Active Community Environments and Health

The Relationship of Walkable and Safe Communities to Individual Health

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The literature suggests that individuals will be healthier if they live in Active Community Environments that promote exercise and activity. Two key elements of such environments are walkability and safety. Examining data from the National Health and Nutrition Examination Survey III, 1988–1994 and using a multilevel analysis, we found that individuals who live in counties that are more walkable and have lower crime rates tended to walk more and to have lower body mass indices (BMIs) than people in less walkable and more crime-prone areas, even after controlling for a variety of individual variables related to health. Among lifelong residents of an area, lesser walkability and more crime were also associated with respondents reporting weight-related chronic illness and lower ratings of their own health. The effect of high crime rates was substantially stronger for women than for men, and taking this interaction into account eliminated gender differences in walking, BMI, weight-related chronic conditions, and self-reported poor health. The results suggest that to promote activity and health, planners should consider community walkability, crime prevention, and safety.

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The Centers for Disease Control and Prevention (CDC) define Active Community Environments (ACES) as places where people of all ages can easily participate in physical activity. A growing literature suggests that ACES can promote physical health among their residents. Figure 1 demonstrates the logic that walkable and safe areas promote greater physical activity, leading to lower levels of obesity, which in turn contribute to lower levels of weight-related chronic conditions and improved overall health. In recent years planners have been exhorted to consider these potential relationships in their work, and to design communities to promote greater physical activity (CDC, 2005; Doyle, 2002; Frank, Engelke, & Schmid, 2003; Hoehner, Brennan, Brownson, Handy & Killingsworth, 2003; Lavizzo-Mowrey & McGinnis, 2003; Northridge, Sclar, & Biswas, 2003).

While these ideas seem sensible, relatively little empirical research has examined the relationship of active environments to the ultimate goal of enhanced health. A number of studies have found that residents walk more in areas that are more interconnected, where there are more street intersections, and blocks are shorter (Brownson, Baker, Housemann, Brennan, & Bacak, 2001; Craig, Brownson, Cragg, & Dunn, 2002; De Bourdeaudhuif, Sallis, & Saelens, 2003; Ewing, Pendall, & Chen, 2002; Frank, 2000; Frank & Engleke, 2001; Giles-Corti & Donovan, 2003; Giles-Corti, Macintyre, Clarkson, Pikora, & Donovan, 2003; Humpel, Owen, & Leslie, 2002; King et al., 2003; Lund, 2003; Saelens, Sallis, Black, & Chen, 2003; Trost, Owen, Bauman, Sallis, & Brown, 2002). Other studies have documented a relationship between perceived safety of neighborhoods and physical activity (CDC, 1999; Humpel et al., 2002; Ross, 2000; Trost et al., 2002), although not all studies found this relationship (e.g., Huston, Evenson, Bors, & Gizlice, 2003). No study has examined the hypothesized causal chain illustrated in Figure 1 in its entirety. Such an examination should look at the relationship of walkable and safe environments to indicators of health in the resident population, while adequately controlling for individual characteristics related to health. Our study provides this analysis.

Three recent studies (Ewing, Schmid, Killingsworth, Zlot, & Raudenbush, 2003; Kelly-Schwartz, Stockard, Doyle, & Schlossberg, 2004; Lopez, 2004) documented a relationship between urban sprawl and measures of health, incorporating multilevel analyses and strong controls for individual characteristics. More sprawling areas tend to be less walkable, often involving designs that incorporate

Active Community Environments (walkable and safe) → **Greater physical activity** → **Lower obesity** → **Fewer weight-related chronic conditions** → **Better overall health**

Figure 1. The hypothesized Active Community Environments (ACES) model.

cul-de-sacs, unconnected streets, and large lots. Results of these studies provide some support for the hypothesis that more walkable environments promote better health. Employing a unidimensional measure of sprawl, using counties as the geographic unit of analysis, and controlling for a wide variety of health-related individual characteristics, both Ewing et al. (2003) and these authors (Kelly-Schwartz et al., 2004) found that people in less sprawling areas tended to walk more and weigh less. Ewing and associates (2003) also found that people in less sprawling counties have lower blood pressure. Using a unidimensional measure of sprawl and Metropolitan Statistical Areas (MSAs) as the unit of analysis, Lopez (2004) also found that people residing in more sprawling areas were more likely to be obese. The same studies show no relationship between sprawl and coronary heart disease (Ewing et al., 2003), lung disease, subjects' own ratings of their overall health, physicians' ratings of subjects' health (Kelly-Schwartz et al., 2004), or diabetes (Ewing et al., 2003; Kelly-Schwartz et al., 2004).

These authors (Kelly-Schwartz et al., 2004) also used MSAs as the unit of analysis with a multidimensional measure of sprawl that differentiated walkability from other theoretical indicators, such as density, a mixture of uses, and well defined central spaces. This analysis found no relationships between the measures of sprawl and frequency of walking, body weight, or presence of chronic disease, but did find that subjects reported better health, and were rated by physicians as having better health, when they lived in MSAs that were more walkable but less dense.[1] We hypothesized that the positive relationship between street connectivity and health might indicate one way community design could promote health, while the negative effect of density on health could be the result of higher stress associated with a very dense urban environment.

Safety, and especially the presence of crime, may be an important source of stress, especially in urban environments. Though safety is a key element of Active Community Environments in theory, we know of no studies to date that incorporate measures of both safety and walkability in analyses of individuals' health, while also including necessary control variables at the individual level. To fill this gap, we explored the relationships between both neighborhood walkability and neighborhood safety and individuals' exercise, body mass, weight-related chronic conditions, and overall health. The ACES literature leads us to expect that both walkability and safety will be related to health, even when we include strong controls for individual characteristics.

We also explored the possibility that women and men may be differentially affected by the safety of their environments. A substantial literature documents that women fear crime more than men, even when objective measures of safety are similar (e.g., Gordon & Riger, 1989; Hollander, 2001; Madriz, 1997; Warr, 1985). Other literature has documented greater incidence of chronic conditions and generally poorer perceptions of health among women, even though women tend to have longer life expectancies than men (Verbrugge, 1985, 1989). Consequently, we examined the possibility that comparably safe environments have different effects on men and women, and the extent to which these may account for differences in health (Sanders-Phillips, 1996), something the ACES literature has not yet addressed.

Data and Method

Our data to test these questions came from the National Health and Nutrition Examination Survey III, 1988–1994 (NHANES III), and from publicly available information on the environments of respondents to this survey. The NHANES survey is a large study, conducted by the National Center for Health Statistics (1996). The sample was selected using a complex, stratified, multistage probability design. Data were gathered through personal interviews in respondents' homes and through medical examinations conducted in a mobile examination center. We limited our analysis to persons 18 years of age and older.[2]

We wished to identify respondents by county of residence, information available only for those living in areas with populations of 500,000 or more, listed in Table 1. Thus, though the full survey represented the civilian, noninstitutionalized population of the United States, our results generalize only to this smaller group of individuals in counties in large urban areas.

We examined 5 dependent variables: frequency of walking, measured by whether or not respondents reported ever walking one mile or more without stopping during the last month; obesity, measured by the standard body mass index [BMI; weight in kilograms/(height in centimeters/100)^2]; subjects' reports of ever being diagnosed with either hypertension or diabetes, two major chronic diseases affected by body weight; a summary rating by respondents of their own health; and a summary health rating by the physician examiner. Each rating used a five-point scale, with 1 being "poor" and 5 being "excellent."[3]

We measured safety as the 1991 county crime rate from the Uniform Crime Report (UCR) as reported in the 1994 *County and City Data Book* (U.S. Bureau of the Census, 1994) except in New York City, for which we report crime rates adjusted to better represent individual counties. Information on the reliability and validity of the UCR data are available from the Federal Bureau of Investigation (2003) and O'Brien (1985).

The literature cited above indicates that a more walkable environment is one with greater connectivity, involving more intersections and shorter block lengths.[4] To capture these concepts, we calculated a composite measure of walkability based on three county-level indicators: the negative of average block size, which should be positively related to connectivity (Ewing et al., 2003); the percent of all blocks having areas of less than 0.01 square miles (Ewing et al., 2003); and the number of 3-, 4-, and 5-way intersections divided by the total number of road miles. Details on the calculations are available on request from the authors. All three measures were highly correlated (Pearson's r ranged from 0.80 to 0.88). To make the measures comparable, we converted them to z-scores. We then added these values to arrive at our measure (coefficient alpha = 0.94). A higher score indicates a more walkable environment (smaller block sizes, and/or a greater share of blocks with areas under 0.01 square miles, and/or more intersections per road mile).[5] Both crime and walkability scores for each sampled county are given in Table 1.

Finally, we included a number of control variables, all measured at the individual level: age, gender, race/ethnicity, income, education, smoking history, and social support. We chose these variables because a substantial body of research has demonstrated that they are highly related to health status. Omitting them from our models could produce serious misspecification. In addition, we included measures of how long the respondents had lived in the area to control for their exposure to the local environment.[6]

We controlled for race and ethnicity using a series of dichotomous variables to identify non-Hispanic Whites, non-Hispanic Blacks, and Mexican Americans. We measured income as the ratio of family income to the poverty level, and education as the highest grade or year of school completed. We captured smoking history with two dummy variables, "smokes now" and "used to smoke," with the omitted category indicating that the subject had never smoked. We included social support using a composite of standardized scores (z-scores) for 5 variables measuring how frequently subjects interacted with others.[7] We measured both age and length of time in the area in years.[8]

Our sample sizes were smaller for questions based on examination data than for questions based on interview data.[9] Respondents in the interview sample, but not the examination sample, tended to be somewhat older, less healthy, and more often non-Hispanic White. Because we included all of these variables as controls in our analysis, these differences should not affect our results.

Analysis

To examine the influence of Active Community Environments on health while controlling for individual-level variables, we used hierarchical linear modeling (HLM) employing SAS PROC MIXED. For the dichotomous dependent variables (the measures of walking and the self-report of hypertension and/or diabetes), we used hierarchical generalized linear models, as recommended by Raudenbush and Bryk (2002), employing a glimmix procedure within SAS to obtain the appropriate estimates. Hierarchical linear modeling provides two distinct advantages over ordinary least squares (OLS) or simple logistic regression in testing hypotheses that involve multiple units of analysis. First, and most important, because of the more appropriate specification of the two-level model, the regression coefficient estimates are more unbiased and consistent, and standard errors are more accurate. Second, the variance of the dependent variable may be partitioned between the individual and group (county) levels. This allows us to obtain estimates of the extent to which the measures of health vary between the counties and the extent to which the environmental measures and the individual-level control variables account for this between-county variation (Raudenbush & Bryk, 2002; Singer, 1998).

We examined two separate models: one includes the measures of walkability and safety plus the individual-level variables; the second includes all of these variables plus the interaction of crime and gender. The coefficients in the models provide estimates of the relationships of the individual- and county-level variables to our measures of health. We also report the extent to which our health measures vary between counties and the extent to which variables in

Table 1. County walkability scores, crime rates, and sample sizes.

County (major city/cities), state	Walkability	1991 Crimes per 100,000 persons	$N = 9{,}252$
Maricopa (Phoenix), Arizona	−0.87	8,179	215
Alameda (Oakland), California	2.32	8,220	219
Fresno (Fresno), California	−0.75	9,100	241
Los Angeles (Los Angeles), California	0.72	7,614	1,245
Orange (Anaheim/Santa Ana), California	0.48	5,873	214
San Bernadino (San Bernadino/Riverside), California	−5.46	6,491	238
San Diego (San Diego), California	−2.64	6,816	219
San Jose (San Jose), California	0.54	5,037	193
Ventura (Oxnard), California	−1.15	4,427	246
Dade (Miami/Hialeah), Florida	1.72	12,311	265
Duval (Jacksonville) Florida	−1.63	10,104	227
Palm Beach (West Palm Beach, Boca Raton), Florida	−3.05	8,593	227
Cook (Chicago), Illinois	1.63	8,475	579
Middlesex (Boston), Massachusetts	−1.49	3,599	208
Oakland (Detroit), Michigan	−3.97	4,995	203
Wayne (Detroit), Michigan	0.15	9,248	255
St. Louis (St. Louis), Missouri	−0.33	4,280	241
Erie (Buffalo), New York	−4.15	5,689	201
Kings (Brooklyn, New York), New York	4.76	8,709	215
Nassau (New York PMSA), New York	3.02	3,343	192
New York (Manhattan, New York), New York	5.40	12,137	214
Queens (Queens, New York), New York	5.87	8,709	259
Westchester (New York PMSA), New York	−1.10	4,330	178
Cuyahoga (Cleveland), Ohio	−2.95	5,425	196
Hamilton (Cincinnati), Ohio	−3.17	6,880	214
Allegheny (Pittsburgh), Pennsylvania	0.99	3,805	199
Delaware (Philadelphia), Pennsylvania	0.61	3,433	178
Philadelphia (Philadelphia), Pennsylvania	6.55	6,836	163
Providence (Providence), Rhode Island	2.51	5,804	219
Bexar (San Antonio), Texas	−0.55	10,994	298
Dallas (Dallas), Texas	−1.28	11,322	181
El Paso (El Paso), Texas	−0.48	8,937	231
Harris (Houston), Texas	−1.70	8,807	348
Tarrant (Fort Worth/Arlington), Texas	−1.11	11,087	258
King (Seattle), Washington	0.56	8,040	273
Mean (unweighted)	0.00	7,361	
Standard deviation (unweighted)	2.82	2,581	

Sources: U.S. Bureau of the Census (1994), Ewing et al. (2003), and authors' calculations.

Note: The measure of walkability is based on three county-level indicators: the negative of average block size, the percentage of blocks having areas of less than 0.01 square miles, and the number of 3-, 4-, and 5-way intersections divided by the total number of road miles. As described in the text, all measures were converted to z-scores for comparability and summed (coefficient alpha = .94). Uniform Crime Report data are from 1991. The rate includes "serious crimes known to the police," or what are commonly called "index crimes": murder and nonnegligent manslaughter, forcible rape, robbery, aggravated assault, burglary, larceny-theft, and motor vehicle theft. We used data on precinct-level crime rates for 1993 from New York City (New York, 1993) to adjust the overall 1991 crime rate for New York City to account for variations in crime across different boroughs. The adjustments raised the rate for New York County (Manhattan) by 31% and decreased the rates for Queens and Kings counties by 6%.

our models can account for these county-level differences. Finally, we reexamined our second model using only the data for subjects who have lived in an area for their entire lives, instead of using the length of time that respondents have lived in the area as a control variable as we did the first time. If effects of exposure to our measures of Active Community Environments cumulate over a lifetime, the influence of these environmental variables should be stronger within this more homogeneous group.

We believe that our analysis of county-level characteristics provides a conservative test of the ACES hypothesis. Neighborhoods within a county can differ substantially in both walkability and levels of crime, thus we do not expect the relationship to be the same at both scales. It is hard to imagine what would make the relationship between these measures and health weaker at the neighborhood level than at the county level, and we believe this is unlikely to occur. Thus we believe the relationship between ACES and health would be stronger at the neighborhood level. In addition, our analysis includes extensive controls for individual-level characteristics related to health, thus helping to ensure that our models are properly specified.

Results

Table 2 shows the means and standard deviations of the dependent and control variables used in the analysis. Slightly fewer than half of the respondents had walked a mile or more without stopping in the last month. The average BMI for the respondents was almost 27, a level that is overweight but not obese.[10] Almost one third of the respondents reported that they had been diagnosed with either high blood pressure or diabetes. On average, respondents rated their health as between very good and good, although respondents tended to rate their health as somewhat worse than did physicians ($t = 43.3$, $df = 7{,}786$, $p < .001$). All of the dependent variables had sufficient variation for analysis.

The data in Table 1 indicate extensive variation in crime rates and walkability among the counties in the sample. The most walkable areas, with scores greater than 5.0, were Philadelphia County in Pennsylvania and Manhattan and Queens in New York City. The counties with the lowest walkability scores were San Bernadino County in Southern California and Eire County, the home of Buffalo, New York. The counties with the highest crime rates were New York County (Manhattan) and Dade County, which is Miami. The counties with the lowest crime rates were Nassau County, in the New York City region; Delaware County, in the Philadelphia area; and Middlesex County, the site of Boston. Crime rates and walkability scores were moderately correlated ($r = .20$, $p < .001$ using individuals as the level of analysis), indicating that people who lived in more walkable counties also tended to live in counties where the crime rate was somewhat higher.[11]

Table 2. Variable means and standard deviations.

	Mean	*SD*
Dependent variables		
Walked mile or more in last month	0.47	0.50
Body mass index (BMI)	26.83	5.65
Hypertension or diabetes	0.30	0.46
Health self rating	3.26	1.09
Health physician rating	3.91	1.05
Individual-level control variables		
Age	46.80	20.03
Female	0.52	0.50
non-Hispanic White	0.32	0.47
non-Hispanic Black	0.28	0.45
Mexican American	0.33	0.47
Income/poverty level	2.41	1.81
Years of education	10.94	3.96
Social support composite	0.00	2.67
Smoke now	0.25	0.43
Used to smoke	0.24	0.43
Years living in area	21.97	18.12

Note: The measures of walking, hypertension, gender, race/ethnicity, and smoking status are all dichotomies, measured as dummy variables. Average values on a dummy variable may be interpreted as the proportion of respondents that are in the category queried. Age, education, and time living in the area are measured in years. The health ratings are on a five-point scale, with a higher value indicating better health.

The Relationship of Crime Rates and a Walkable Environment to Walking Behavior, BMI, and Health

We first examined an intercept-only (unconditional means) model, testing the hypothesis that the mean of the dependent variable is equal across counties. This model is equivalent to a one-way analysis of variance with the counties as the factor. All of the *z* values associated with the random coefficient variance estimates for this first model were statistically significant, indicating that the health of respondents varied significantly across counties. The intraclass correlation coefficient (rho; the share of the variance in the dependent variable explained by differences between counties) ranged from a low of .01 (for BMI) to a high of .15 (for the physician's rating of the respondent's health).[12]

Table 3. Hierarchical regression of health-related dependent variables on individual and environmental variables.

	Walking a mile or more				Body mass index			
	Model 1		Model 2		Model 1		Model 2	
	Coeff.	*SE*	**Coeff.**	*SE*	**Coeff.**	*SE*	**Coeff.**	*SE*
Intercept	0.058	0.221	−0.042	0.233	23.856	0.460***	24.510	0.507***
Age	−0.014	0.001***	−0.014	0.001***	0.018	0.004***	0.018	0.004***
Gender (female)	−0.242	0.045***	−0.048	0.149	0.920	0.126***	− 0.353	0.419
non-Hispanic Black	0.301	0.100**	0.299	0.100**	1.449	0.270***	1.471	0.271***
non-Hispanic White	0.272	0.104**	0.271	0.104**	− 0.285	0.281	− 0.265	0.282
Mexican American	0.060	0.105	0.057	0.105	1.313	0.272***	1.330	0.273***
Income/poverty	0.045	0.014**	0.045	0.014**	− 0.050	0.041	− 0.049	0.041
Years of education	0.057	0.007***	0.057	0.007***	− 0.020	0.019	− 0.020	0.019
Social support	0.052	0.009***	0.052	0.009***	0.016	0.023	0.016	0.023
Smoke now	−0.016	0.054	−0.020	0.054	− 0.600	0.152***	− 0.572	0.152***
Used to smoke	−0.054	0.057	−0.053	0.057	0.950	0.161***	0.946	0.161***
Time in area	−0.001	0.001	−0.001	0.001	0.028	0.004***	0.028	0.004***
Walkability	0.052	0.020**	0.053	0.020**	− 0.052	0.027[a]	− 0.054	0.028*
Crime rate (10^{-5})	−4.000	2.100[a]	−2.000	2.400	7.500	2.900**	− 2.000	4.200
Crime/gender interaction (10^{-5})	—	—	−3.000	1.900	—	—	16.70	5.300***
Random coefficient variance	0.078	0.025***	0.080	0.025***	0.022	0.042	0.032	0.045
PRE from intercept-only model	0.091		0.072		0.920		0.883	
Residual	0.997	0.015***	0.997	0.015***	30.357	0.474***	30.312	0.474***

	Diabetes or hypertension				Self-rated health			
	Model 1		Model 2		Model 1		Model 2	
	Coeff.	*SE*	**Coeff.**	*SE*	**Coeff.**	*SE*	**Coeff.**	*SE*
Intercept	−3.481	0.199***	−3.381	0.216***	3.172	0.084***	3.090	0.091***
Age	0.046	0.002***	0.046	0.002***	−0.013	0.001***	−0.013	0.001***
Gender (female)	0.300	0.052***	0.109	0.167	−0.128	0.021***	0.031	0.070
non-Hispanic Black	0.426	0.114***	0.430	0.115***	0.076	0.047[a]	0.074	0.047
non-Hispanic White	−0.284	0.119*	−0.281	0.119*	0.281	0.048***	0.279	0.048***
Mexican-American	0.036	0.117	0.041	0.118	−0.084	0.048[a]	−0.087	0.048[a]
Income/poverty	−0.040	0.016**	−0.040	0.016*	0.089	0.007***	0.089	0.007***
Years of education	0.006	0.008	0.006	0.008	0.051	0.003***	0.051	0.003***
Social support	−0.008	0.010	−0.008	0.010	0.015	0.004***	0.015	0.004***
Smoke now	0.017	0.064	0.021	0.064	−0.199	0.026***	−0.202	0.026***
Used to smoke	0.237	0.062***	0.236	0.062***	−0.091	0.027***	−0.090	0.027***
Time in area	0.003	0.001*	0.003	0.001*	−0.0004	0.001	−0.0004	0.001
Walkability	−0.001	0.011	−0.001	0.011	0.006	0.006	0.006	0.006
Crime rate (10^{-5})	0.467	1.200	−0.978	1.700	−0.456	0.637	0.692	0.801
Crime/gender interaction (10^{-5})	—	—	2.500	2.100	—	—	−2.000	0.880*
Random coefficient variance	0.006	0.008	0.006	0.008	0.004	0.002**	0.004	0.002**
PRE from intercept-only model	0.833		0.833		0.857		0.855	
Residual	0.983	0.015***	0.982	0.015***	0.954	0.014***	0.953	0.014***

Table 3 (continued).

	Physician-rated health			
	Model 1		Model 2	
	Coeff.	SE	Coeff.	SE
Intercept	5.025	0.223***	5.019	0.225***
Age	−0.026	0.001***	−0.026	0.001***
Gender (female)	−0.092	0.019***	−0.081	0.064
non-Hispanic Black	−0.267	0.042***	−0.267	0.042***
non-Hispanic White	−0.020	0.044	−0.020	0.044
Mexican American	−0.002	0.044	−0.002	0.044
Income/poverty	0.055	0.006***	0.055	0.006***
Year of education	0.021	0.003***	0.021	0.003***
Social support	0.009	0.004*	0.009	0.004*
Smoke now	−0.061	0.023**	−0.061	0.023**
Used to smoke	0.007	0.025	0.007	0.025
Time in area	−0.004	0.001***	−0.004	0.001***
Walkability	0.030	0.025	0.031	0.025
Crime rate (10^{-5})	−0.994	2.800	−0.910	2.800
Crime/gender interaction (10^{-5})	—	—	−0.155	0.803
Random coefficient variance	0.162	0.040***	0.162	0.040***
PRE from intercept-only model	0.051		0.051	
Residual	0.667	0.011***	0.667	0.011***

***$p < .001$; **$p < .01$; *$p < .05$; $^{a}p < .10$

Note: To obtain actual coefficients associated with crime rate and gender by crime rate interaction, multiply by 10^{-5}. The random coefficient variance is associated with counties, while the residual variance term is associated with the individuals. The PRE measure indicates the extent to which variation between counties is reduced, compared to the intercept-only model, when variables in the model are considered. For the intercept-only model, the random coefficient variance was 0.086, $p < .001$ for walking; 0.277, $p = .003$ for BMI; 0.036, $p = .004$ for diabetes and hypertension; 0.029, $p < 0.001$ for self-rated health; and 0.171, $p < .001$ for physician-rated health.

Model 1 in Table 3 includes all of the individual-level control variables and our crime and walkability measures. We use the random coefficient variances and associated probabilities to test the hypotheses that average values for the dependent variables do not vary between counties once the independent variables in the model are considered (analogous to an analysis of covariance). Our results indicate the average amount that people walk, their own ratings of their health, and physicians' ratings of their health differ significantly across counties even after we control for the variables in the models. By contrast, variation between counties in BMI and chronic conditions can be totally accounted for by variables within the models. In other words, if residents of these counties had similar individual characteristics and the counties had equivalent levels of crime and walkability, then the average BMIs and proportion of people with chronic conditions would not be significantly different between the counties. Individuals, of course, would continue to differ in BMI and presence of chronic conditions, as indicated by the significant residual values.

Proportionate Reduction in Error (PRE) measures indicate the reduction in variance between counties we obtain by adding the individual-level and ACES measures (Model 1) and the interaction terms (Model 2) to the intercept-only model. It is calculated by dividing the difference between the variance estimates in the intercept-only and explanatory models by the variance estimate for the intercept-only model. The PRE results indicate that the model can account for less than 10% of differences in walking behavior and physicians' health ratings between counties, but for over 80% of between-county differences in BMI, diabetes and hypertension, and self-ratings of health.[13]

The coefficients associated with each variable in Model 1 indicate that the individual-level variables influenced each of the dependent variables as expected. Older people and women were significantly less likely than younger people and men to have walked a mile or more, and were significantly more likely to have a higher BMI, diabetes or hypertension, and poorer ratings of health, holding constant the values of the other variables in Model 1. The influence of race and ethnicity varied somewhat with the dependent variable and the group considered. For instance, non-Hispanic Blacks tended to walk significantly more than those in other groups, but had higher BMIs, a higher incidence of diabetes and hypertension, and significantly worse health ratings from physicians. Non-Hispanic Whites also tended to walk significantly more than others, but had significantly lower rates of chronic conditions, and rated their own health as significantly better than others did. Mexican Americans differed from other groups only in their significantly higher BMIs, all else equal. Subjects with higher incomes, higher levels of education, and/or higher levels of social support walked significantly more than others and had better health ratings, once other variables were controlled. In addition, those with higher incomes had lower rates of diabetes and/or hypertension when the other variables in the model were controlled. Subjects who currently smoked had significantly lower BMIs but poorer health ratings, while those who smoked in the past had higher BMIs, higher rates of diabetes and/or hypertension, and poorer self-ratings of health.

Model 1 results also indicate that our walkability and crime rate measures were related to some of our health measures. All of the relationships were in the expected direction, but only some were statistically significant. Specifically, as hypothesized, subjects who lived in more walkable counties and/or counties with lower crime rates tended to walk significantly more and to have lower BMIs, even after all of the individual-level characteristics were controlled. The relationships of walkability and crime to diabetes and hypertension and ratings of health, the dependent variables that are further removed from ACES in the hypothesized causal chain, were not statistically significant.

The Interaction of Gender and Crime

Model 2 in Table 3 adds the interactions of crime with gender. As noted above, we expected that crime would affect females more than males, given women's greater fear of crime. While the interaction of crime and gender was statistically significant in only two of the five analyses, all interaction terms were in the predicted direction, and the coefficient associated with gender became statistically insignificant in all five analyses and substantially smaller or even reversed in direction. The one exception to this pattern involved physician-rated health. While the coefficient associated with gender became insignificant in that case, its size changed very little. In general, once we took into account the differential influence of high crime rates on women's and men's health, gender differences in walking, BMI, weight-related chronic conditions, and self-rated poor health were different than first appeared.

Table 4 further illustrates these results by showing the predicted values of each of the dependent variables for males and females in counties with low, medium, and high crime rates, assuming that people in these counties have scores on all other variables in the model that equal the average for the total population. The values for BMI and the ratings of poor health in Table 4 are expected values; values for walking and chronic conditions are the expected odds of walking a mile without stopping or having a weight-related chronic condition. The low crime rate value used in these calculations (3,433 crimes per 100,000 people) is that of Delaware County, Pennsylvania; the medium crime rate (7,614 crimes per 100,000 people) is that of Los Angeles County; and the high crime rate (12,311 per 100,000 people) is that of Dade County, Florida, from Table 1. Of course, these are not likely the real average values of the dependent variables among the residents of these counties, because their residents have different values for other variables in the model.[14]

Table 4 indicates that females had worse health on all of our measures: they less often had walked at least a mile in the previous month, they had, on average, higher BMIs, they more often had weight-related chronic conditions, and they were less likely to have ratings of good health, either from themselves or the physician examiner. Yet these differences were, with the exception of physician-rated health ratings, substantially smaller in areas with low crime rates than in areas with high crime rates. For instance, the gender difference in the odds of walking was over twice as great in high-crime areas as in low-crime areas. The gender differences in the predicted BMI, the odds of having a weight-related chronic condition, and in self-ratings of health were more than three times greater in high-crime areas than in low-crime areas. In short, as hypothesized, an environment with high rates of crime appears to be more detrimental to women's health than to men's, at least with respect to walking, obesity, the incidence of diabetes and hypertension, and respondents' ratings of their own health.

The results from Model 2 shown in Table 3 also illustrate the differential importance of walkable and crime-free environments for men and women. (To see this, calculate the t-ratios associated with the coefficients by dividing a coefficient by its associated standard error.) For both men

Table 4. Expected values of dependent variables by gender and three levels of crime.

	County crime rate		
	Low	Medium	High
Walking			
Males	1.10	1.01	0.92
Females	0.99	0.80	0.64
Male-female difference	0.11	0.21	0.28
Body mass index			
Males	26.47	26.39	26.30
Females	27.05	27.66	28.35
Male-female difference	−0.57	−1.27	−2.06
Diabetes and hypertension			
Males	0.33	0.32	0.30
Females	0.36	0.39	0.41
Male-female difference	−0.03	−0.07	−0.11
Self-rated health			
Males	3.29	3.32	3.36
Females	3.23	3.17	3.11
Male-female difference	0.07	0.15	0.25
Physician-rated health			
Males	3.94	3.90	3.86
Females	3.93	3.89	3.84
Male-female difference	0.01	0.01	0.02

Note: Values for walking and for diabetes and hypertension represent the odds that a male or female subject would walk a mile without stopping or have one of these weight-related chronic conditions if all other characteristics equaled the mean value for the sample. We used the following values for crime rates: low, 3,433 per 100,000 people; medium, 7,614 per 100,000 people; high,12,311 per 100,000 people.

and women, a walkable environment had a stronger influence than crime rates on both the measures of walking and physician-rated health. Similarly, for both men and women, crime rates had a stronger influence than walkability on weight-related chronic conditions. Yet, with respect to both BMI and self-ratings of health, the influence of a walkable environment was more important than a crime-free environment for men, while the opposite was true for women.

ACES and Lifelong Residents

It is possible that the effects of living in a safe and walkable community accumulate over time and would be most noticeable among lifelong residents.[15] We examined this possibility by repeating our analysis including only subjects who had lived in an area for their entire lives (n = 2,231). These analyses included all of the individual-level control variables in Table 3 (except time in residence), thus controlling for demographic factors that might also be related to residential stability. Table 5 summarizes the results of this analysis for Model 2, the model that includes the interaction of gender and crime, showing only the coefficients associated with gender, walkability, crime, and the interaction of crime with gender.

Results for walking were similar to those with the total sample, as were those for physician health ratings (except that the coefficient associated with gender was significant). The influence of our ACES variables, crime rates and walkability, on the other three dependent variables were, as expected, stronger among those who had lived in an area all their lives than among the general population, even though the analysis of the full sample controlled for the time subjects had lived in the county studied. The pattern of differences varied slightly from one dependent variable to another. For BMI, walkability was no longer significant, although the coefficient was in the expected direction (b = −0.039, p = 0.46). At the same time, the interaction of crime and gender was stronger among the lifelong residents than in the total sample ($b = 20.9 \times 10^{-5}$, p = 0.07), indicating that a high crime rate was more detrimental to BMI among women than among men. Stronger results for the lifelong residents also appeared in the analyses of weight-related chronic conditions and self-ratings of health. Specifically, among the lifelong residents of the sampled counties, those who lived in more walkable areas had fewer weight-related chronic conditions and rated their health significantly higher. The influence of the interaction of crime and gender on the presence of diabetes and hypertension was also much stronger among the lifelong residents than in the total sample.

Conclusions

The ACES literature suggests that individuals will be healthier if they live in communities that promote exercise and activity. Two key elements of such active environments are walkability and safety. Our results, based on a multilevel analysis of a large, national data set that incorporated strong individual level controls, provides some support for this perspective. We find that individuals who live in counties that are more walkable and have lower rates of crime tend to walk more and to have lower body mass indices than people in less walkable and more crime-prone areas, even when a wide variety of individual variables related to health are controlled. When the sample is restricted to life-

Table 5. Key results from hierarchical regression of dependent variables on individual and environmental variables, lifelong residents only.

	Walking		BMI		Diabetes or hypertension		Self-rated health		Phyician-rated health	
	Coeff.	*SE*	Coeff.	*SE*	Coeff.	*SE*	Coeff.	*SE*	Coeff.	*SE*
Gender (female)	−0.349	0.284	−0.510	0.890	−0.336	0.324	−0.034	0.138	−0.259	0.122*
Walkability	0.055	0.018**	−0.039	0.053	−0.035	0.020[a]	0.026	0.009**	0.022	0.027
Crime rate (10^{-5})	−4.000	2.900	−5.000	8.900	1.100	3.300	−2.000	1.500	−3.000	3.100
Crime/gender interaction (10^{-5})	0.870	3.700	20.900	11.400[a]	8.800	4.100*	−0.945	1.800	2.400	1.600

**$p < .01$; *$p < .05$; [a]$p < .10$

Note: All models include, but do not show, the same independent variables as Model 2 in Table 3, except for tenure of residence. Coefficients may be directly compared to those in Model 2 in Table 3.

long residents of an area, walkability and crime rates are also associated with having a weight-related chronic illness and lower self-ratings of health. In all of the analyses, the effect of high crime rates is substantially stronger for women than for men. When this interaction is taken into account, gender differences in frequency of walking, BMI, incidence of weight-related chronic conditions, and self-rated poor health disappear.

Our results provide some support for those who tout the benefits of Active Community Environments. Even when we included controls for individual characteristics strongly related to health, people who lived in areas that were more walkable and that had lower crime rates tended to walk more often and to have lower body mass indices. For the total sample, these environmental variables were not significantly related to respondents' rates of chronic diabetes or hypertension or to their own or physicians' ratings of their health, although the signs of the coefficients were in the expected direction. In other words, among adult residents of the sampled counties, our results support the first part of the causal chain posited by the ACES literature, but not the later parts of that chain.

It is possible that the stronger relationships of our environmental measures with walking and BMI reflect where they are located within the hypothesized ACES causal chain. Our results also suggest that environmental factors may have less influence on some health-related variables than others. For instance, Table 3 showed that the differences between counties' average rates of weight-related chronic conditions disappeared entirely as a result of controlling for individual differences in Model 1, and the county-level environmental variables were not a significant influence.

It is also possible, as noted above, that the full impact of community walkability and safety accumulates over time. While we included a control for length of residence in the area in our analyses of the total population, this may have been insufficient to fully account for the lifelong effect of these aspects of Active Community Environments. Our analysis of the subsample of residents who had lived in an area throughout their lives provides some support for this premise, for with this group the walkability and safety variables had a significant influence on both weight-related chronic conditions and respondents' ratings of their own health, variables at the end of the causal chain depicted in Figure 1.

We again emphasize that our results probably provide conservative estimates of the relationship of Active Community Environments to health. We included strong individual-level controls in our models. In addition, because our geographic unit of analysis was counties and single counties can include neighborhoods with widely varying characteristics, our results may indicate a lower bound to relationships that might be found with smaller units of analysis.

Our finding that gender differences in health-related variables decline markedly when the interaction of crime rates and gender is considered is, to our knowledge, unprecedented in the literature. A large proportion of health care costs are devoted to chronic conditions, many of which could be prevented or stabilized through exercise and better health, including weight control. At present, because women have higher body mass indices and higher rates of weight-related chronic illness, they account for a disproportionate amount of these expenditures. Our results illustrate the ways in which geographic variations in crime exacerbate this problem and suggest that promoting more crime-free environments might help reduce these costs.

Our finding that *both* walkable and safe environments influence exercise and weight is extremely important for practitioners. A growing literature focuses on the ways in which transportation planning and the creation of more walkable environments can promote better health (CDC, 2001; Litman, 2003; Pollard, 2003), yet our results suggest that such changes will be ineffective if planners do not simultaneously address neighborhood safety. If a neighborhood is walkable but unsafe, residents, and especially women, will be far less likely to walk extensively, and will be more likely to have higher BMIs.

Our results also indicate that social support is an important influence on walking and health ratings. Although we measured social support on the individual level, it can also be measured, and developed, on the community level. A growing literature shows planners how they can create neighborhoods that are walkable and safe, and that encourage supportive interactions (Carter, Carter, & Dannenberg, 2003; Meck, 2005). Our results suggest that we could have healthier communities if planners more often heeded these guidelines. Designing walkable communities is an important factor in promoting health, but it will probably not be sufficient (Best, Stokols, Green, Leischow, Holmes, & Buchholz, 2003; Handy, 2004). Incorporating crime-deterring elements into urban design appears to be equally important, especially for the health of women.

Further research could include analyses of the relationship of ACES to other health measures, and should also use smaller, more specific, geographic units of analysis, focusing more closely on the neighborhoods in which people live and work. Because our research focused only on urbanized areas, other studies should also focus on more rural environments. Future research should also include more precise measures of walking behavior than used for this study, especially measures that capture periodic episodes of walking that are theoretically more common in heavily gridded and compact settings. Finally, further research could explore the impact of neighborhoods on gender differences in health. Besides attempting to replicate our findings, it might examine how other ways in which we design neighborhoods differentially affect the well-being of men and women.

Overall, our results suggest that if planners are to develop communities that promote physical activity and better health, they should consider elements of both walkability and safety in their designs.

Notes

1. We attribute the different results we obtained for walking and obesity depending on whether MSAs or counties were the geographic unit of analysis to the fact that counties are smaller, and thus provide a more precise measure of the environment in which people live.

2. The very old were examined in their homes with a shorter battery.

3. Great care was taken to ensure that all measures collected were both reliable and valid. Details on the NHANES study may be obtained from the National Center for Health Statistics Web site (National Center for Health Statistics, 2005).

4. In preliminary analyses, we also employed measures of access to parks, using data from the Trust for Public Lands. These measures were generally not available at the county level and were also not available for a number of areas within our sample. In addition, they tended to be relatively highly correlated with the measure of walkability, which was available for all units in the sample.

5. To test the validity of this measure and to ensure that our measure of walkability indicated street connectivity rather than simple density, we calculated correlations between these measures and the factor scores related to density and street connectivity that Ewing et al. (2003) developed in their analysis of sprawl at the metropolitan scale. We retained only those measures that had higher correlations with the street factor score than with the density factor score. This is important because, as we explained earlier, our previous work found a positive relationship between walkability and health, but a negative relationship between density and health (Kelly-Schwartz et al., 2004).

6. We used linear regression to estimate missing values for some independent variables. We needed such estimates only for the measures of income, time in the area, education, and social support. Income data were missing for 12% of the cases, and data for the other variables were missing for 2% or fewer. In rare instances we recoded these predicted values because they fell outside the theoretical range. In those cases we used the closest possible value within the range.

7. The composite includes measures of talking on the phone with family, friends, and neighbors; getting together with friends and relatives; visiting with neighbors; attending religious services; and attending meetings of clubs or organizations. The standardized alpha was 0.39. All of these elements are positively correlated to varying degrees. The highest correlations were between talking on the phone and visiting friends and relatives ($r = .21$), between visiting friends and relatives and visiting neighbors ($r = .29$), and between attending religious services and attending meetings of clubs or organizations ($r = .23$). We chose to combine the items into a single scale even though the alpha is relatively low because all the items are positively correlated, all relate to the concept we are concerned with, and the somewhat lower correlations (e.g., between attending religious services and talking on the phone) could be expected theoretically.

8. As an extra check on our results, we added the percentage of fat in the subject's diet to the models. This variable was obtained in clinical interviews conducted during the medical examination and was available for only a portion of the sample. No results reported here changed when diet was added to the model. Because including this variable reduced the sample size substantially, we omitted it from what we report in this article.

9. For the analysis of walking, $n = 9{,}229$; for BMI, $n = 8{,}230$; for weight-related chronic disease, $n = 9{,}137$; for self-ratings of health, $n = 9{,}245$; and for physicians' ratings of health, $n = 7{,}790$.

10. A person is commonly considered overweight if they have a BMI between 25 and 29.9, and obese if they have a BMI greater than or equal to 30.

11. If counties are used as the unit of analysis, $r = 0.18$, $df = 34$, $p = .30$.

12. Rho, the intraclass correlation coefficient, is calculated by dividing the covariance estimate associated with the intercept-only model (the between-class variation) by the sum of the residual and between-class variation. For example, for walking, rho = 0.086/(0.086 + 0.997) = .079. The value of rho for weight-related chronic disease was .035, and the value of rho for self-ratings of health was .018.

13. For example, to calculate the PRE measure for Model 1 for walking, PRE = (.086 – .078)/.086 = .09.
14. Estimated values in Table 4 were calculated by multiplying the coefficients in Table 3 by the average value for the total group for the associated variable (shown in Table 2) and then summing the scores. As explained in the text, we used three different estimates of crime rates. We made separate calculations for males and females, but used the same average values for all predictors. We calculated the odds of walking and having a weight-related chronic condition by exponentiating the results.
15. We are grateful to an anonymous reviewer for suggesting this additional analysis.

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