

The Role of the Built Environment in the Disablement Process

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The Disablement Process model explicates the transition from health conditions to disability and specifically emphasizes the role of intervening factors that speed up or slow down the pathway between pathology and disability.

We used hierarchical Poisson regression analyses with data on older adults from central North Carolina to examine the role of the built environment as a modifying factor in the pathway between lower extremity functional limitations and activities of daily living. We found that, despite declining physical function, older adults report greater independence in instrumental activities when they live in environments with more land-use diversity.

Independence in self-care activities is modified by housing density, in part through the effect of substandard and inadequate housing. (*Am J Public Health*. 2005;95:1933–1939. doi:10.2105/AJPH.2004.054494)

SEVERAL CONCEPTUAL

models explicate the transition from health conditions to disability.^{1–3} The Disablement Process model³ specifically emphasizes the *intervening factors* that “speed up and slow down” the pathway between pathology and disability. The main pathway in the model starts with *pathology* (e.g., disease, injury), which in turn influences *impairments* (e.g., dysfunctions in specific body systems), which lead to *functional limitations* (restrictions in basic physical and mental actions), which ultimately influence the ability to perform everyday activities, or *disability*.³ In particular, this sociomedical model calls attention to the modifying effects of social, psychological, and environmental factors that transform disablement into a dynamic process.

We focused on the role of the built environment as a modifying factor in the latter pathway between functional limitations and 2 domains of disability: self-care activities of daily living (ADL) and instrumental activities of daily living (IADL). Verbrugge and Jette³ dichotomized modifying factors into intraindividual (e.g., psychosocial attributes, coping styles, activity accommodations) and extraindividual (e.g., rehabilitation, external supports, and the built, physical, and social environment). Although a number of studies have examined the effect of intraindividual characteristics on disability outcomes,^{4,5} little research has considered the role of extraindividual forces in the disablement process. We specifically investigated the impact of the local built environment as

it exacerbates or narrows the gap between individual function and an activity’s demand.³

There is a considerable body of work in the transportation literature on the effect of the built environment on travel choices, emphasizing the influence of the 3 Ds: density, diversity, and design.⁶ Compact neighborhoods, measured either through housing or population density, are associated with fewer vehicle trips and more nonmotorized travel.^{6–8} Land-use diversity, where retail, office, and commercial buildings co-exist with residential housing, promotes more in-neighborhood walking and cycling trips.^{8–10} Pedestrian-oriented designs that encourage more nonautomobile travel include the continuity and quality of sidewalks, the accessibility of public transit stops, frequency of 4-way-crossing signals, and the availability of pedestrian amenities.^{6,11}

More recently, public health researchers have been giving attention to the effect of the 3 Ds of the built environment on health outcomes by investigating how characteristics such as urban sprawl, mixed-use neighborhoods, and pedestrian-oriented designs influence physical activity,^{12–15} obesity,¹⁶ traffic-related injuries and fatalities,^{17–19} as well as operating indirectly on health through their impact on social cohesion and social capital.^{12,20} The more proximate built environment, captured by substandard and inadequate housing, has also been found to have health consequences.^{21,22} Housing units with insufficient heat generate cold, damp con-

ditions, and mold growth, which are associated with respiratory and gastrointestinal problems.^{23,24} A reliance on combustion home-heating fuels releases toxic chemicals into the indoor air.²⁴ Porches and steps in disrepair increase the fear of falling and prevent older adults from safely leaving their homes.²⁵ Largely because of higher poverty rates, deteriorating and substandard housing are disproportionately located in rural and inner-city areas.^{24,26}

The purpose of this article is to examine the role of the local built environment in the pathway between functional limitations and disability in a sample of older Americans. We used a sample of older adults because disability is most prevalent in later life²⁷ and because older adults tend to rely more heavily on their local environments in day-to-day activities.^{28,29} We also focused on the effect of *lower extremity* functional limitations (i.e., mobility, lower extremity strength, and balance) because these have been shown to be predictive of disability^{5,30,31} and most vulnerable to neighborhood conditions.³²

Consistent with the transportation literature, we hypothesized that housing density and land-use diversity will promote more accessible pedestrian- and public transit-friendly environments (i.e., less car dependent),⁶ characterized by continuous, safe sidewalks, street lighting, and accessible bus stops, which facilitate local shopping and nonautomobile commuting options. We anticipate that, for

older adults with functional limitations, such environments will support independence in instrumental activities that require trips outside the home, especially when they are no longer able to drive. For example, older adults living in less dense or less diverse environments may experience more difficulty traveling independently to access shops, pharmacies, and banks, which in turn can prevent independence in activities such as meal preparation (if it is difficult to access a grocery store for easy-to-prepare meals), taking medications (obtaining refills from the pharmacy), and managing money (paying bills at the bank). Environments that deter walkability may also constrain independence through increased crime fears if there are fewer persons out on the streets in day-to-day life.

We also hypothesize that decreasing housing density, as a measure of more rural areas, will be associated with increased difficulty with self-care activities. Because rural areas have higher rates of inadequate and substandard housing,²⁶ older adults living in rural areas may encounter more obstacles for independent self-care inside the home. For example, older adults with lower extremity limitations who live in a rural home without indoor plumbing may report more difficulty in self-care activities such as bathing and using the toilet.

METHODS

Data

Data were drawn from the first wave (1986) of the Duke University site of the Established Populations for Epidemiological Studies of the Elderly (EPESE)

project,³³ a multiwave study conducted over 10 years. In-person interviews were conducted with a stratified random sample of 4162 community dwelling adults aged 65 years and older residing in 5 contiguous counties in central North Carolina. The data collection and processing protocol were approved by the institutional review board at Duke University.

The Duke EPESE sample was divided equally into rural and semiurban residents. Roughly half of the sample resided in Durham County, a semiurban area incorporating the city of Durham with an average of 369.23 housing units per square mile.³⁴ The other half of the sample resided across 4 rural counties with an average housing density of 61.78 units per m².³⁴ Access to public transportation in these rural counties is highly constrained. Although the city of Durham has a public bus system with discounted senior fares, older residents claim that the system is inaccessible because of widely dispersed bus stops with inadequate patron facilities.²⁵ Marked differences also exist in the housing characteristics across the rural and semiurban counties. County-level data on housing units from the 1990 census³⁴ indicate that in the 4 rural counties, 24.9% of the housing units were mobile homes or trailers (compared with 1.6% in the semiurban Durham County); 3.76% lacked adequate kitchen facilities (vs 86% in Durham County); and 5.5% lacked complete plumbing facilities (compared with 0.6% in Durham County).

We obtained data on the local built environment by coding each respondent's address to the 1990 census tract, which was linked to the US Decennial Census in 1990. Census tracts typically have be-

tween 1500 and 8000 people, with an average population size of 4000. Tract boundaries are defined with local input and are designed to be relatively homogeneous with respect to population characteristics, economic status, and living conditions.

Measures

Disability is a count of the number of activities the respondent is unable to do without help. Five items from the Katz ADL scale³⁵ tapped disability in basic self-care activities: (1) bathing, (2) dressing, (3) eating, (4) transferring, and (5) using the toilet. Seven questions from the Older Americans Resources and Services instrument³⁶ probed independence in more complex IADL: (1) using the telephone, including looking up numbers and dialing, (2) driving a car or traveling alone on buses or taxis, (3) shopping for groceries or clothes, (4) preparing meals, (5) doing light housework, (6) taking medications (in the right doses at the right time), (7) managing money, including writing checks and paying bills. An index was created for each measure by summing the number of tasks the respondent reported that he/she is unable to perform without help. α reliability is 0.840 for self-care ADL and 0.891 for IADL.

The measure of *lower extremity functional limitations* consists of 3 items that assess severe difficulty in lower extremity strength and balance:^{1,3,32} (1) climbing a flight of stairs, (2) walking half a mile, (3) stooping, crouching, or kneeling. Responses were coded 1 if the participant reported either a lot of difficulty or was unable to do the task without help. Scores were summed (α reliability is .822).

We used 2 measures from the 1990 census to capture *density and diversity* in the built environment.³⁴ There are no measures of neighborhood design for these census tracts (e.g., quality and continuity of sidewalks, street lighting), so we can only speculate about their effects in our results. *Housing density* is a ratio of the number of housing units per square mile in each census tract. *Land-use diversity* is assessed by the proportion of workers in the tract who commute to work within 5 min. This short commuting time reflects the greater probability of commercial, institutional, or industrial buildings within a short distance from residential housing, indicating more mixed-use neighborhoods.¹⁰

We also controlled for 5 *predisposing factors* that capture longstanding behaviors or attributes that increase the risk of functional limitations and disabilities³ and could also select individuals into more challenging built environments. *Age* was measured in years. *Female* was a dummy variable that is coded 1 for females and 0 for males. *Race* was coded 1 for African Americans and 0 for Whites and others. Current *marital status* was dichotomized into married and unmarried. Individual socioeconomic status was measured by completed *education* in years. We also examined a control for *residential stability* (number of years at current address) to account for the duration of exposure to built environments.

Mediators

The *housing quality* of each respondent's home was assessed through 2 questions: "Does your house/apartment/mobile home

have: (1) a complete bathroom including a tub or shower, a toilet, and a sink? (2) hot and cold running water?" For each question, negative responses were coded 1, and affirmative responses were coded 0. Respondents also reported on their perceptions of *neighborhood crime* according to an ordinal 5 category measure ranging from "very safe" (coded 1) to "not safe at all" (coded 5) from crime. Finally, *car-dependent environments* were captured through a census measure of the proportion of workers in the census tract who commute to work by car (as opposed to public transit or walking).

Statistical Analyses

We used hierarchical nonlinear models to examine the modifying effect of decreasing density and diversity at the tract level on the relationship between individual functional limitations and disability. Because the disability variables are a count of the number of activities the respondent is unable to perform without help, we used hierarchical Poisson regression to model the logarithm of the expected number of dependent activities.³⁷ This is an extension of the basic hierarchical linear model with a log link function and specifies that the data are conditionally distributed according to the Poisson distribution, given the random effects. An examination of the residuals from an unconditional model for both the ADL and IADL measures confirmed that the errors follow a Poisson distribution. Analyses were performed with the NLMIXED procedure in SAS (SAS Institute, Cary, NC), and the built environment variables were grand mean centered with a standard deviation of 1.³⁸ Statistical

significance was assessed with a 2-tailed α of 0.05.

Following the unconditional model, analyses progressed by examining the separate effects of lower extremity functional limitations and built environment characteristics on the disability measures. We then used first-order interaction terms to examine how the effect of functional limitations on disability is modified by the built environment variables. Final models added controls and hypothesized mediators to explain the modifying effect of the built environment on disability.

RESULTS

Descriptive Statistics

A total of 4154 individuals had complete disability data and were included in our analyses.

Respondents lived in a total of 95 census tracts, resulting in an average of 43.73 persons per tract. Table 1 summarizes the characteristics of the individuals in our sample and their surrounding environments. These older adults were generally long-term residents in their local neighborhoods, residing at their current address for an average of 22 years. According to the 1990 census, these tracts are not highly dense, reflecting the rural and small city characteristics of the Central Piedmont region of North Carolina, and they are characterized as car dependent (with a high proportion of car commuters) with little mixed-land use.

Because we hypothesized that disability, housing, and built environment characteristics would

vary by housing density, the summary statistics in Table 1 are also displayed separately for high- and low-density areas. Average ADL and IADL disability are slightly higher for older adults living in low-density tracts, which tend to be more car dependent with a greater proportion of respondents living in homes with an inadequate bathroom. Somewhat paradoxically, higher-density tracts have less diversity in land use, but residents report more concerns about crime.

Random Variance in Disability

Results from unconditional models indicate that there is significant variation in disability between tracts ($T_{00} = .276, P < .0001$ for IADL; $T_{00} = .229, P < .0001$ for ADL), suggesting that

TABLE 1—Descriptive Statistics for Individuals and Their Local Environments: Duke Established Populations for Epidemiological Studies of the Elderly Project, 1986

	Overall mean (SD)	Mean in high-density ^a areas (SD)	Mean in low-density ^a areas (SD)
Individual			
Age, y	73.55 (6.72)	73.77 (6.75)	73.38 (6.79)
Female	0.65 (0.48)	0.69 (0.46)	0.63 (0.48)
African American	0.54 (0.50)	0.71 (0.45)	0.52 (0.50)
Married	0.38 (0.49)	0.26 (0.44)	0.42 (0.49)
Education, y	8.51 (4.09)	7.90 (3.92)	8.11 (3.89)
ADL disability	0.35 (0.98)	0.32 (0.86)	0.38 (1.04)
IADL disability	0.94 (1.79)	0.82 (1.66)	1.05 (1.88)
Lower extremity limitations	0.84 (1.07)	0.83 (1.07)	0.89 (1.08)
Perceptions of crime	1.80 (0.86)	2.17 (1.01)	1.64 (0.78)
Residential stability, years at address	22.43 (17.46)	19.57 (15.38)	24.64 (19.04)
Housing			
Incomplete bathroom	0.07 (0.26)	0.01 (0.11)	0.12 (0.33)
No hot and cold running water	0.06 (0.24)	0.01 (0.09)	0.11 (0.32)
Built environment			
Commute by car, %	92.46 (6.20)	82.48 (4.52)	94.54 (2.71)
Land-use diversity, % commute in 5 minutes	3.34 (2.05)	2.07 (1.35)	3.94 (2.14)
Housing density, housing units/mile ²	276.97 (226.41)	876.26 (174.54)	23.34 (21.52)

Note. ADL = self-care activities of daily living; IADL = instrumental activities of daily living. N = 4154 persons in 95 census tracts.
^aHigh- and low-density cut points were calculated at 1 standard deviation above and below the mean number of housing units per square mile, respectively.

TABLE 2—Effects of Lower Extremity Functional Limitations and Built Environment Characteristics on Disability in Older Adults: Results From Hierarchical Poisson Regression Models

	Functional Limitations	Environment Characteristics	Functional Limitations× Environment Characteristics
Results for ADL disability			
Fixed effects			
Functional limitations	0.978***		0.984***
Decreasing housing density		0.053	-0.181*
Functional limitations × decreasing housing density			0.106**
Variance components			
Intercept	0.285**	0.223**	0.238*
Functional limitations	0.056**		0.038*
Results for IADL disability			
Fixed effects			
Functional limitations	0.804***		0.794***
Decreasing land-use diversity		-0.019	-0.026
Functional limitations × decreasing land-use diversity			0.050*
Variance components			
Intercept	0.251***	0.251***	0.251***
Functional limitations	0.030**		0.028**

Note. ADL = self-care activities of daily living; IADL = instrumental activities of daily living.
* $P < .05$; ** $P < .01$; *** $P < .001$ (2-tailed tests).

there are differences in disability across built environments.

Effect of Lower Extremity Functional Limitations

Lower extremity functional limitations are positively associated with both ADL and IADL disability (first column of Table 2). Because the Poisson model is an exponential model ($E[y/x] = e^{\beta x}$), we can interpret the coefficients by taking the antilog of the parameter estimates.³⁹ Thus, a 1 unit increase in the number of functional limitations increases the expected number of IADL disabilities by a factor of 2.23 ($= e^{0.804}$). Alternatively, we can express an effect in terms of the percent change in the expected number of disabilities ($100(e^{\beta x} - 1)$). Hence, for every additional functional limitation, the expected number of ADL disabilities increases by 166%. Significant variation also exists in the effect of

functional limitations on disability across tracts (variance components for functional limitations in Table 2), and the built environment variables may account for some of this variation.

Effect of Housing Density

We found no direct effect of housing density on either ADL or IADL disability (Table 2), but housing density modified the effect of lower extremity functional limitations on ADL disability. Older adults with functional limitations living in lower-density tracts reported more self-care disability than those in higher-density tracts. This interaction is plotted in Figure 1a at 4 levels of functional limitations. For older adults with a score of 3 on the functional limitations scale, a 1 standard deviation decrease in density increases the expected number of ADL disabilities by a factor of 1.147. Statistical tests of

the model parameters indicate that housing density has no modifying effect when the functional limitation score is 1 or 2, but for older adults with no functional limitations, living in more rural environments is associated with less ADL disability. For these unimpaired adults, a 1 standard deviation decrease in housing density reduces the expected number of ADL disabilities by a factor of 0.834.

Effect of Land-Use Diversity

Contrary to our expectations, we found no modifying effect of housing density for IADL disability, but we did find a significant interaction between functional limitations and decreasing land-use diversity (bottom panel of Table 2). Older adults with functional limitations living in low mixed-use tracts reported more difficulty with instrumental activities. This interaction is plotted in

Figure 1b. For those with a score of 3 on the functional limitations measure, a 1 standard deviation decrease in land-use diversity increases the expected number of instrumental disabilities by a factor of 1.130. Land-use diversity has no significant modifying effect for those with a functional limitation score below 3.

Adding Controls and Mediators

The base models in Table 3 (first column) display the exponentiated effects of the built environment on disability at the significant levels of functional limitations. The second column adds the controls. For older adults with severe functional limitations (score = 3), the control variables account for some of the effect of the built environment on disability (explaining 1% to 1.6% of the effect on ADL and IADL disability, respectively), but significant contextual effects remain. However, for unimpaired adults, the apparent protective effect of decreasing density for ADL disability is rendered spurious because of common individual level characteristics that are associated both with greater self-care independence and rural residence. Residential stability had no effect on either ADL or IADL disability and was excluded from these models.

The final 2 columns of Table 3 add mediators to attempt to explain the effects of the built environment on disability. In the top panel, we added the housing quality variables as mediators of rural environments on ADL disability. Both an incomplete bathroom and the absence of hot and cold running water are significantly associated with ADL disability, but the effect is opposite to what we expected.

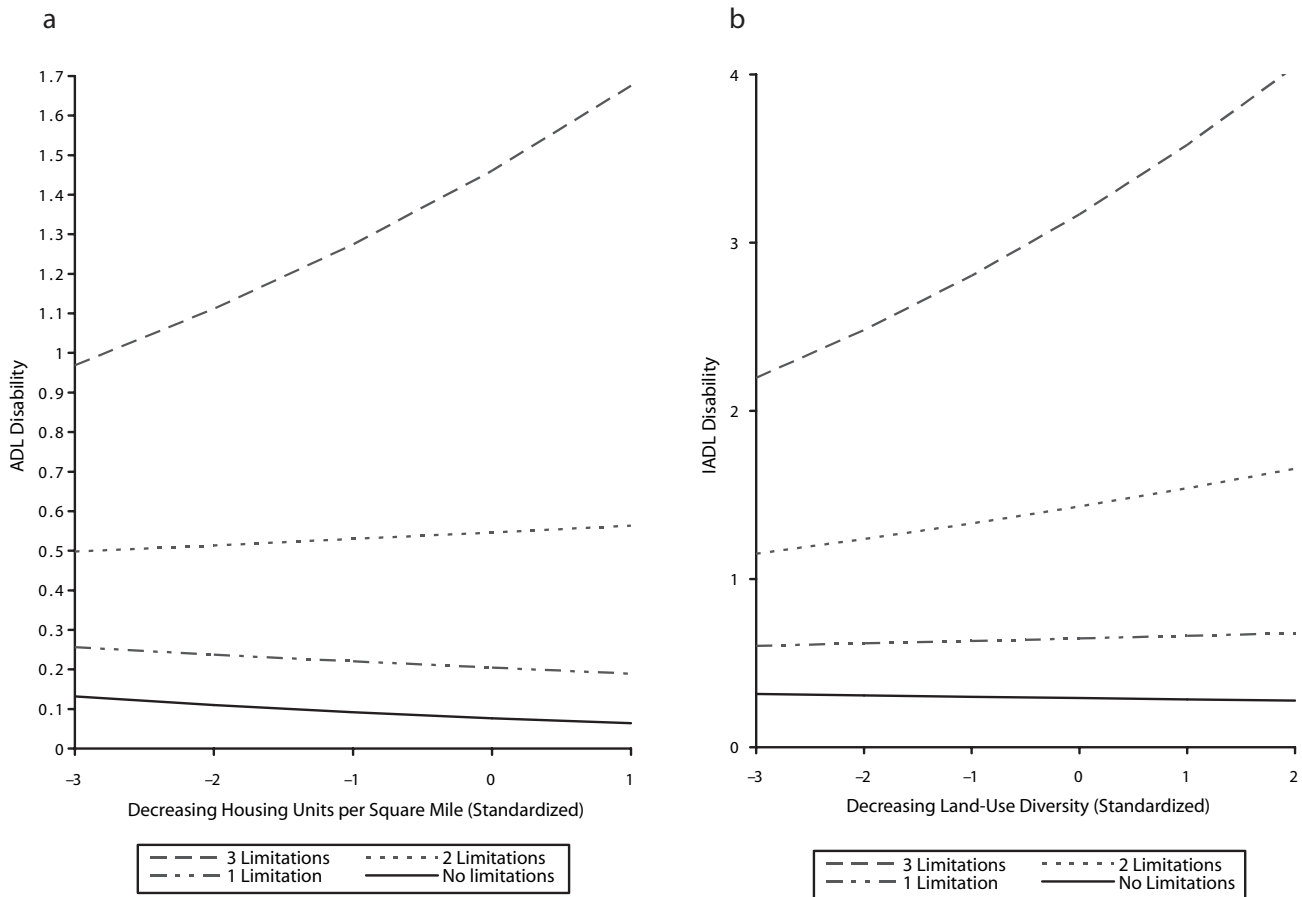


FIGURE 1—Effect of housing density and land-use diversity on (a) ADL and (b) IADL disability by lower extremity functional limitations.

For older adults without a complete bathroom, the expected number of ADL disabilities is actually *reduced* by a factor of 0.658, and for those without running water, ADL disabilities are reduced by a factor of 0.698. As a result, the effect of decreasing density on ADL disability increases in both the final 2 models, indicating that the housing quality variables act as intervening suppressors.

In the bottom panel of Table 3, the final 2 columns add mediators to explain the effect of land-use diversity on IADL disability. As expected, declining land-use diversity is associated with greater car dependence at

the tract level. For each standard deviation increase in the proportion of car commuters, the expected number of IADL disabilities increases by a factor of 1.08. This overall positive effect mediates a small part (around .5%) of the adjusted positive effect of decreasing land-use diversity on instrumental disability for older adults with severe functional limitations. Although we hypothesized that the adverse effect of decreasing diversity would be explained by perceptions of crime, the neighborhood safety variable was not significantly related to IADL disability (final column of Table 3).

DISCUSSION

While the surrounding environment is emphasized in the model of the Disablement Process, it is rarely tested explicitly. We tested the effects of the broader context in which the Disablement Process takes place and pointed to ways in which independence is constrained by the characteristics of the surrounding built environment. We found that with declining physical function, older adults experience greater dependence in daily instrumental activities when they live in an environment characterized by limited land-use mixtures. Consistent

with the transportation literature, decreased diversity in local environments precipitates car dependence, which likely has spillover effects on neighborhood design, including a lack of continuous, safe sidewalks, and accessible public transit. In the Disablement Process, these structural barriers operate as “exacerbators”³ that increase the gap between an individual’s functional capacity and their ability to carry out desired activities, calling attention to the importance of the “person–environment fit.”^{40–42} These results have implications for neighborhood design and town planning since, as Verbrugge and Jette emphasize,

TABLE 3—Effects of the Built Environment on the Pathway Between Lower Extremity Functional Limitations and Disability in Older Adults: Results From Hierarchical Poisson Regression Models With Controls and Mediators

	Base Model	+ Controls	+ Mediators	
Results for ADL disability				
Effect of decreasing housing density:				
for adults with 3 functional limitations	1.147*	1.135*	1.159**	1.151**
for adults with 0 functional limitations	-0.834*	-0.825	-0.841	-0.839
Control variables				
Age, y		0.026***	0.025***	0.025***
Female		-0.021	-0.026	-0.022
African American		0.127*	0.152*	0.145*
Education, y		0.015	0.012	0.012
Married		0.175*	0.160*	0.165*
Mediating variables				
Incomplete bathroom			-0.418**	
No hot/cold running water				-0.360**
Variance components				
Intercept	0.238*	0.303**	0.302**	0.303**
Functional limitations	0.038*	0.033*	0.031*	0.032*
Results for IADL disability				
Effect of decreasing land-use diversity:				
for adults with 3 functional limitations	1.130*	1.112*	1.106*	1.111*
Control variables				
Age, y		0.046***	0.046***	0.041***
Female		-0.272***	-0.270***	-0.286***
African American		0.162***	0.172***	0.102*
Education, y		-0.038***	-0.037***	-0.040***
Married		-0.054	-0.058	-0.036
Mediating variables				
Commute by car (in census tract), %			0.079*	
Perceptions of crime				0.027
Variance components				
Intercept	0.251***	0.184***	0.195***	0.173***
Functional limitations	0.028**	0.019*	0.018*	0.013

Note. ADL = self-care activities of daily living; IADL = instrumental activities of daily living. **P* < .05; ***P* < .01; ****P* < .001 (2-tailed tests).

“disability can be diminished swiftly and markedly if the physical and mental demands of a given task are reduced.”^{3(p9)} If planners and developers incorporated diversity and accessibility in areas with a high proportion of older adults, disability could ostensibly be reduced in later life, with potential implications for expenditures in health and long-term care.

One of the advantages of the data used in this study was the relatively large proportion of nonurban subjects, allowing us to explore contingencies in disability across a continuum of rural and semiurban environments. We hypothesized that compact neighborhoods would represent more accessible pedestrian- and public transit-friendly environments, which would be associ-

ated with greater IADL independence. However, we found no effects of housing density on IADL. While declining density has typically been used to measure urban sprawl and car-dependent neighborhoods,^{16,19} the data in our study do not include metropolitan areas. Declining density in our case reflects rural versus semiurban living, which *was* associated with self-

care disability. Although we hypothesized that substandard housing conditions in rural areas would explain this association, we found that inadequate plumbing was actually associated with greater self-care independence. Perhaps this is because individuals rely on less physically demanding sponge baths for activities such as bathing when their home has an incomplete bathroom.

Our findings are limited by the lack of more extensive variables capturing the built environment at both the structural and individual level. Ideally, we would like to have had detailed measures on neighborhood design to explicitly test our theories about land-use diversity and IADL independence. Qualitative data on the subjective perceptions of respondents themselves would also help to clarify the mechanisms by which density and diversity facilitate independence. Nevertheless, our article emphasizes the importance of considering the role of the built environment in the process of becoming disabled. ■

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Contributors

P. Clarke conceptualized and conducted the analyses and wrote the article. L.K. George contributed to the conceptualization and interpretation of the analyses and assisted with the editing of the article.

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Human Participant Protection

The larger study on which these secondary data analyses were based was approved by the institutional review board at Duke University.

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