources, with high minority, low educated populations at strong disadvantage. Further, the research shows a significant association of such facilities with individual-level health behavior. The inequity in environmental supports for physical activity may underlie health disparities in the US population.

Keywords: Built environment; Food prices; Food choice; Activity patterns; Adolescents

1. Introduction

There are major gaps in our understanding of the way shifts in the physical and social environments affect changes in dietary intake, physical activity patterns and weight change. Nonetheless we have made major progress in the past decade to understand some aspects of this complex relationship. Much of this evidence suggests that environmental factors bear significant influence on diet, physical activity, and obesity [1–3]. Further, extensive research is either underway or planned to continue to push forward knowledge in this area. The environment is conceptualized very differently in the social and biological literature. For this paper, environment is defined as the macro- and community-level factors, including physical, legal, and policy factors that influence household and individual decisions. Thus, environment is conceived as the external context in which household and individual decisions are made.

Much of the literature on environmental correlates of diet, activity, and obesity has focused on the built environment. The built environment is defined as a multidimensional concept, broadly including patterns of human activity at various scales of geography within the physical environment. Handy et al. [4] state that the built environment includes: 1) "urban design, the design of a city and its physical elements; 2) land use, location and density of residential, commercial, industrial, forest, and others; and 3) transportation system, physical infrastructure of roads, sidewalks, bike paths, and others." In this paper we will present data on these built environment factors as well as macro- and community-level factors that influence diet, physical activity, and obesity.

* Corresponding author. Carolina Population Center, University of North Carolina, 123 W. Franklin St., Chapel Hill, NC 27516-3997, United States. Tel.: +1 919 966 1732; fax: +1 919 966 9159/6638.

E-mail address: popkin@unc.edu (B.M. Popkin).

0031-9384/$ - see front matter © 2005 Elsevier Inc. All rights reserved.
doi:10.1016/j.physbeh.2005.08.051

There are a number of key points to keep in mind. Dietary patterns have shifted remarkably across the globe over the past several decades. The foods we eat, the location of eating, the number of eating events, and even the composition of the persons at each eating event have changed. Behind these changes lie vast shifts in food production, processing, and distribution systems as well as food shopping and eating options. Similarly, the ways we move at work [be it market work or home production], shopping, leisure, and travel have shifted markedly over the past several decades. The changes in our built environment and the technology of work are most important in explaining many of these shifts. These changes have led to equally marked shifts in energy imbalance and obesity patterns across the globe. Elsewhere we summarize some of these points as they relate to adults and children [5,6].

This paper is mainly a review of what we know about dietary and physical activity patterns and trends and their environmental determinants and correlates. In addition, we include built environment factors plus a wider range of environment factors including economic, legal, and policy factors. We present two case studies in a nationally representative cohort of US adolescents. These case studies illustrate the potential importance of key environment factors in shaping physical activity and obesity, and further how these environment factors may impact health disparities in the US population. The focus is on higher income countries as most of the research and programmatic activity in this area that has been studied and evaluated comes from the US, Europe and Australia.

2. Diet and the eating environment

2.1. Dominant US dietary trends

Extant knowledge appears to show that total caloric intake is increasing among all race, age, gender and socioeconomic groups (though there is no way to address some methodological differences in survey methods between the 1980s and the 1990s). These calories are more frequently coming from energy-dense, nutrient poor snacks [1,7–9] at a greater frequency throughout the day [10,11]. Furthermore, a greater number of meals are being consumed away from home [9,12–14], particularly from restaurants and fast food places [9]. Overall, the greatest increases have been in the consumption of salty snacks, sweetened soft drinks, pizza, Mexican food, French fries, and cheeseburgers [1,9,15–17] with a concurrent decrease in fruit and vegetable consumption, particularly among low income families and men aged 18–39 [1,18,19]. The obesity and related non-communicable disease implications of the increased use of fast foods, beverages, and selected dietary components are studied elsewhere [20,21]. The effects of each of these dietary components on obesity are complex and controversial. This is made particularly clear by the vast array of responses from industry and others to the literature linking calorically sweetened beverage intake with obesity [22,23].

2.2. Role of food stores and away from home eating establishments in population eating patterns

Neighborhood environment is related to obesity, dietary patterns and practices, health outcomes, and health-related behaviors [24–34] and may have independent effects on disease risk [35–39]. Consistent positive associations are found between proximity to supermarkets/health food stores and diet patterns and weight status [40–42]. The number of fast food establishments and expenditure on away from home eating are growing at an exponential rate [34,43,44]. These meals, particularly “fast food” meals, typically have higher energy densities and larger portion sizes than meals prepared at home [8,45–47] which may affect total energy intake [48–52] and consequently, weight status [53]. Away from home eating, including restaurant and fast food consumption, is shown to be associated with a decrease in macro/micro-nutrient intake and diet quality, weight gain, and increased BMI, energy density and total energy intake [54–61]. In two different studies, women maintaining “fast food” or “restaurant” eating patterns tended to have the greatest intakes of energy, total fat, saturated fat, cholesterol and sodium, and these patterns tended to be associated with younger age, lower-income, greater BMI and non-white ethnicity [62,63]. Comparison of these studies, however, is limited either by overlapping definitions or a failure to differentiate between sources of food obtained away-from-home.

2.3. Role of socioeconomic status (SES) and food stores, and away from home eating in population dietary patterns

There are ethnic and socioeconomic disparities in an individual’s disease risk, likelihood of becoming overweight or obese, and access to eating establishments and food sources [64–69]. Pertinent studies find wealthier neighborhoods having greater access to supermarkets, convenience stores, and a wider variety of foods [39,70]. Furthermore, persons living in high SES neighborhoods are more likely to meet healthy eating guidelines regardless of individual SES level [71]. Results are similar across ethnic groups. A cross-sectional study of four U.S. cities found that predominantly white neighborhoods have significantly greater access to low-cost, quality food sources than black neighborhoods matched for SES [70]. Moreover, availability [70,72,73] and the perception of availability [18] may influence consumption, suggesting that less wealthy, minority neighborhoods are at a distinct disadvantage regarding food choice, particularly if they perceive that alternative food options are not accessible. While the research to date has provided a foundation for understanding the interaction between neighborhood SES, food access, and dietary patterns, studies are limited by small population sizes, non-longitudinal designs, and geographic isolation.

2.4. Longitudinal work on the eating environment context

There are precious few studies that incorporate longitudinal measures of contextual factors and their relationship to health.

In a position paper, a leading scholar indicated that incorporating life-course and longitudinal dimensions into studies of context and health is urgently needed in this field [38].

Longitudinal data offer a unique advantage to answer many critical questions. For example, time-varying data allow the examination of influences of environmental correlates over time and the effects of these correlates on adoption, maintenance and extinction of obesity-related behaviors, and in turn, the effect of these behaviors on weight maintenance and change. Further, longitudinal data are crucial in understanding sequence of behaviors and outcomes and potential chains of causality. Given the concern for confronting the obesity epidemic and the role of environmental determinants of obesity, understanding the etiologic contribution of environment factors on obesity is of utmost importance.

2.5. Role of food prices

Food prices represent a critical qualitative dimension of fast food, other restaurant, and small and large grocery store options that must be considered to separate price from pure "placement/proximity effects." Economics research has examined issues relevant to this study, such as away from home eating patterns, shifts to processed foods, selection of most types of commodities, retail price effects on overall purchase patterns and such, while almost none have examined health-related behaviors per se other than the effects of commodity pricing on production and consumption of selected commodities [74–77]. It is clear that food cost plays a significant role in determining eating patterns and health behaviors [78–80]. The results from several recent smaller-scale studies suggest that food expenditure patterns for high priced products, which are characteristic of inner cities, significantly reduces the number of servings of fruits, vegetables and dairy products consumed by lower income families [81–83]. Individual food choice is also affected by pricing. Both adults and adolescents indicate price as the one of the most influential factors in determining food choice, second only to taste [84–88]. Intervention studies indicate that price reductions alone, or in combination with promotional materials, serve to increase purchases of lower-fat sale items and fruits/vegetables in cafeterias, workplaces and school vending machines [13,86,89,90]. Finally, one recent state-level ecological analysis states that food price and the shopping environment play a critical role in explaining the obesity epidemic [91].

3. Physical activity and the role of the environment

3.1. Physical environment/context

Environments may restrict a range of physical activity behaviors by promoting or discouraging physical activity through factors such as, access to safe recreation, accessibility of recreation facilities, and transit options. The physical activity literature is just beginning work on the conceptualization of environmental variables; thus there is limited understanding of the influence of such factors on physical activity. Early research has examined environmental determinants such as community sports, access to home fitness equipment [92,93], outdoor play space [94], time spent outdoors [95], family environments [96], and exercise opportunity [97]. Minimal research has addressed the impact of proximity of exercise facilities on physical activity [98,99] until recently.

Three recent review articles conclude that environmental factors, either objectively or perceptively measured, are consistently related to physical activity [2,3,100]. Perceived neighborhood characteristics, such as aesthetics, convenience, and accessibility of activity resources have been shown to be associated with physical activity [101–104]. For example, a North Carolina study found that perceived presence of neighborhood trails and general access to places for physical activity were positively associated with actual physical activity [105]. Population studies have not used adequate methodologies or objective measures to address this question [98,106]. Until recently, scant attention has been given to ecological determinants [107] or impact of facilities on physical activity levels [108], despite evidence that physical activity is associated with environmental factors [109,110], including neighborhood context [111,112]. Much of the research has been methodologically crude [113], given that physical activity is influenced by the interaction among several factors [100,108,114,115]. Understanding the population impact of environmental factors is critical to pushing forth population-wide interventions to promote physical activity [95]—now a major focal point of public health dialogue in this arena.

A review of fourteen studies shows a consistent association between built environment factors (i.e., higher residential density, land mix, and connectivity) and walking or cycling [3]. Urban planners looking at environment and transportation find extremely low rates of walking for transport [116] and few pedestrian-favorable land-use policies [117]. Walking/biking increases with proximity, density, connectivity [118–120], higher population density [121,122], land-use mix and pedestrian advances (e.g., sidewalk connectivity) [123–125] and air pollution [117]. Other objectively measured environmental factors, such as distance and density of resources, proximity to coast, sloped terrain, and composite measures, have been shown to be associated with physical activity levels [98,126–128]. Strong predictors of walkability include population density [121,123,129]. Residential land use diversity has been shown to be a very important predictor of walking, while bicycling is associated with density, diversity and design, particularly of the origin, or residence, destination [130]. Individuals living in highly walkable neighborhoods report approximately two times the number of walking trips per week in contrast to low walkable neighborhood residents [3].

This research tends to control only for rough SES; there is no concerted effort to look at relationships between individual factors and physical activity within different physical environments [4,125,131,132]. Only recently has work become more focused in this area. For example, Ewing et al. [119] found that relative to dense urban form, urban sprawl has been shown to be associated with lower rates of walking and higher BMI. How these factors are mediated by sociodemographic factors

and the impact of these transportation factors on physical activity levels is not known.

The vast majority of the built environment and health literature has focused on adults. Few empirical studies have been conducted to examine the relationship of the built environment with physical activity among children. In a recent review of correlates of physical activity in youth, Sallis et al. [95] found that although built environment factors were understudied, there were consistent associations between childhood and adolescent activity patterns and factors such as access to programs, facilities, and opportunities for physical activity. Despite limited research, access to facilities and opportunities to exercise are consistent predictors of physical activity in children and adolescents [95] and the presence of places to exercise, sidewalks, and spatial access to open space have been related to physical activity in adults [127,133,134]. Access to resources including walking trails varies by SES with lower and middle SES populations having fewer free resources [135].

In sum, research on physical activity determinants has ignored the most modifiable factors for public policy—the physical environment. Clearly a major source of potential change is the community and its social/physical environment. These factors change tremendously for young adults as they transition into middle adulthood. It is critical to understand the biological impact of these social/physical environment factors on physical activity, a major determinant of health.

3.2. Role of environment in population physical activity levels

A call for a greater focus on environmental factors is common to most recent examinations of the obesity epidemic and the need for added activity. This includes factors such as urban design, transport and policy to promote physical activity [136–138]. Neighborhood environment is related to obesity, physical activity and other health-related behaviors [31,27,29,112,119,120] and may have independent effects on disease risk [36,139–141]. Living in a disadvantaged neighborhood, independent of individual SES, is associated with increased CHD incidence [38], providing a strong argument for inclusion of individual and area-level factors in research [142–145]. Others argue for population-wide physical activity-focused environmental interventions [100], despite the fact that environmental influences are understudied [101,146–148].

While clearly there is not yet the empirical base to assert that wide-spread changes in the built environment will lead to population-wide increases in physical activity, early research is promising [3,95,149,150]. Furthermore, future work must seek to understand how specific types of environmental changes are likely to impact physical activity, which is at present unknown [2].

3.3. Role of SES and environment in explaining ethnic health disparities

National health objectives call for reducing ethnic health disparities [151]. However, economic and racial inequality [152–154] and disparities in mortality by SES [155–157] have increased in recent decades. Regardless of ethnicity, the poor have higher acute and chronic disease morbidity and mortality [158–161]. SES-health differentials increase with age [162]. SES may have different meaning by ethnicity, such that ethnic minority individuals do not receive the same economic/social benefits at identical SES as whites [163–165]. Spatial dimensions, such as the effects of clustering of the poor at the local and state level, and broader social class factors including access to resources, prestige, and stressors (e.g., racism) may play an important role. Large ethnic-specific spatial factors may contribute to inequality [166–168]. Societal inequality beyond individual SES may be related to health [169–172]. Even after adjusting for SES factors, physical activity is still lower among blacks than whites [173], implicating other factors, such as environmental context. In a case study presented later in this paper we present some evidence of inequality in the built environment.

3.4. Longitudinal relationships

While there are some cross-sectional studies on the relationship between SES and physical activity, and to a lesser extent on the effect of contextual factors on physical activity, there is very limited longitudinal research on this topic. Similar to dietary research, there are precious few studies that incorporate longitudinal measures of contextual factors and their relationship to health.

4. Case study one [109]

The objective of the research conducted for the case study below is to examine environmental and sociodemographic determinants of leisure-time physical activity, with particular attention to participation in school Physical Education (PE), community recreation center use, and neighborhood crime. The implication is that these findings can point towards societal-level intervention strategies for increasing physical activity and decreasing inactivity among adolescents.

4.1. Survey Design

The study population consists of over 20,000 adolescents enrolled in the National Longitudinal Study of Adolescent Health (Add Health), a longitudinal, nationally representative, school-based sample of adolescents in grades 7–12 (ages 11–21) in the US. The Add Health study included a core sample and additional subsamples of selected ethnic and other groupings collected following informed consent procedures established by the institutional review board of the University of North Carolina at Chapel Hill. We utilized the Wave I sample (20,747 eligible adolescents measured between April and December, 1995) excluding adolescents who used a walking aid device (e.g., cane, crutches, wheelchair) and Native Americans ($N=178$) because of small sample size. Our final sample totaled 17,766 for prevalence estimates and logistic regression analysis. The survey design and sampling frame have been described elsewhere (109,175).

In-school and in-home surveys of adolescents provided the activity data and components of the determinants data, including self-reported PE and community recreation center use. In-home surveys of parents provided income, education, and other key sociodemographic data. Race and ethnicity were determined using data from a combination of all the surveys. Hours/week of inactivity (TV/video viewing, video/computer games) and times/week of moderate–vigorous physical activity were collected by questionnaire. Community data come from the Add Health contextual database, which includes a series of variables geographically linked to the Add Health respondents through address geocoding and GPS matching.

4.2. Main outcome measure

Moderate–vigorous physical activity (5–8 METs) was assessed using standard 7-day recall (times per week) questionnaire methodology relevant for epidemiological studies to assess leisure activity. The assessment employed an array of questions similar to those used and validated in many other smaller studies to categorize adolescents into high, medium, and low activity and inactivity patterns with reasonable reliability and validity. The Add Health adolescents were asked about the times/week spent in various physical activities (e.g., "During the past week, how many times did you go roller-blading, roller-skating, skate-boarding, or bicycling"). Each activity grouping was assigned a MET value based on the Compendium of Physical Activity developed for adults to categorize activity as low, moderate, or vigorous. It is realized that the energy cost of activities is about 10% higher in children; however, at the present time no norms exist for children. One MET is defined as the energy expenditure associated with quiet sitting. Higher intensity activities, such as skating, cycling, dance, martial arts activities, and active sports were assigned 5–8 METs and are thus considered moderate to vigorous physical activity.

4.3. Correlates

Sociodemographic and environmental correlates of physical activity were used as exposure and control variables and included sex, age, urban residence, participation in school physical education program, use of community recreation center, total reported incidents of serious crime in neighborhood, socioeconomic status, ethnicity, generation of residence in the US, presence of mother/father in household, pregnancy status, work status, in-school status, region, and month of interview.

The crime data included in this study come from the 1993 Uniform Crime Reports, U.S. Federal Bureau of Investigation, and are reported as the total reported incidents of serious crime per 100,000 population (high crime = 7170–16,855 per 100,000 population) at the county level.

4.4. Statistical analysis

Logistic regression models of physical activity were used to investigate sex and ethnic interactions in relation to environmental and sociodemographic factors in order to examine evidence for the potential impact of physical education and recreation programs and sociodemographic factors on physical activity and patterns.

4.5. Results

Moderate to vigorous physical activity was lower for non-Hispanic black and Hispanic adolescents relative to their white counterparts. Participation in school physical education programs was considerably lower for these adolescents, and decreased with age, similar to what has been shown in other national surveys [174].

Participation in school PE programs and use of a community recreation center had a substantial effect on likelihood of the adolescents engaging in moderate to vigorous physical activity. Relative to their counterparts with no participation in PE program classes, adolescents who participated in daily school PE program classes (Adjusted Odds Ratio, AOR = 2.21; Confidence Interval, CI = 1.82–2.68; $p \leq 0.00001$) or between 1 and 4 days per week (AOR = 1.44; CI 1.09–1.92; $p \leq 0.01$) were at statistically significant increased likelihood of engaging in moderate to vigorous physical activity. Similarly, relative to their peers who did not use a community recreation center, adolescents who did use a community recreation center were at significantly increased likelihood of engaging in moderate to vigorous physical activity (AOR = 1.75; CI 1.56–1.96; $p \leq 0.00001$).

Total reported incidents of serious neighborhood crime decreased the likelihood of engaging in moderate to vigorous physical activity, although the magnitude of this effect was not as great as that seen for participation in school PE or use of a community recreation center. High levels of serious crime in the county of the respondent's residential neighborhood was associated with a statistically significant decreased likelihood of falling in the highest category of moderate to vigorous physical activity (AOR = 0.77; 0.66–0.91; $p \leq 0.002$).

To an extent, the results are somewhat intuitive; if the adolescents are participating in school PE and using a recreation center, they should be expected to have higher activity levels. However, the results underscore the importance of such programs and facilities in raising activity levels of adolescents. These findings provide some sense of the large and significant potential influence of environmental factors on physical activity. We found that environmental factors, such as PE and community recreation center use, and neighborhood crime, had a major impact on adolescents' likelihood of being active. While our results show important effects of participation in PE, particularly on a daily basis, on leisure-time physical activity patterns, few teens participate in school PE programs. These findings argue for continued and expanded support of school PE programs and community recreation centers.

5. Case study two [175]

Case study two is also from our work with the National Longitudinal Study of Adolescent Health. In this nationally

representative adolescent cohort, we use Geographic Information Systems (GIS) to assess the availability of recreational facilities in the neighborhoods of our sample. We explore the distribution of these facilities by population characteristics to assess the geographic and social distribution of physical activity facilities and how disparity in access might underlie population-level physical activity and overweight patterns.

5.1. Survey design

The study population consists of 20,745 adolescents enrolled in wave I (1995) of the National Longitudinal Study of Adolescent Health (Add Health), as described above (109).

5.2. Environmental measures

Environmental data were compiled using GIS. Residential locations of US adolescents in wave I (1994–1995) of the National Longitudinal Study of Adolescent Health [N=20,745] were geocoded and a 5-mile buffer around each residence drawn [N=42,857 census block groups (19% of U.S.)]. Physical activity facilities, measured by national databases and satellite data, were linked with GIS technology to each respondent.

5.3. Physical activity facilities and resources

A commercially purchased set of digitized business records recorded in a proprietary four-digit extension to the four-digit Standard Industrial Classification codes (SIC) was used. Comprehensive retrospective data for time period of interest were used. A comprehensive list of 169 of the eight-digit SIC codes for physical activity facilities and resources was built. All records of interest matching the criteria and falling within the ZIP code areas specified were returned along with facility names and street addresses contemporaneous to the wave I calendar year 1995.

Measures of recreational facilities were derived from the larger list of SIC resources. The SIC codes were subdivided into nine categories of facilities, including schools, youth organizations, parks, YMCA's, and the following types of facilities: public, public fee, instructional, outdoor, and member. A single measure of all facilities was created by summarizing across all of the nine categories. There was some overlap between categories (e.g., outdoor facilities and public facilities).

5.4. Block group sociodemographics

Census variables (reported at the block group level) were extracted from 1990 Census of Population and Housing Summary Tape File 3A (STF3A). A census block group is the second lowest level geographic entity, generally containing between 300 and 3000 people. Variables included population density (total number of individuals in block group divided by block group area reported in square miles); proportion of population with college degree or higher; non-white (ethnic minority) proportion of the population. Education level of the census block group is used as the primary indicator of SES.

5.5. Statistical analysis

The aim of the research summarized here is to investigate the association between block group level sociodemographic factors and availability of physical activity and recreational facilities. Further, the work aims to examine the association between community physical activity and recreational facilities and individual level physical activity and overweight. Logistic regression analyses tested the relationship of physical activity-related facilities with block group socioeconomic status (SES) [at the community level] and the subsequent association of facilities with overweight and physical activity [at the individual level], controlling for population density.

5.6. Results

The set of findings in Gordon-Larsen et al. [175] relate to the association between block group level sociodemographic factors and availability of physical activity and recreational facilities. The central question was to explore whether physical activity facilities were equitably distributed by neighborhood sociodemographics. Our results show that higher SES block groups had significantly greater likelihood of any type of physical activity facility (OR=2.18, CI, 1.94–2.44). Of particular relevance is the fact that all nine categories of facilities, (e.g., schools, youth organizations, parks, YMCAs, and the following types of facilities: public, public fee, instructional, outdoor, and member) were more likely to be located in higher versus lower SES block groups. Further work will relate the distribution of these facilities to individual-level behaviors, such as physical activity and obesity.

6. Conclusions

A call for a greater focus on built environmental factors is common to most recent examinations of the obesity and inactivity epidemic and includes factors such as urban design, transport, and policy to promote physical activity [136,137,176]. Several research agendas for work on the built environment and health have been proposed in recent years [177–179]. A wealth of research questions and methodological issues have been elucidated by these authors with a shared emphasis on the need to foster interdisciplinary approaches and a need to better understand the factors that mediate and moderate the association between the built environment, physical activity and health outcomes.

Transportation, city and regional planning, and the physical activity literatures are all making headway in understanding environment–health relationships albeit from different perspectives. Innovative work across fields is essential in understanding the environment–health relationships. Further development of innovative and sophisticated methodologies to assess the built environment and health outcomes of interest is needed. Research on the built environment and health effects

must expand to include diverse populations and environmental settings, including youth. Longitudinal data on environmental exposures and health outcomes will be crucial in understanding sequence of behaviors and outcomes and potential chains of causality.

7. Contribution of environmental factors to physical activity patterns

Results from the case studies in the nationally representative cohort of adolescents suggest that environmental factors play a major role in shaping physical activity and overweight. Our work shows important associations between modifiable environmental factors, such as participation in PE and community recreation programs with activity patterns of adolescents. Despite the marked and significant impact of participation in physical education programs on physical activity patterns of US adolescents, few adolescents participate in such physical education programs. In addition to the more readily modifiable factors, high crime level was significantly associated with a decrease in weekly moderate to vigorous physical activity.

The data presented here confirm what researchers and pediatricians have known intuitively; however, these relationships have not been tested empirically, nor have they been studied in any nationally representative survey of US school age children. These findings suggest that national-level strategies include attention to PE and community recreation programs, particularly for segments of the US population without access to resources and opportunities that allow participation in physical activity. Research to measure and explore the effects of other environmental determinants of activity are important future research goals.

8. Inequality in access to the built environment and its effects

Our work with availability of physical activity facilities across over 20,000 adolescents and 19% of all US census block groups provides the first empirical evidence that all major categories of physical activity-related resources are inequitably distributed, with high minority, low educated neighborhoods at a strong disadvantage. Importantly, the inequitable distribution of facilities is apparent across all major categories of facilities including those facilities that we consider to be more equitably distributed (e.g., parks, public facilities, YMCAs).

The inequitable distribution of facilities by SES and race/ethnicity and the association of availability of facilities with positive health outcomes are suggestive of the potential role of environmental factors in the higher rates of obesity and lower activity levels of US race/ethnic minority groups. These results suggest that public health officials address the inequitable distribution of physical activity facilities as one strategy to increase physical activity levels and reduce overweight prevalence in the US.

The second case study also provides important directions for future research beyond availability of facilities. Detailed research on access to neighborhood facilities is an important area, including such factors as walkability, road network distance, and land use. In addition, details on affordability and barriers to access, such as crime, social cohesion, and lack of incentives for use are also important.

9. Summary

Taken together, our national work suggests that environmental factors play an important role in shaping obesity-related behaviors, particularly physical activity. This is a field in its infancy. While we clearly do not have the empirical base to assert that wide-spread changes in the built environment will lead to population-wide increases in physical activity, there is building evidence of the important relationship between environmental correlates and physical activity behavior. Innovative work across fields, such as public health, geography, and city and regional planning, as well as methodological advances in those fields is essential in understanding the environment–health relationships. In addition, future work should explore diverse population and environmental settings, and longitudinal changes in environmental factors and behavioral outcomes.

Acknowledgments

Major funding for this study comes from the National Institutes of Health: NICHD (R01-HD39183-01, R01 HD041375-01and K01 HD044263-01). Additional funding comes from NIH (R01-HD39183-01, and DK56350), the Centers for Disease Control and Prevention (CDC SIP 5-00), and the Carolina Population Center. The authors would like to thank Ms. Frances Dancy for her helpful administrative assistance. This research uses data from Add Health, a program project designed by J. Richard Udry, Peter S. Bearman, and Kathleen Mullan Harris, from the National Institute of Child Health and Human Development, with cooperative funding from 17 other agencies. Special acknowledgment is due Ronald R. Rindfuss and Barbara Entwisle for assistance in the original design. Persons interested in obtaining data files from Add Health should contact Add Health, Carolina Population Center, 123 W. Franklin Street, Chapel Hill, NC 27516-2524 (www.cpc.unc.edu/addhealth/contract.html).

References

[1] French S, Story M, Neumark-Sztainer D, Fulkerson J, Hannan P. Fast food restaurant use among adolescents: associations with nutrient intake, food choice, and behavioral and psychosocial variables. Int J Obes 2001; 25:1823–33.

[2] Humpel N, Owen N, Leslie E. Environmental factors associated with adults' participation in physical activity: a review. Am J Prev Med 2002; 22:188–99.

[3] Saelens BE, Sallis JF, Frank LD. Environmental correlates of walking and cycling: findings from the transportation, urban design, and planning literatures. Ann Behav Med 2003;25:80–91.

[4] Handy SL, Boarnet MG, Ewing R, Killingsworth RE. How the built environment affects physical activity: views from urban planning. Am J Prev Med 2002;23(2S):64–73.

[5] Popkin BM. The nutrition transition in the developing world. Dev Policy Rev 2003;21(5):581–97.

[6] Popkin BM, Gordon-Larsen P. The nutrition transition: worldwide obesity dynamics and their determinants. Int J Obes 2004;28:s2.
[7] Haines P, Hama M, Guilkey D, Popkin B. Weekend eating in the United States is linked with greater energy, fat and alcohol intake. Obes Res 2003;11:945–9.
[8] Nielsen S, Popkin BM. Patterns and trends in portion sizes, 1977–1998. JAMA 2003;289(4):450–3.
[9] Nielsen S, Siega-Riz AM, Popkin BM. Trends in energy intake in the U.S. between 1977 and 1996: similar shifts seen across age groups. Obes Res 2002;10(5):370–8.
[10] Nielsen S, Siega-Riz AM, Popkin BM. Trends in food locations and sources among adolescents and young adults. Prev Med 2002;35:107–13.
[11] Zizza C, Siega-Riz AM, Popkin BM. Significant increase in young adults' snacking between 1977–1978 and 1994–1996 represents a cause for concern! Prev Med 2001;32(4):303–10.
[12] Kant AK, Graubard BI. Eating out in America, 1987–2000: trends and nutritional correlates. Prev Med 2004;38:243–9.
[13] French S, Story M, Jeffery R. Environmental influences on eating and physical activity. Annu Rev Public Health 2001;22:309–35.
[14] Jeffery R, Utter J. The changing environment and population obesity in the United States. Obes Res 2003;11:12S–22S.
[15] Cavadini C, Siega-Riz AM, Popkin BM. US adolescent food intake trends from 1965 to 1996. Arch Dis Child 2000;83:18–24.
[16] French S, Lin B, Guthrie J. National trends in soft drink consumption among children and adolescents age 6–17 years: prevalence, amounts and sources, 1977/1978 to 1994/1998. J Am Diet Assoc 2003;103(10): 1326–31.
[17] Nielsen S, Popkin BM. Changes in beverage intake between 1977–2001. Am J Prev Med 2004;27:205–10.
[18] Dibsdall LA, Lambert N, Bobbin RF, Frewer LJ, Preville M, Hebert R, et al. Low-income consumers' attitudes and behaviour towards access, availability and motivation to eat fruit and vegetables. Public Health Nutr 2003;6(2):159–68.
[19] Guthrie JF, Lin BH, Frazao E. Role of food prepared away from home in the American diet, 1977–78 versus 1994–96: changes and consequences. J Nutr Educ Behav 2002;34(3):140–50.
[20] Pereira MA, Jacobs Jr DR, Van Horn L, Slattery ML, Kartashov AI, Ludwig DS. Dairy consumption, obesity, and the insulin resistance syndrome in young adults: the CARDIA Study. JAMA 2002;287: 2081–9.
[21] Pereira MA, Kartashov AI, Ebbeling CB, Van Horn L, Slattery ML, Jacobs Jr DR. Fast-food habits, weight gain and insulin resistance (the CARDIA) study: 15-year prospective analysis. Lancet 2005;365:36–42.
[22] Ludwig D, Peterson K, Gortmaker S. Relation between consumption of sugar-sweetened drinks and childhood obesity: a prospective, observational analysis. Lancet 2001;357:505–8.
[23] Raben A, Vasilaras TH, Moller AC, Astrup A. Sucrose compared with artificial sweeteners: different effects on ad libitum food intake and body weight after 10 wk of supplementation in overweight subjects. Am J Clin Nutr 2002;76:721–9.
[24] Ellaway A, Macintyre S. Does where you live predict health related behaviours? A case study in Glasgow. Health Bull (Edinb) 1996;54: 443–6.
[25] Ellaway A, Anderson A, Macintyre S. Does area of residence affect body size and shape? Int J Obes Relat Metab Disord 1997;21:304–8.
[26] Kahn HS, Tatham LM, Pamuk ER, Heath Jr CW. Are geographic regions with high income inequality associated with risk of abdominal weight gain? Soc Sci Med 1998;47:1–6.
[27] Sundquist J, Malmstrom M, Johansson SE. Cardiovascular risk factors and the neighbourhood environment: a multilevel analysis. Int J Epidemiol 1999;28:841–5.
[28] Sundquist K, Winkleby M, Ahlen H, Johansson SE. Neighborhood socioeconomic environment and incidence of coronary heart disease: a follow-up study of 25,319 women and men in Sweden. Am J Epidemiol 2004;159:655–62.
[29] Diez-Roux AV, Nieto FJ, Muntaner C, Tyroler HA, Comstock GW, Shahar E, et al. Neighborhood environments and coronary heart disease: a multilevel analysis. Am J Epidemiol 1997;146(1):48–63.
[30] Diez Roux AV, Jacobs DR, Kiefe CI. Neighborhood characteristics and components of the insulin resistance syndrome in young adults: the coronary artery risk development in young adults (CARDIA) study. Diabetes Care 2002;25:1976–82.
[31] Diez Roux AV. Residential environments and cardiovascular risk. J Urban Health 2003;80:569–89.
[32] Lee RE, Cubbin C. Neighborhood context and youth cardiovascular health behaviors. Am J Public Health 2002;92:428–36.
[33] Sharma S, Malarcher AM, Giles WH, Myers G. Racial, ethnic and socioeconomic disparities in the clustering of cardiovascular risk factors. Ethn Dis 2004;14(1):43–8.
[34] Mainous III AG, King DE, Garr DR, Pearson WS. Race, rural residence, and control of diabetes and hypertension. Ann Fam Med 2004;2:563–8.
[35] Henderson C, Roux Diez AV, Jacobs Jr DR, Kiefe CI, West D, Williams DR. Neighbourhood characteristics, individual level socioeconomic factors, and depressive symptoms in young adults: the CARDIA study. J Epidemiol Community Health 2005;59:322–8.
[36] Kaplan GA. People and places: contrasting perspectives on the association between social class and health. Int J Health Serv 1996;26: 507–19.
[37] Borrell LN, Diez Roux AV, Rose K, Catellier D, Clark BL. Neighbourhood characteristics and mortality in the atherosclerosis risk in communities study. Int J Epidemiol 2004;33:398–407.
[38] Diez Roux AV, Merkin SS, Arnett D, Chambless L, Massing M, Nieto FJ, et al. Neighborhood of residence and incidence of coronary heart disease. N Engl J Med 2001;345:99–106.
[39] Morland K, Wing S, Diez Roux A. The contextual effect of the local food environment on residents' diets: the atherosclerosis risk in communities study. Am J Public Health 2002;92:1761–7.
[40] Cheadle A, Psaty BM, Curry S, Wagner E, Diehr P, Koepsell T, et al. Community-level comparisons between the grocery store environment and individual dietary practices. Prev Med 1991;20:250–61.
[41] Ransley JK, Donnelly JK, Botham H, Khara TN, Greenwood DC, Cade JE. Use of supermarket receipts to estimate energy and fat content of food purchased by lean and overweight families. Appetite 2003;41:141–8.
[42] Laraia BA, Siega-Riz AM, Kaufman JS, Jones SJ. Proximity of supermarkets is positively associated with diet quality index for pregnancy. Prev Med 2004;39:869–75.
[43] Jekanowski M. Causes and consequences of fast food sales growth. USDA report;1999. Can be found at: www.ers.usda.gov/publications/foodreview/jan1999/frjan99b.pdf.
[44] Jekanowski M. Convenience, accessibility and the demand for fast food. J Agric Resour Econ 2001;26:58–74.
[45] Prentice AM, Jebb SA. Fast foods, energy density and obesity: a possible mechanistic link. Obes Rev 2003;4:187–94.
[46] Young LR, Nestle M. The contribution of expanding portion sizes to the US obesity epidemic. Am J Public Health 2002;92(2):246–9.
[47] Young L, Nestle M. Expanding portion sizes in the US Marketplace: implication for nutrition counseling. J Am Diet Assoc 2003;103:231–4.
[48] Poppitt SD, Prentice AM. Energy density and its role in the control of food intake: evidence from metabolic and community studies. Appetite 1996;26:153–74.
[49] Diliberti N, Bordi PL, Conklin MT, Roe LS, Rolls BJ. Increased portion size leads to increased energy intake in a restaurant meal. Obes Res 2004; 12:562–8.
[50] Rolls BJ, Bell EA, Castellanos VH, Chow M, Pelkman CL, Thorwart ML. Energy density but not fat content of foods affected energy intake in lean and obese women. Am J Clin Nutr 1999;69:863–71.
[51] Rolls BJ, Morris EL, Roe LS. Portion size of food affects energy intake in normal-weight and overweight men and women. Am J Clin Nutr 2002;76:1207–13.
[52] Rolls BJ, Roe LS, Meengs JS, Wall DE. Increasing the portion size of a sandwich increases energy intake. J Am Diet Assoc 2004;104:367–72.
[53] Poppitt SD. Energy density of diets and obesity. Int J Obes Relat Metab Disord 1995;19(Suppl 5):S20–6.
[54] Thompson OM, Ballew C, Resnicow K, Must A, Bandini LG, Cyr H, et al. Food purchased away from home as a predictor of change in BMI z-scores among girls. Int J Obes 2004;28:282–9.

[55] Zoumous-Morse C, Rock C, Sobo E, Neuhouser M. Children's patterns of macronutrient intake and associations with restaurant and home eating. J Am Diet Assoc 2001;101(8):923–5.
[56] Bowman SA, Vinyard BT. Fast food consumption of U.S. adults: impact on energy and nutrient intakes and overweight status. J Am Coll Nutr 2004;23:163–8.
[57] Ebbeling CB, Sinclair KB, Pereira MA, Garcia-Lago E, Feldman HA, Ludwig DS. Compensation for energy intake from fast food among overweight and lean adolescents. JAMA 2004;291:2828–33.
[58] French S, Story M, Neumark-Sztainer D, Fulkerson J, Hannan P. Fast food restaurant use among adolescents: associations with nutrient intake, food choice, and behavioral and psychosocial variables. Int J Obes 2001; 25:1823–33.
[59] Lin B, Frazao E, Guthrie J. Away from home foods increasingly important to quality of American diet. Agric Inf Bull 1999;749.
[60] McCrory M, Fuss P, Hays N, Vinken A, Greenberg A, Roberts S. Overeating in America: association between restaurant food consumption and body fatness in healthy men and women ages 19 to 80. Obes Res 1999;7(6):564–71.
[61] Satia JA, Galanko J, Siega-Riz AM. Eating at fast-food restaurants is associated with dietary intake, demographic, psychosocial and behavioral factors among African Americans in North Carolina. Pub Health Nutr 2004;7(8):1089–96.
[62] Haines PS, Hungerford DW, Popkin BM, Guilkey DK. Eating patterns and energy and nutrient intakes of US women. J Am Diet Assoc 1992;92(6):698–704, 707.
[63] French S, Harnack L, Jeffery R. Fast food restaurant use among women in the Pound of Prevention Study: dietary, behavioral and demographic correlates. Int J Obes Relat Metab Disord 2000;24:1353–9.
[64] McMurray RG, Harrell JS, Deng S, Bradley CB, Cox LM, Bangdiwala SI. The influence of physical activity, socioeconomic status, and ethnicity on the weight status of adolescents. Obes Res 2000;8:130–9.
[65] Dubbert PM, Carithers T, Sumner AE, Barbour KA, Clark BL, Hall JE, et al. Obesity, physical inactivity, and risk for cardiovascular disease. Am J Med Sci 2002;324:116–26.
[66] Jebb SA, Rennie KL, Cole TJ. Prevalence of overweight and obesity among young people in Great Britain. Public Health Nutr 2004;7(3): 461–5.
[67] Okosun IS, Boltri JM, Anochie LK, Chandra KM. Racial/ethnic differences in prehypertension in American adults: population and relative attributable risks of abdominal obesity. J Hum Hypertens 2004; 18(12):849–55.
[68] Thiele S, Mensink GB, Beitz R. Determinants of diet quality. Public Health Nutr 2004;7:29–37.
[69] Zhang Q, Wang Y. Trends in the association between obesity and socioeconomic status in U.S. adults: 1971 to 2000. Obes Res 2004;12: 1622–32.
[70] Morland K, Wing S, Diez Roux A, Poole C. Neighborhood characteristics associated with the location of food stores and food service places. Am J Prev Med 2002;22:23–9.
[71] Kaufman PR. Rural poor have less access to supermarkets, larger grocery stores. Rural Dev Perspect 2002;13(3):19–26.
[72] Yim A, Humphries D, Abuova G. Food, alcohol and cigarette availability and consumption in Almaty, Kazakstan: results and appraisal of a rapid assessment. Public Health Nutr 2003;6(8):791–800.
[73] Pei-Lin H. Factors influencing students' decisions to choose healthy or unhealthy snacks at the University of Newcastle, Australia. J Nurs Res 2004;12:83–91.
[74] Frazao E, Allshouse J. Strategies for intervention: commentary and debate. J Nutr 2003;133:844S–7S.
[75] Huang KS. Nutrient elasticities in a complete food demand system. Am J Agric Econ 1997;78:21–9.
[76] Guo X, Mroz TA, Popkin BM, Zhai F. Structural changes in the impact of income on food consumption in China, 1989–93. Econ Dev Cult Change 2000;48:737–60.
[77] Guo X, Popkin BM, Mroz TA, Zhai F. Food price policy can favorably alter macronutrient intake in China. J Nutr 1999;129:994–1001.
[78] Darmon N, Ferguson EL, Briend A. A cost constraint alone has adverse effects on food selection and nutrient density: an analysis of human diets by linear programming. J Nutr 2002;132(12):3764–71.
[79] Darmon N, Ferguson EL, Briend A. Do economic constraints encourage the selection of energy dense diets? Appetite 2003;41(3):315–22.
[80] Drewnowski A, Darmon N, Briend A. Energy-dense diets are associated with lower diet costs: a community study of French adults. Public Health Nutr 2004;7(1):21–7.
[81] Chung C, Myers S. Do the poor pay more for food? An analysis of grocery store availability and food price disparities. J Consum Aff 1999; 33(2):276–96.
[82] MacDonald JM, Nelson PE. Do the poor still pay more? Food price variations in large metropolitan areas. J Urban Econ 1991;30: 344–59.
[83] Kirkpatrick S, Tarasuk V. The relationship between low income and household food expenditure patterns in Canada. Public Health Nutr 2003;6:589–97.
[84] Shannon C, Story M, Fulkerson JA, French SA. Factors in the school cafeteria influencing food choices by high school students. J Sch Health 2002;72(6):229–34.
[85] Glanz K, Basil M, Maibach E, Goldberg J, Snyder D. Why Americans eat what they do: taste, nutrition, cost, convenience, and weight control concerns as influences on food consumption. J Am Diet Assoc 1998;98: 1118–26.
[86] French S, Jeffery R, Story M, Hannan P, Snyder M. A pricing strategy to promote low-fat snack choices through vending machines. Am J Public Health 1997;87(5):849–51.
[87] French SA, Story M, Hannan P, Breitlow KK, Jeffery RW, Baxter JS, et al. Cognitive and demographic correlates of low-fat vending snack choices among adolescents and adults. J Am Diet Assoc 1999;99: 471–5.
[88] French S, Jeffety R, Story M, Breitlow K, Baxter J, Hannan P, et al. Pricing and promotion effects on low-fat vending snack purchases: the CHIPS Study. Am J Public Health 2001;91(1):112–7.
[89] Fiske A, Cullen KW. Effects of promotional materials on vending sales of low-fat items in teachers' lounges. J Am Diet Assoc 2004;104(1): 90–3.
[90] French SA, Story M, Jeffery RW, Snyder P, Eisenberg M, Sidebottom A, et al. Pricing strategy to promote fruit and vegetable purchase in high school cafeterias. J Am Diet Assoc 1997;97(9):1008–10.
[91] Chou SY, Grossman M, Saffer H. An economic analysis of adult obesity: results from the behavioral risk factor surveillance system. J Health Econ 2004;23:565–87.
[92] Trost SG, Pate RR, Dowda M, Saunders R, Ward DS, Felton G. Gender differences in physical activity and determinants of physical activity in rural fifth grade children. J Sch Health 1996;66:145–50.
[93] Trost SG, Pate RR, Saunders R, Ward DS, Dowda M, Felton G. A prospective study of determinants of physical activity in rural fifth grade children. Prev Med 1997;26:257–63.
[94] Sallis JF, McKenzie TL, Elder JP, Broyles SL, Nader PR. Factors parents use in selecting play spaces for young children. Arch Pediatr Adolesc Med 1997;151:414–7.
[95] Sallis JF, Prochaska JJ, Taylor WC. A review of correlates of physical activity of children and adolescents. Med Sci Sports Exerc 2000;32(5): 963–75.
[96] Dowda M, Ainsworth BE, Addy CL, Saunders R, Riner W. Environmental influences, physical activity, and weight status in 8- to 16-year olds. Arch Pediatr Adolesc Med 2001;155:711–7.
[97] Bungum TJ, Vincent ML. Determinants of physical activity among female adolescents. Am J Prev Med 1997;13:115–22.
[98] Sallis JF, Hovell MF, Hofstetter CR, Elder JP, Hackley M, Caspersen CJ, et al. Distance between homes and exercise facilities related to frequency of exercise among San Diego residents. Pub Health Rep 1990;105:179–85.
[99] Dishman RK, Sallis JF, Orenstein DR. The determinants of physical activity and exercise. Public Health Rep 1985;100:158–71.
[100] Sallis JF, Bauman A, Pratt M. Environmental and policy interventions to promote physical activity. Am J Prev Med 1998;15:379–97.

[101] King AC, Castro C, Wilcox S, Eyler AA, Sallis JF, Brownson R. Personal and enivronmental factors associated with physical inactivity among difference racial-ethnic groups of US middle-aged and older-aged women. Health Psychol 2000;19:354–64.
[102] Ball K, Bauman A, Leslie E, Owen N. Perceived environmental and social influences on walking for exercise in Australian adults. Prev Med 2001;33:434–40.
[103] Booth ML, Owen N, Bauman A, Clavisi O, Leslie E. Social-cognitive and perceived environmental influences associated with physical activity in older Australians. Prev Med 2000;31:15–22.
[104] Wilcox S, Castro C, King AC, Houseman RA, Brownson R. Determinants of leisure time physical activity in rural compared with urban older and ethnically diverse women in the United States. J Epidemiol Community Health 2000;54:667–72.
[105] Huston SL, Evenson KR, Bors P, Gizlice Z. Neighborhood environment, access to places for activity, and leisure-time physical activity in a diverse North Carolina population. Am J Health Promot 2003;18:58–69.
[106] Killingsworth RE. Health promoting community design: a new paradigm to promote healthy and active communities. Am J Health Promot 2003; 17:169–70.
[107] Goran MI, Reynolds KD, Lindquist CH. Role of physical activity in the prevention of obesity in children. Int J Obes Relat Metab Disord 1999; 23(Suppl 3):S18.
[108] Sallis JF, Simons-Morton BG, Stone EJ, Corbin CB, Epstein LH, Faucette N, et al. Determinants of physical activity and interventions in youth. Med Sci Sports Exerc 1992;24:S248.
[109] Gordon-Larsen P, McMurray RG, Popkin BM. Determinants of adolescent physical activity and inactivity patterns. Pediatr 2000; 105(e83):1–8.
[110] Brownson RC, Housemann RA, Brown DR, Jackson-Thompson J, King AC, Malone BR, et al. Promoting physical activity in rural communities: walking trail access, use, and effects. Am J Prev Med 2000;15:235–41.
[111] Ross CE. Walking, exercise and smoking: does neighborhood matter? Soc Sci Med 2000;18:265–74.
[112] Yen IH, Kaplan GA. Poverty area residence and changes in physical activity level: evidence from the Alameda County Study. Am J Public Health 1998;88:1709–12.
[113] Khol HW, Hobbs KE. Development of physical activity behaviors among children and adolescents. Pediatr 1998;101:549–54.
[114] Taylor WC, Sallis JF. Determinants of physical activity in children. World Rev Nutr Diet 1997;82:159–67.
[115] Booth SL, Sallis JF, Ritenbaugh C, Hill JO, Birch LL, Frank LD, et al. Environmental and social factors affect food choice and physical activity: rationale, influences, and leverage points. Nutr Rev 2001;59:S21–39.
[116] Newman PWG, Kenworthy JR. Transport and urban form in thirty-two of the world's principal cities. Transp Rev 1991;11:249–72.
[117] Frank L. Land use and transportation interaction: implications of public health and quality of life. J Plann Educ Res 2000;20:6–22.
[118] Frank L, Pivo G. Impacts of mixed use and density of utilization of three modes of travel: single-occupant vehicle, transit, and walking. Transp Res Rec 1994;1466:44–52.
[119] Ewing R, Schmid T, Killingsworth R, Zlot A, Raudenbush S. Relationship between urban sprawl and physical activity, obesity, and morbidity. Am J Health Promot 2003;18:47–57.
[120] Huston S, Evenson K, Bors P, Gizlice Z. Neighborhood environment, access to places for activity, and leisure-time physical activity in a diverse North Carolina population. Am J Health Promot 2003; 18:58–69.
[121] Ross C, Dunning A. Land use transportation interaction: an examination of the 1995 NPTS Data. Federal Highway Administration Report No. FHWA-PL-99-003:129-91.
[122] Cervero R. Mixed land-uses and commuting: evidence from the American Housing Survey. Transp Res Part A Gen 1996;30:361–77.
[123] Frank LD, Pivo G. Impacts of mixed use and density on utilization of three modes of travel: single occupant vehicle, transit, and walking. Transp Res Rec 1994;1466:44–52.
[124] Cervero R, Kockelman K. Travel demand and the 3Ds: density, diversity, and design. Transp Res Part D Transp Environ 1997;2:199–219.
[125] Cervero R, Radisch C. Travel choices in pedestrian versus automobile oriented neighborhoods. Working paper, vol. 644. Berkeley, CA: University of California at Berkeley, Institute of Urban and Regional Development; 1995.
[126] Troped PJ, Saunders RP, Pate RR, Reininger B, Ureda JR, Thompson SJ. Associations between self-reported and objective physical environment factors and use of a community rail–trail. Prev Med 2001;32: 191–200.
[127] Giles-Corti B, Donovan RJ. Socioeconomic status differences in recreational physical activity levels and real and perceived access to a supportive physical environment. Prev Med 2002;35:601–11.
[128] Bauman A, Smith B, Stoker L, Bellew B, Booth ML. Geographic influences upon physical activity participation: evidence of a "coastal effect". Aust N Z J Public Health 1990;105:179–85.
[129] Parsons, Brinkerhoff, Quade, Douglas Inc. The pedestrian environment. Portland OR: 1000 Friends of Oregon; 1993. p. 4A.
[130] Cervero R, Duncan M. Walking, bicycling, and urban landscapes: evidence from the San Francisco Bay area. Am J Public Health 2003;93: 1478–83.
[131] Cervero R, Gorham R. Commuting in transit versus automobile neighborhoods. J Am Plann Assoc 1995;61:210–25.
[132] Handy SL. Urban form and pedestrian choices: study of Austin neighborhoods. Transp Res Rec 1996;1552:135–44.
[133] Evenson KR, Sarmiento OL, Tawney KW, Macon ML. Personal, social, and environmental correlates of physical activity in North Carolina Latina Immigrants. Am J Prev Med 2003;25(3Si):77–85.
[134] Ainsworth BE, Wilcox S, Thompson WW, Richter DL, Henderson KA. Personal, social, and physical environmental correlates of physical activity in African-American women in South Carolina. Am J Prev Med 2003;25(Si):23–9.
[135] Estrabrooks PA, Lee RE, Gyurcsik NC. Resources for physical activity participation: does availability and accessibility differ by neighborhood socioeconomic status. Ann Behav Med 2003;25(2):100–4.
[136] U.S. Department of Health and Human Services. The surgeon general's call to action to prevent and decrease overweight and obesity. Rockville, MD: U.S. Department of Health and Human Services, Public Health Service, Office of the Surgeon General; 2001.
[137] Kahn E, Heath G, Powell K, Stone E, Brownson R. Increasing physical activity: a report on recommendations of the task force on Community Preventive Services. MMWR 2001;50:1–14.
[138] Wilkinson R, Marmot M. Solid facts: social determinants of health. Denmark: World Health Organization; 2003.
[139] Haan M, Kaplan GA, Camacho T. Poverty and health: prospective evidence from the Alameda County study. Am J Epidemiol 1987;125: 989–98.
[140] MacIntyre S, Maciver S, Sooman A. Area, class and health: should we be focusing on places or people. J Soc Policy 1993;22:213–34.
[141] Cohen D, Spear S, Scribner R, Kissinger P, Mason K, Wildgen J. "Broken windows" and the risk of gonorrhea. Am J Public Health 2000; 90:230–6.
[142] Krieger N, Williams DR, Moss NE. Measuring social class in US Public health research: concepts, methodologies, and guidelines. Annu Rev Public Health 1997;18:341–78.
[143] O'Campo P, Gielen AC, Faden RR, Xzue X, Kass N, Wang MC. Violence by male partners against women during the childbearing year: a contextual analysis. Am J Public Health 1995;85:1092–7.
[144] Diez-Roux AV. Bringing context back into epidemiology: variables and fallacies in multilevel analysis. Am J Public Health 1998;88:216–22.
[145] Diez-Roux AV. Investigating area and neighborhood effects on health. Am J Public Health 2001;92:1783–9.
[146] Owen N, Leslie E, Salmon J, Fotheringham MJ. Environmental determinants of physical activity and sedentary behavior. Exerc Sport Sci Rev 2000;28:153–8.
[147] Clark DO. Physical activity and its correlates among urban primary care patients aged 55 years or older. J Geront Ser B Psychol Sci Soc Sci 1999; 54B:S41–8.
[148] Sallis J, Owen N. Physical activity and behavioral medicine. Thousand Oaks, CA: Sage Publications; 1999.

[149] Humpel N, Owen N, Leslie E, Marshall A, Bauman A, Sallis JF. Associations of location and perceived environmental attributes with walking in neighborhoods. Am J Health Promo 2004;18:239–42.
[150] Frank LD, Andresen MA, Schmid TL. Obesity relationships with community design, physical activity and time spent in cars. Am J Prev Med 2004;27:87–96.
[151] NIH. Strategic plan to reduce and ultimately eliminate health disparities; 2000 [October 6, 2000. Available at: http://www.nih.gov/about/hd/strategicplan.pdf].
[152] Danzinger S, Gottschalk P. Uneven tides: rising inequality in America. New York: Russell Sage Foundation; 1993.
[153] Lenfant C. Conference on socioeconomic status and cardiovascular health and disease. Circulation 1996;94:2041–4.
[154] Atkinson AB, Bourguignon F. Handbooks in economics, vol. 16. Amsterdam: Elsevier Science, North-Holland; 2000. p. 958.
[155] Duleep HO. Mortality and income inequality. Soc Secur Bull 1995;58:34–50.
[156] Feldman JJ, Makuc DM, Kleinman JC, Cornoni-Huntley J. National trends in educational differences in mortality. Am J Epidemiol 1989;129:919–33.
[157] Pappas G, Queen S, Hadden W, Fisher G. The increasing disparity in mortality between socioeconomic groups in the United States, 1960 and 1986. N Engl J Med 1993;329:103–9.
[158] Lynch JW, Kaplan GA. Understanding how inequality in the distribution of income affects health. J Health Psychol 1997;2:297–314.
[159] Preston SH, Taubman P. Socioeconomic differences in adult mortality and health status. In: Martin LG, Preston SH, editors. Demography of aging. Washington, D.C.: National Academy Press; 1994. p. 279–318.
[160] Marmot MG, Kogevinas M, Elston MA. Social/economic status and disease. In: Breslow L, Fielding JE, Lave LB, editors. Annual review of public health. Palo Alto, CA: Annual Reviews Inc.; 1987. p. 111–35.
[161] Kaplan GA, Keil JE. Special report: socioeconomic factors and cardiovascular disease: a review of the literature. Circulation 1993;88:1973–98.
[162] House JS, Lepkowski JM, Kinney AM, Mero RP, Kessler RC, Herzog AR. The social stratification of aging and health. J Health Soc Behav 1994;35:213–34.
[163] Kreiger N. Analyzing socioeconomic and racial/ethnic patterns in health and health care. Am J Public Health 1993;83:1086–7.
[164] Williams DR, Collins C. Socioeconomic and racial differences in health: patterns and explanations. Annu Rev Sociology 1995;21:349–86.
[165] Kaufman JS, Cooper RS, McGee DL. Socioeconomic status and health in blacks and whites: the problem of residual confounding and the resiliency of race. Epidemiology 1997;8:609–11.
[166] Massey DS. The age of extremes: concentrated affluence and poverty in the twenty-first century. Demography 1996;33:395–412.
[167] Wilson WJ. The truly disadvantaged: the inner city, the underclass and public policy. Chicago: University of Chicago Press; 1987.
[168] Pebley AR, Sastry N. Neighborhoods, poverty and children's well-being: a review. In: Neckerman, K., editor. Social dimensions of inequality. New York: Russell Sage Foundation [In press].
[169] McIsaac S, Wilkinson RG. Income distribution and cause-specific mortality. Eur J Public Health 1997;7:45–53.
[170] Steckel RH. Stature and the standard of living. J Econ Lit 1995;33:1903–40.
[171] Wilkinson RG. Income distribution and life expectancy. Am J Prev Med 1992;30:165–8.
[172] Wilkinson RG. Unhealthy societies: the afflictions of inequality. New York: Routledge; 1996.
[173] Crespo CJ, Smit E, Andersen RE, Carter-Pokras O, Ainsworth BE. Race/ethnicity, social class and their relation to physical inactivity during leisure time: results from the Third National Health and Nutrition Examination Survey, 1988–1994. Am J Prev Med 2000;18:46–53.
[174] Lowry R, Wechsler H, Kann L, Collins JL. Recent trends in participation in physical education among US high school students. J Sch Health 2001;71(4):145–52.
[175] Gordon-Larsen P, Nelson MC, Page P, Popkin BM. Inequality in the built environment underlies key health disparities in physical activity and obesity. Pediatr [In press].
[176] Kahn E, Heath G, Powell K, Stone E, Brownson R. Increasing physical activity: a report on recommendations of the Task Force on Community Preventive Services. MMWR 2001;50:1–14.
[177] Owen N, Humpel N, Leslie E, Bauman A, Sallis J. Understanding environmental influences on walking: review and research agenda. Am J Prev Med 2004;27(1):67–76.
[178] Dannenberg A, Jackson R, Frumkin H, Schieber R, Pratt M, Kochtitzky C, et al. The impact of community design and land-use choices on public health: a scientific research agenda. AJPH 2003;93(9):1500–8.
[179] Srinivasan S, O'Fallon L, Dearry A. Creating healthy communities, healthy homes, health people: initiating a research agenda on the built environment and public health. AJPH 2003;93:1446–50.