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Original Contribution

Mobility Disability and the Urban Built Environment

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Research on the effects of the built environment in the pathway from impairment to disability has been largely absent. Using data from the Chicago Community Adult Health Study (2001–2003), the authors examined the effect of built environment characteristics on mobility disability among adults aged 45 or more years ($n = 1{,}195$) according to their level of lower extremity physical impairment. Built environment characteristics were assessed by using systematic social observation to independently rate street and sidewalk quality in the block surrounding each respondent's residence in the city of Chicago (Illinois). Using multinomial logistic regression, the authors found that street conditions had no effect on outdoor mobility among adults with only mild or no physical impairment. However, among adults with more severe impairment in neuromuscular and movement-related functions, the difference in the odd ratios for reporting severe mobility disability was over four times greater when at least one street was in fair or poor condition (characterized by cracks, potholes, or broken curbs). When all streets were in good condition, the odds of reporting mobility disability were attenuated in those with lower extremity impairment. If street quality could be improved, even somewhat, for those adults at greatest risk for disability in outdoor mobility, the disablement process could be slowed or even reversed.

aging; lower extremity; mobility limitation; social environment; urban health

Abbreviations: GIS, geographic information systems; ICF, *International Classification of Functioning, Disability, and Health*; SSO, systematic social observation.

Although the prevalence of disability has been declining since the 1990s (1–4), disability continues to be a major health and social issue (5–8). Disability is generally defined as a substantial limitation in life activities (9) and is most prevalent in later life (10). Yet, becoming disabled is not a de facto response to aging or to the onset or progression of health problems. Disability is a dynamic process reflecting an interaction of forces at the cellular, psychological, social, and environmental levels. As pointed out by the sociologist Saad Nagi, one of the early pioneers in this field, ''disability is the expression of a physical or a mental limitation in a social context'' (11, p. 103). In this paper, we focus on the built environment and examine how physical limitations are more likely to lead to mobility disability in different urban contexts.

Models of disability (11–13) have increasingly incorporated contingency in the pathway between impairment and disability by explicitly recognizing the role of contextual factors. The *International Classification of Functioning, Disability, and Health* (ICF) is one such model that is part of the family of international classifications developed by the World Health Organization (12). The ICF model addresses functioning at three levels: 1) the body (mental, physiologic, or anatomic structures or functions), 2) the person (performance or accomplishment of an activity), and 3) society (participation in life situations) (14). Negative

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functioning at these three levels is represented by impairments, activity limitations (or disability), and participation restrictions. For example, an individual with arthritis may experience pain (impairments in body functions and structures) that leads to severe difficulty in walking (mobility disability), which may restrict his or her involvement in life situations, such as meeting with close friends (participation restriction).

The ICF model also incorporates environmental factors, including natural and human-made environments, which modify the consequences of impairments for disability or participation. In this research, we investigate the modifying effect of the *urban built environment* in the pathway between impairment and disability. Specifically, we examine how middle-aged and older adults with equivalent levels of physical impairment experience divergent levels of mobility disability across different built environments.

The built environment is generally defined as all buildings, spaces, and products that are created or modified by people (15, 16), and a growing body of research has been investigating the effect of the built environment on health outcomes. Pedestrian-oriented designs (e.g., continuous, barrier-free sidewalks, four-way stop signals, adequate street lighting, and pedestrian amenities) have been shown to be positively associated with physical activity (17–20) and negatively related to obesity (21). Poor street conditions, heavy traffic, and excessive noise have been shown to be associated with the onset of physical impairment 1–3 years later (22, 23). Curb cuts (depressed curbs that act as ramps in sidewalks), smooth pavement, and barrier-free sidewalks (24) are some of the environmental characteristics that can easily prevent mobility disability and promote independence in adults at greatest risk, such as those with underlying weakness in movement-related functions and balance. Yet, relatively little work has examined the effect of the built environment on mobility disability, particularly across those with different levels of physical impairment (25).

In this research, we examine the effect of the built environment on mobility disability across different levels of physical impairment by specifically testing for an interaction between street/sidewalk quality and lower extremity physical impairment. We hypothesize that less accessible built environments are likely to increase mobility disability (decrease independence) among those with more severe physical impairment but, following earlier work (25), we hypothesize that the built environment will have little or no effect among those with mild or no impairment.

Studies examining the relation between the built environment and health have typically relied on secondary data sources to obtain objective characteristics of the built environment through proxy measures, such as population density (25), land use diversity (17, 25), or block size (18). Linked to individual records at the level of the census tract or block group, these are simple aggregates of individual or land use characteristics within areas, not direct measures of the built environment per se. They are also constrained by administrative definitions of "neighborhoods" (e.g., census tracts), which are often too large to meaningfully capture the physical environments faced by individuals when they walk outside their front door. As a result, administrative data sources likely introduce nontrivial heterogeneity in built environment measures.

Directly constructed measures of the built environment are arguably better, and researchers are increasingly using automated resources, such as geographic information systems (GIS), to characterize traffic volume (26), the number of hills (27), and the availability of recreational facilities (28) within person-centered neighborhoods. However, information on these built environment characteristics is not always publicly available or cataloged in GIS format (29).

Direct observation of built environment features by using an audit instrument allows researchers to capture many of the relevant structural characteristics that are currently not available with GIS or administrative data. While driving or walking through small-area respondent-centered neighborhoods, researchers observe and document built environment features using a standardized instrument (30). In this study, we use built environment data that were collected by using a direct observational method known as systematic social observation (SSO) (31–33), whereby survey raters systematically rate each respondent's neighborhood block at the time the survey interview is conducted. Using SSO data from the city of Chicago, we examined the effect of block-level built environment characteristics on mobility disability among adults aged 45 or more years who vary in their level of lower extremity physical impairment.

MATERIALS AND METHODS

Data

The data source for this research is the Chicago Community Adult Health Study (2001–2003), conducted through face-to-face interviews with a multistage probability sample of 3,105 adults aged 18 or more years, living in the city of Chicago, and stratified into 343 neighborhood clusters previously defined by the Project on Human Development in Chicago Neighborhoods (34). A response rate of 72 percent is one of the highest in a major American city in recent decades (35). For our purposes, we focus on the characteristics of residential blocks (roughly one respondent per block) and restrict our analyses to 1,195 adults aged 45 or more years (39 percent of the sample; age range: 45–92 years) in order to focus on the age group most at risk for health-related disability (36).

Built environment measures

Using the SSO method (32), trained survey raters blind to respondent characteristics collected observational data for each block. We use the raters' assessment of the condition of the streets and sidewalks in the block surrounding each respondent's residential address under the premise that broken curbs and streets in disrepair are likely to be associated with more obstacles (e.g., rubble, uneven pavement) for pedestrians navigating along sidewalks and crossing streets. For each block, raters documented the condition of streets (typically four streets surrounding each block) according to the following response scale: good (no cracks, potholes, broken curbs); fair (some cracks, potholes, broken curbs); and very poor (many cracks, potholes, broken curbs) (interrater agreement = 0.803.) For our analyses, we use a dummy variable to contrast blocks where any street was in fair or very poor condition with blocks in which all streets were in good condition.

In order to better isolate the effects of street quality on mobility disability, we also control for other aspects of neighborhood conditions, which may exist concurrently with deteriorating street conditions, that may also operate as physical or psychosocial barriers for mobility among persons with lower extremity impairments. A measure of neighborhood *social and physical disorder* (32) is derived from observations of the block faces surrounding each block with respect to the presence of graffiti, garbage, litter or broken glass, cigarette butts, empty beer/liquor bottles, abandoned cars, and drug-related paraphernalia or condoms on sidewalks or in street gutters. We also include a measure of *residential security* based on the presence of neighborhood crime watch signs and security warning signs in the block faces surrounding each block. For each construct, the presence of the items on block faces was used to create multilevel item response models that weight infrequent items more heavily than less frequent items (32). Because an item's presence is dichotomous, the overall measures are expressed on a logit scale (ranging from negative to positive), with a high score indicating a high presence of disorder or residential security, respectively. Convergent validity of the scales has been demonstrated when compared against census measures of concentrated poverty as well as crime reports (32). The reliabilities for the security and disorder scales are 0.720 and 0.935, respectively. Interrater agreement ranges from 0.675 to 0.974 for the neighborhood disorder items and from 0.753 to 0.831 for the neighborhood security items.

Individual measures

Mobility disability is captured by the respondent's self-reported level of difficulty walking 2–3 blocks by himself/herself, recorded on a three-point scale (no difficulty, some difficulty, a lot of difficulty or unable to do without help). *Lower extremity physical impairments* were assessed on a similar three-point scale on the basis of the level of difficulty performing six activities requiring lower extremity strength and balance. Respondents were asked how much difficulty (none, some, a lot, coded 0, 1, 2, respectively) they have 1) stooping/kneeling, 2) getting up from a stooping/kneeling position, 3) standing up from a chair, 4) pushing a large object, 5) doing heavy housework, and 6) carrying a heavy bag of groceries. Scores across the six items were averaged (alpha reliability = 0.893), and a dummy indicator for severe impairment was created by contrasting mean scores greater than 1 with those less than or equal to 1 (representing mild or no impairment).

TABLE 1. Descriptive statistics for 1,195 adults aged 45 or more years, Chicago Community Adult Health Study, 2001–2003

	Weighted mean (SD*) or %
Mobility disability (difficulty walking 2–3 blocks)	
No difficulty	80.76
Some difficulty	9.29
A lot of difficulty	9.95
Lower extremity impairment	
No/mild impairment	81.92
Severe impairment	18.08
Sociodemographic characteristics	
Age, years	
45–59	54.10
60–69	22.57
≥70	23.33
Gender	
Male	43.93
Race/ethnicity	
White	50.39
Black	37.31
Hispanic	7.03
Other race/ethnicity	5.27
Marital status	
Married	50.31
Separated/divorced	22.16
Widowed	15.80
Never married	11.73
Lives alone	24.31
Socioeconomic position	
Less than high school education	30.19
High school education	45.68
College education	24.13
Economic hardship	52.21
Comorbid health status	
No. of chronic health problems, mean (SD)	1.99 (1.79)
Current smoker	20.80
Body mass index, mean (SD)	29.12 (6.49)
Cognitive impairment score, mean (SD)	0.61 (0.93)
Built environment	
Any street in fair/poor condition	63.62
Physical disorder, mean (SD)	−2.86 (1.69)
Residential security, mean (SD)	−0.75 (0.86)

* SD, standard deviation.

Individual controls

Through social selection processes over the life course, individuals at greater risk for disability and physical impairments (e.g., women, minorities, lower educated and older

TABLE 2. Multinomial logistic regression models for mobility disability category 2 (some disability)† among 1,195 adults aged 45 or more years, Chicago Community Adult Health Study, 2001–2003

Parameter	Model A			Model B		
	Estimate	Odds ratio	95% confidence interval	Estimate	Odds ratio	95% confidence interval
Intercept	−5.101***			−5.060***		
Sociodemographics						
Age, years						
60–69	0.738*	2.09	1.15, 3.81	0.732*	2.08	1.14, 3.80
≥70	1.496***	4.46	2.39, 8.32	1.505***	4.51	2.42, 8.41
Gender						
Male	0.531*	1.70	1.05, 2.77	0.532*	1.70	1.05, 2.77
Race/ethnicity						
Black	0.539‡	1.71	0.99, 2.95	0.535‡	1.71	0.99, 2.94
Hispanic/other	0.223	1.25	0.54, 2.89	0.242	1.27	0.55, 2.96
Marital status						
Separated/divorced	−0.382	0.68	0.35, 1.31	−0.375	0.69	0.36,1.32
Widowed	−0.392	0.68	0.31, 1.46	−0.398	0.67	0.31, 1.46
Never married	0.246	1.28	0.56, 2.90	0.265	1.30	0.57, 2.97
Lives alone	−0.208	0.81	0.44, 1.50	−0.235	0.79	0.42, 1.47
Socioeconomic position						
Less than high school education	−0.271	0.76	0.38, 1.54	−0.270	0.76	0.38, 1.54
High school education	−0.331	0.72	0.38, 1.35	−0.331	0.72	0.38, 1.36
Economic hardship	0.504*	1.66	1.03, 2.66	0.500*	1.65	1.02, 2.65
Health status						
Health conditions	0.378***	1.46	1.27, 1.68	0.378***	1.46	1.27, 1.68
Cognitive impairment	−0.042	0.96	0.75, 1.22	−0.036	0.97	0.75, 1.24
Current smoker	0.850**	2.34	1.37, 4.01	0.857**	2.36	1.37, 4.05
Body mass index	0.002	1.00	0.97, 1.04	0.001	1.00	0.97, 1.04
Lower body impairment	2.308***	10.06	5.81, 17.41	2.186***	8.90	3.84, 20.67
Built environment						
Neighborhood disorder	0.082	1.09	0.93, 1.27	0.084	1.09	0.93, 1.28
Neighborhood security	−0.170	0.84	0.63, 1.13	−0.166	0.85	0.63, 1.14
Any street in fair/poor condition	0.542*	1.72	1.02, 2.91	0.513	1.67	0.85, 3.29
Fair/poor streets × lower body impairment				0.276	1.32	0.47, 3.70

* $p < 0.05$; **$p < 0.01$; ***$p < 0.001$.
† No disability is the reference group.
‡ $p < 0.10$.

adults, and those with multiple health problems) may be more likely to live in neighborhoods characterized by less accessible built environments. Analyses therefore control for key sociodemographic and health factors that aim to minimize selection bias in the results. *Sociodemographic factors* capture underlying behaviors and resources that are associated with physical impairments and disability, including age, gender, marital status, race/ethnicity, and socioeconomic position. Age is represented by two dummy variables contrasting older adults (ages 60–69 years) and very old adults (age 70 or more years) with middle-aged adults (ages 45–59 years). Male gender is a dummy variable that equals 1 for males and 0 for females. Marital status is captured by three dummy variables contrasting divorced/separated, widowed, and never married with married respondents. We also use a dummy variable to indicate whether or not the respondent lives alone. Race/ethnicity is categorized according to three dummy variables contrasting Black, Hispanic, and other race/ethnicity (including Native American, Asian, or Pacific Islander) with Whites. Socioeconomic position is assessed through the respondent's level of education, classified as less than high school, high school diploma, or college degree. Because of a high proportion of missing data (20 percent) on annual household

TABLE 3. Multinomial logistic regression models for mobility disability category 3 (severe disability)† among 1,195 adults aged 45 or more years, Chicago Community Adult Health Study, 2001–2003

Parameter	Model A			Model B		
	Estimate	Odds ratio	95% confidence interval	Estimate	Odds ratio	95% confidence interval
Intercept	−9.294***			−8.631***		
Sociodemographics						
Age, years						
60–69	0.758‡	2.13	0.96, 4.75	0.743‡	2.10	0.94, 4.72
≥70	2.304***	10.02	4.40, 22.81	2.389***	10.90	4.73, 25.13
Gender						
Male	0.574‡	1.78	0.95, 3.33	0.620‡	1.86	0.98, 3.52
Race/ethnicity						
Black	1.520***	4.57	2.26, 9.25	1.513***	4.54	2.23, 9.23
Hispanic/other	0.441	1.55	0.50, 4.86	0.530	1.70	0.53, 5.41
Marital status						
Separated/divorced	−0.837‡	0.43	0.18, 1.05	−0.758‡	0.47	0.19, 1.15
Widowed	0.017	1.02	0.42, 2.46	0.029	1.03	0.42, 2.51
Never married	0.459	1.58	0.53, 4.70	0.570	1.77	0.59, 5.30
Lives alone	0.174	1.19	0.58, 2.44	0.075	1.08	0.52, 2.24
Socioeconomic position						
Less than high school education	0.617	1.85	0.69, 5.00	0.619	1.86	0.68, 5.06
High school education	0.024	1.02	0.39, 2.67	0.007	1.01	0.38, 2.65
Economic hardship	1.210***	3.35	1.81, 6.20	1.155***	3.17	1.71, 5.88
Health status						
Health conditions	0.608***	1.84	1.54, 2.19	0.614***	1.85	1.58, 2.20
Cognitive impairment	0.009	1.01	0.76, 1.34	0.004	1.00	0.76, 1.33
Current smoker	0.653‡	1.92	0.93, 3.96	0.670‡	1.95	0.94, 4.05
Body mass index	−0.010	0.99	0.95, 1.03	−0.012	0.99	0.95, 1.03
Lower body impairment	3.862***	47.55	23.43, 96.52	2.903***	18.23	6.62, 50.16
Built environment						
Neighborhood disorder	−0.157	0.85	0.70, 1.04	−0.156	0.86	0.70, 1.05
Neighborhood security	−0.071	0.93	0.65, 1.33	−0.056	0.95	0.66, 1.35
Any street in fair/poor condition	0.786*	2.20	1.15, 4.19	−0.149	0.86	0.33, 2.27
Fair/poor streets × lower body impairment				1.509**	4.52	1.29, 15.84

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.
† No disability is the reference group.
‡ $p < 0.10$.

income, we use a subjective indicator of financial hardship. On the basis of a question about difficulty paying bills (scored on a five-point scale ranging from no difficulty making monthly payments on family bills to extreme difficulty), we create a dummy variable for economic hardship (coded 1 for those reporting any difficulty paying bills and coded 0 for those reporting no difficulty). (Sensitivity analyses using the income variable with a dummy indicator for missing values yielded results similar to those using the economic hardship indicator.) We control for *comorbid health status* using an index of self-reported health problems that sums the number of medically diagnosed health conditions (e.g., heart attack, stroke, arthritis, diabetes, peripheral artery disease). Cognitive impairment is assessed with five items from the Short Portable Mental Status Questionnaire (37). We also account for current cigarette smoking and body mass index (weight (kg)/(height (m)^2) to capture preclinical declines in health that are likely to have adverse consequences for impairment and mobility.

Statistical analyses

We use multinomial logistic regression to examine the effects of individual and built environment characteristics on three levels of outdoor mobility disability (no difficulty, some difficulty, severe difficulty walking 2–3 blocks). All models are estimated in SAS, version 9.1.3, software (SAS Institute, Inc., Cary, North Carolina) and weighted by post-stratification sample weights to account for the sampling design, as well as differential coverage and nonresponse across neighborhood clusters. The weighted sample matches the 2000 Census population estimates for the city of Chicago in terms of age, race/ethnicity, and gender.

RESULTS

Descriptive statistics

Table 1 reports the descriptive characteristics of the study sample. Roughly half of the respondents are in the midlife stage of adulthood (ages 45–59 years), while the other half are in the later stages of the life course (ages 60 or more years). The sample is well balanced in terms of gender, racial/ethnic minority groups, and marital status. Of these adults, over one quarter have less than a high school education, and over half report some degree of economic hardship. On average, over 60 percent of the residential blocks have at least one street that is in fair or very poor condition. Signs of physical disorder are relatively low (scale range: from −7.7 to 2.3 on the logit scale), and average residential security falls in the mid range of the logit scale (range: from −2.5 to 1.7).

The vast majority of respondents report no difficulty with mobility, while 20 percent report at least some difficulty walking 2–3 blocks. Similarly, most respondents experience little difficulty in tasks requiring lower extremity strength and balance, yet 18 percent report more than some difficulty on average. Roughly one in five adults is a current smoker, and respondents have an average of almost two comorbid health problems (range: 0–9). Cognitive impairment is generally low (mean score: <1 on a five-point scale), and respondents have an average body mass index of approximately 29.

Multinomial logistic regression

Tables 2 and 3 report the results from the multinomial logistic regression analyses for the three categories of mobility disability (no disability is the reference group). The tables present the logistic regression coefficients and odds ratios for the independent variables as they relate to some difficulty walking 2–3 blocks (table 2) and a lot of difficulty walking 2–3 blocks (table 3). Not surprisingly, older age, a greater number of health problems, and cigarette smoking increase the odds of mobility disability. Males and African Americans are also more likely to experience mobility disability compared with females and Caucasians. (Because of small numbers, Hispanics and other race/ethnic groups were collapsed in the analyses.) Mobility disability is not associated with education after adjustment for covariates, but economic hardship is associated with an increased odds of reporting difficulty walking 2–3 blocks. As expected, lower extremity physical impairments are strongly associated with mobility disability. For those with severe impairment, the log odds of reporting some difficulty walking 2–3 blocks increase by 2.31 (table 2, model A), for an adjusted odds ratio of 10.06 (95 percent confidence interval: 5.81, 17.41). The log odds of reporting a lot of difficulty walking 2–3 blocks (table 3, model A) increase by 3.86 for those with severe impairment, for an adjusted odds ratio of 47.55 (95 percent confidence interval: 23.43, 96.52).

FIGURE 1. Odds ratios of risk for severe mobility disability by street conditions and lower extremity physical impairment among 1,195 adults aged 45 or more years, Chicago Community Adult Health Study, 2001–2003. "Street conditions" refer to the four streets surrounding the residential block where each respondent lives. Predicted values for the intercept are calculated for an African-American male, aged 70 years or more, with a high school education, never married, living alone, with three underlying chronic health problems, a current smoker, and reporting economic hardship.

The presence of any street in fair or very poor condition increases the odds of mobility disability, all other things being equal (tables 2 and 3, model A), but this represents an averaged effect across people with a range of physical impairments. In tables 2 and 3, model B adds the interaction term to assess how the relation between street quality and disability varies according to the degree of lower extremity impairment among individuals. Among adults with only mild or no impairment, street quality has no statistically significant effect on severe mobility disability (table 3). However, for those with more severe impairment, the odds of reporting severe mobility disability are greater for those living on a block where streets are in fair or very poor condition. Street quality plays a similar modifying role in the relation between physical impairment and the odds of some mobility disability (table 2, model B), although it is not statistically significant.

The easiest way to understand this interaction is to express the differences in the log odds ratios for disability as a function of impairments and street quality, compared with some reference group, such as an adult with mild or no physical impairment living on a block where all streets are in good condition. The log odds ratio for severe disability for an adult living on the same street who has severe lower extremity impairment is 2.903 plus some constant representing the values of the covariates. Similar calculations for distinct levels of physical impairment and street quality can be made, and we plot the predicted odds ratios in figure 1.

With all other factors held constant, the difference in the log odds ratios for severe mobility disability as a result of underlying lower extremity impairment is 1.509 greater (the regression coefficient for the interaction) when the streets surrounding the residential block are in less than optimal condition. Exponentiating this coefficient yields an odds ratio of 4.52 (95 percent confidence interval: 1.29, 15.84), indicating that the difference in the odds ratios for reporting a lot of difficulty walking 2–3 blocks in those with and without severe impairment is over four times greater among those living on streets that are in poor compared with good condition. This relation persists even after adjustment for neighborhood social disorder and residential security.

DISCUSSION

The struggle to maintain independence in the face of declining health and function is a dynamic process that includes interpersonal, social, and environmental resources (11–14). In this work, we focused on the moderating role of the urban built environment. Using direct independent observation of the built environment and multinomial logistic regression, we found that street and sidewalk conditions had no effect on mobility disability among adults with only mild or no physical impairment. However, among adults with more severe impairment of neuromuscular and movement-related functions, the difference in the odd ratios for reporting a lot of difficulty walking 2–3 blocks was over four times greater for those living in neighborhoods where streets were in very poor or only fair condition. These results indicate that the built environment has a greater effect on mobility disability for those with existing lower extremity impairment. For adults who live in areas where all streets around their block are in good condition, the impact of lower extremity impairment on severe mobility disability is considerably attenuated. Thus, physical impairments are not necessarily catastrophic for mobility, and the negative consequences of severe restrictions in lower extremity strength and balance can be minimized when adults live in environments with fewer obstacles.

This study is limited to a geographically defined sample in an urban setting. Measures of impairment and disability were based on self-report. Ideally, a measure of street quality should capture more detail in order to be able to identify the specific characteristics that facilitate mobility. Cross-sectional data also preclude an understanding of the prospective association between neighborhood design and mobility disability decline or onset. However, our capacity to examine the impact of the built environment on mobility disability was considerably enhanced by using independent observational measures. Moreover, our focus on disability has allowed us to examine the effect of the built environment where it is likely to have the most proximate impact, that is, among those at risk for disability because of increased physical impairment. Although the built environment effects on impairment have lagged effects operating over time (22, 23), sidewalk repair or the provision of pedestrian amenities can reduce mobility disability almost immediately for someone who was previously unable to navigate outside independently because of impaired gait or balance.

If street quality could be improved, even somewhat, for those adults at greatest risk for disability, the disablement process could be reversed or attenuated (13). The subsequent consequences for participation in life situations are nontrivial if adults with physical impairments are better able to engage in employment, recreation, and social interaction; to access health-care facilities; or simply to go shopping for their daily needs. A better understanding of the role of these barriers in disability onset and progression can ostensibly postpone and, perhaps, even prevent disability in groups at high risk.

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