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Residential Modifications and Decline in Physical Function Among Community-Dwelling Older Adults

Sze Y. Liu, MPH,^{1,2} and Kate L. Lapane, PhD²

Purpose: The purpose of this study is to quantify the effect of residential modification on decreasing risk of physical function decline in 2 years. **Design:** Cohort study using propensity scores method to control for baseline differences between individuals with residential modifications and those without residential modifications. **Participants:** Participants ($N = 9,447$) were from the Second Longitudinal Study on Aging, a nationally representative sample of the civilian noninstitutionalized population, aged 70 years and older in the United States at the time of baseline interview in 1994–1995. **Methods:** Participants self-reported residential modifications at baseline (e.g., railings, bathroom modifications). Decline in physical functioning was measured by comparing self-reported activities of daily living at baseline and at 2-year follow-up. **Results:** Compared with individuals without baseline modifications, a higher proportion of those with baseline modifications were aged 85 years and older (16% vs. 10%), used special aides (36% vs. 14%), and lived alone (40% vs. 31%). Using a weighted propensity score method, we found a modest decrease in risk of decline at Wave 2 for those with baseline modifications (risk difference = 3.1%). Respondents with a baseline residential modification were less likely to experience subsequent decline in functional ability (adjusted odds ratio = 0.88, 95% confidence interval = 0.79–0.97) after adjusting for quintile of propensity score in a survey-weighted regression model. **Implications:** Baseline modifications may be associated with reduced risk of decline among a nationally representative sample of

older community-dwelling adults. Widespread adoption of residential modifications may reduce the overall population estimates of decline.

Key Words: Disability, Residential modifications, Propensity score models

Introduction

Residential modifications and personal assistive devices prevent disability by reducing task demand (Verbrugge & Sevak, 2002). Although use of personal assistive devices has been associated with lower self-reports of disability (Agree, 1999; Verbrugge, Rennert, & Madans, 1997), the effect of residential modifications alone has not been well studied (Newman, 2003). Previous studies found an association between residential modifications and decreased likelihood of entering a nursing home (Newman, Struyk, Wright, & Rice, 1990), decreased need for bathing personal care among frail older adults (Gitlin, Miller, & Boyd, 1999), and less functional decline as part of a comprehensive intervention (Mann, Ottenbacher, Fraas, Tomita, & Granger, 1999). One study reported that users of architectural modifications were more independent in activities of daily living (ADLs) than nonusers (Fox, 1995). Another study found that the presence of home accommodations decreased the odds of having unpaid help among a nationally representative sample of adults who use wheelchairs (Allen, Resnick, & Roy, 2006). These results suggest that environmental modifications in a residential setting can potentially influence an individual's ability to perform basic tasks necessary for daily functioning. In this manner, widespread adoption of residential modifications may theoretically lead to significant decrease in prevalence of

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later life disability. If home modifications or assistive technologies could reduce the amount of time spent living with disability by 25%, disability prevalence would decline from 20% to 16% (Freedman et al., 2006). To date, there is little empirical evidence examining the effects of residential modifications on an individual's functional ability.

According to the disablement process model, disability is a limitation in performing defined roles and tasks within a given sociocultural and physical environment. The disablement model not only describes a pathway where impairments can lead to functional limitations and disability but also recognizes the dynamic and nonlinear aspects of this process; impairment does not necessarily lead to disability (Verbrugge & Jette, 1994). Some studies estimated that up to 25%–30% of older adults with a disability eventually recover (Gill, Robison, & Tinetti, 1997; Katz, 1983). A wide variety of factors can potentially influence the disablement process. These factors can be broadly characterized as intraindividual (e.g., behavioral, psychological) and extraindividual (e.g., physical and social environment) characteristics.

A large body of empirical research has examined individual and environmental characteristics associated with disability. The most commonly reported intraindividual characteristics associated with disability are older age, marital status, household income, race/ethnicity, and education (Branch & Ku, 1989; Crimmins, Hayward, & Saito, 1996; Freedman, Martin, & Schoeni, 2004; Mendes de Leon et al., 1997; Mor, Wilcox, Rakowski, & Hiris, 1994; Tabbarah, Silverstein, & Seeman, 2000). Overall health status and chronic health conditions such as arthritis and depression are also strongly associated with decline in functional ability (Crimmins & Saito, 1993; Freedman & Martin, 2000; Struck et al., 1999; Tabbarah et al.). Healthy behaviors that are protective against decline include regular exercise and participation in social activity (Struck et al., 1999).

Studies that attempt to identify risk factors that predict longitudinal changes in the disablement process have been less successful. One study using the disablement process identified several key physical, cognitive, and psychosocial characteristics that predicted longitudinal changes in disability within the next 2–4 years (Fauth, Zarit, Malmberg, & Johannson, 2007). However, another study argued that most of the variability in disability trajectories among older adults cannot be explained by individual sociodemographic charac-

teristics alone (Li, 2005). For these reasons, it is important to place the biological process, whereby physical limitation progresses to functional disability in the larger extraindividual context where it occurs.

Building on the disablement model, the Health Environmental Integration (HEI) framework includes the built and natural physical environment as determinants of disability (Stineman, 2001). The HEI framework explicitly acknowledges the role of natural and man-made environment in facilitating or reversing the disability pathway. ADL difficulties arise when there is a mismatch between physical limitations and physical environment. Biological impairment limits an individual's physical function. Environmental factors set the threshold of when limitations become a disability (Stineman, 2001; Stineman, Ross, Masilin, & Gray, 2007). Therefore, residential modifications can potentially prevent disability from occurring, stop or slow down the process of further disablement, or, theoretically, even reverse the disablement process. For example, an older adult who has difficulty getting in and out of a bathtub may be considered disabled. The same individual may not be considered disabled if the addition of a grab bar allowed him to perform this ADL without any difficulty.

Using the HEI model as our framework, the purpose of this study is to quantify the effect of having a residential modification on subsequent risk of decline in functional ability in a nationally representative sample of adults aged 70 years and older in the United States. The decision to have household modifications is driven by a number of factors including level of awareness, affordability, and beliefs of beneficiality (Kutty, 1999; Pynoos, 1993). The presence of household modifications is associated with individual's characteristics such as age and current disability status (Tabbarah et al., 2000; Uppal, 2005; Yuen & Carter, 2006). Our analysis takes into account the substantial and systematic differences between individuals with home modifications and those without home modifications. The ability of residential modifications to predict risk of decline in functional ability will probably be most evident over a short time frame. We hypothesized that the presence of home modifications at baseline will be associated with lower risk of decline in functional ability 2 years later. Decline in functional ability is associated with higher medical costs, risk for hospitalization, institutionalization, and mortality (Inouye et al., 1998; Mor et al., 1994; Narrain et al., 1988). Identifying

risk factors that predict functional decline, which can be addressed through changes in policy (i.e., increased insurance reimbursement for specific home modifications), will be instrumental in formulating effective public health interventions.

Methods

This study used data from two waves of the Second Longitudinal Study on Aging (LSOA II). The study sample is representative of the civilian non-institutionalized population aged 70 years and older in the United States at the time of baseline interview. Baseline information was collected in face-to-face interviews from 1994 to 1995. Follow-up telephone interviews were conducted in 1997–1998 ($N = 9,447$). Although respondents must be community dwelling at baseline, follow-up interviews were administered to all sample persons regardless of subsequent residence type. Therefore, sample persons who moved to an institutional setting were still eligible for follow-up interviews. Proxy respondents completed the survey if they were incapable of carrying out the follow-up interview. Study design for LSOA II is similar to that for the first Longitudinal Study on Aging (LSOA), previously described in detail (Kovar & Fitti, 1987). LSOA II surveyed individuals about their sociodemographic characteristics, health behaviors and attitudes, preexisting illness, health care utilization, and social and environmental support. The survey weights provided in the publicly available data are based on the 1995 population estimates from the Census Bureau and accounts for the complex multistage probability design (Centers for Disease Control and Prevention, 2002). Approval from the institutional review board was exempt because this study used publicly available anonymous data.

Definition of the Residential Modification

The main determinant of interest was residential modification. Although conceptually, we considered the entire time between baseline and follow-up to be the relevant etiologic period, LSOA only inquired about residential modifications at baseline. Due to the lack of information at follow-up, we assumed that all respondents with a baseline home modification were continuously exposed throughout the 2 years of the study. Residential modifications were evaluated on the basis of responses to the following specific questions: “Do you

have ramps or street-level entrance, railings, automatic/easy doors, bathroom modifications, kitchen modifications, elevator or lift, alerting devices, and other special features?” Respondents who answered the following: “needs feature; no or don’t know if has,” “refused; no or don’t know,” or “not ascertained; no or don’t know if has,” to all the above-mentioned modifications were considered unexposed. LSOA data-coding schema restricted our ability to disentangle these responses further.

Definition of the Outcome Variable—Decline in Functional Ability

The outcome of interest is decline in functional ability over a 2-year period. LSOA II includes the same questions about difficulty with basic ADLs in the baseline and follow-up surveys, which allows us to evaluate the progression in functional decline. ADL measures independence of personal care (Verbrugge & Jette, 1994), with proven reliability, validity, sensitivity, and clinical relevance (Katz, Ford, Moskowitz, Jackson, & Jaffe, 1963). Respondents self-reported difficulties with bathing or showering, dressing, eating, getting in and out of bed, walking, and toileting. Baseline disability levels were classified according to the number of ADLs that the participant had difficulty with: none (0 ADL), moderate (1–2 ADLs), and severe (3 or more ADLs). Follow-up disability levels were classified as none (0 ADL), moderate (1–2 ADLs), severe (3 or more ADLs), and dead. A binary outcome variable, decline in functional ability (yes vs. no), was created based on the reported baseline and follow-up disability level. We considered respondents to have experienced decline in functional ability if they died or if they reported a higher disability level at follow-up compared with baseline (e.g., participant reported no disability at baseline and moderate disability level at follow-up). We considered respondents not to have experienced decline in functional ability if they were in the same group or in a group with lower disability level at follow-up compared with baseline (e.g., participant was classified as moderate disability level at baseline and follow-up). There was a small proportion of persons with unknown disability level (answered “don’t know,” “refused,” or “missing” to all questions about disability) at baseline ($n = 20$) or at follow-up ($n = 66$). For the purposes of this analysis, we considered the unknown participants as having experienced decline at follow-up. This conservative

assumption would lead to an underestimation of our measure of effect.

Potential Confounders—Other Covariates

We considered factors strongly associated with risk for decline in functional ability and plausibly associated with residential modifications as potential confounders. Based on previous literature, we included the following covariates in our analysis: age, sex, marital status, household income, education, race/ethnicity, years living in current residence, regular exercise, and participation in social activity. We included preexisting conditions strongly associated with decline in functional ability—whether the respondent was frequently depressed and frequently confused and had arthritis, broken hip, cancer, diabetes, heart disease, hypertension, other heart disease, osteoporosis, stroke of cerebrovascular accident (CVA), trouble seeing even with corrective lenses, number of lower body limitations, number of upper body limitations, and overall health (Crimmins & Saito, 1993; Freedman & Martin, 2000; Struck et al., 1999; Tabbarah et al., 2000). Because many modifications rely on appropriate architectural and housing features that vary geographically, we included city size and geographic region of residence as potential confounders. Replacement forms of help are potentially strong confounders (Verbrugge & Sevak, 2002), so we included use of personal assistance (i.e., homemaker services, planning to move to receive services, living arrangement, and type of residence) and equipment assistance (i.e., uses special aides).

Data Analysis

The main measure of interest was the risk difference. We estimated a crude risk difference by subtracting the proportion with decline among those with baseline residential modifications from the proportion with decline among those without baseline residential modifications. The crude risk difference used the final sampling weights in the publicly available data to account for the core LSOA II sampling design. We also used propensity score stratification models to estimate the risk difference after accounting for identified potential confounders. Propensity score methods permit the estimate of causal effects from nonexperimental study designs (Rubin, 1997). The two-step method allows for adjustment of baseline differences in those with and without residential modifications.

In the first step, a propensity score is developed for each participant, reflecting the likelihood that a participant will have a residential modification based on the covariate information. Essentially, the propensity score is a summary measure that controls for multiple potential confounders simultaneously. This score is calculated using a nonparametric logistic regression model. We included 32 sociodemographic, health, behavioral, service utilization, and geographical characteristics strongly associated with decline or baseline modification in our propensity score model (Branch & Ku, 1989; Crimmins & Saito, 1993; Mendes de Leon et al., 1997; Tabbarah et al., 2000). Area under the curve (0.70) indicated sufficient overlap in the distribution of the propensity scores for those with and without residential modifications. In the second step, respondents were divided into five strata of equal sizes based on their propensity scores. We evaluated the extent to which balance of the distribution of potential confounders for having residential modifications was similar within each strata using graphs and tables. We estimated risk difference within each quintile and also estimated the overall effect as a weighted average. We calculated the 95% confidence intervals (CIs) using the standard Wald method for binomial proportions. We used an indirect poststratification adjustment to the final survey weights to estimate an overall treatment effect representative of the population (Zanutto, 2006; Zanutto, Lu, & Hornik, 2005). Finally, we conducted additional analysis using the propensity score quintile as a covariate in a logistic regression model (Hahs-Vaughn & Onweuegbuzie, 2006). In this regression model, the propensity score quintile serves as a summary variable of available confounders with Quintile 1 as the reference category:

$$\text{Ln} \frac{P(\text{Decline} = 1)}{1 - P(\text{Decline} = 1)} = \beta_0 + \beta_1 \text{Environmental Adaptation} + \beta_2 \text{Quintile 2} + \beta_3 \text{Quintile 3} + \beta_4 \text{Quintile 4} + \beta_5 \text{Quintile 5}.$$

This regression model estimates the average of the individual odds ratio (OR) for sample persons with baseline environmental adaptation compared with those without environmental adaptation after adjusting for the probability of having residential modification. We used the `proc surveylogistic` command, which allowed us to directly specify the cluster and strata and include the survey weights.

All analyses were performed using SAS, Version 9.1 (SAS Institute, Inc., Cary, NC).

Results

Baseline Characteristics

Approximately 19% of all LSOA II respondents had one residential modification, and an additional 19% had multiple residential modifications. The most commonly reported modifications were the presence of railings, bath modifications, and street-level ramps. The least commonly reported modifications were the presence of an elevator, any type of kitchen modification, and other unspecified special feature (Figure 1). A higher proportion of those with baseline modifications compared with those without baseline modifications had specific health conditions such as arthritis (63% vs. 53%) and hypertension (50% vs. 41%). In addition, a higher proportion of those with baseline modifications reported concurrent use of special aides (36% vs. 14%) and older age (proportion 85 years and older was 16% vs. 10%). By contrast, a lower proportion of those with baseline modifications did not have lower body limitations (35% vs. 52%) and reported being in excellent or very good health (33% vs. 40%; Table 1).

Figure 2 demonstrates the extent to which the propensity score model increased the comparability between those with and without baseline residential modifications within each quintile for four characteristics with the greatest level of initial imbalance. Balance between the two groups within each quintile indicates that we have adjusted for that specific confounder. For example, Panel A shows that overall, 36% with residential modifications used special aides versus 14% of those without residential modifications. However, analyses stratified by propensity score quintile revealed balance within each quintile (e.g., Quintile 5: 84% with residential modifications vs. 88% without residential modifications). Respondents in Quintile 1 have the lowest probability of having a residential modification, whereas those in Quintile 5 have the highest probability of having a residential modification at baseline.

Table 2 shows the estimates of the effect of residential modifications on risk of decline in functional ability in 2 years. The proportion of participants with baseline modifications varied greatly according to quintile, ranging from 19% in the lowest quintile to 67% in the highest quintile. There was essentially no difference between the average

proportion of persons with decline among those with and without baseline residential modifications in the unadjusted risk difference (44.1% vs. 43.7%). Within each propensity score quintile, presence of residential modifications at baseline was associated with a reduction in risk of physical decline in 2 years (range in risk difference = 2%–5%; Table 2). The quintile-specific risk differences are an estimate of the average treatment effect for that subpopulation. The overall survey-weighted effect size of 3.1% indicates a modest difference in risk of decline (43.9% vs. 47%).

There was no association between a baseline home modification and decline in functional ability in the unadjusted logistic regression model (OR = 1.02, 95% CI = 0.93–1.19; Table 3). However, after adjusting for quintile of propensity score, we found that sample persons with baseline residential modification were less likely to experience subsequent decline in functional ability (adjusted OR = 0.88, 95% CI = 0.79–0.97; Table 3). In addition, after adjusting for the presence of residential modification, sample persons in propensity score Quintiles 4 and 5 were more likely to have experienced decline in physical function at follow-up compared with those in propensity score Quintile 1.

Discussion

Disability among elderly adults has decreased by 1% a year in the past decades (Cutler, 2001; Freedman et al., 2004). Disentangling the extent to which these trends are reflective of improvements in underlying health or reflective of the increasing popularity of environmental modifications has been hampered by a gap in the literature. The unique strength of this study is its use of a survey-weighted propensity score to estimate causal effects using a nationally representative sample of older adults in the United States. In the absence of such control for such substantial confounding, the beneficial effects of residential modifications would likely have been obscured. Our results suggest that having residential modifications may be associated with a modest reduction in risk of decline among older community-dwelling adults.

A better understanding of the factors that can prevent functional decline among elderly persons is warranted. Despite declines in disability trends, the aging U.S. population (Freedman et al., 2004) and the reality of the economics associated with disability among elderly adults suggest the need for

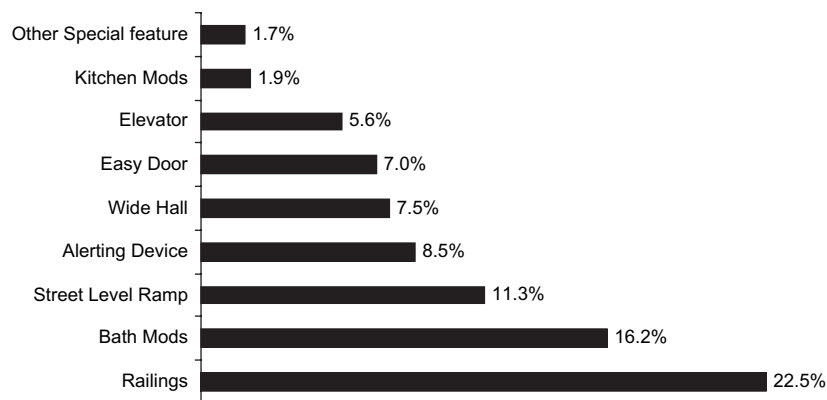


Figure 1. Description of residential modifications at baseline. Proportion of community-dwelling adults aged 70 years and older with various types of residential modifications. Analysis permits multiple residential modifications. Estimates are representative of the older adult population in the United States, 1994–1995.

effective strategies for prevention. In addition, earlier reports suggest a possible synergistic interaction between personal assistive devices and residential modifications, where use of personal assistive devices should be accompanied by environmental modifications to maximize benefits of reducing task difficulty (Agree, 1999; Hoenig, Taylor, & Sloan, 2003). Our results support the general idea raised by others that environmental modifications may have independently contributed to recent decreases in the overall prevalence of disability among the elderly adults in the United States (Cutler, 2001).

According to our analysis, approximately 38% of the elderly population in the United States had at least one modification in their place of residence in 1994–1995, with the proportion that had any one specific type of environmental modification varying greatly. This is consistent with previous published reports (Naik & Gill, 2005; Newman, 2003; Tabbarah et al., 2000). According to national estimates from the Asset and Healthy Dynamics Study, the proportion of the households that reported “some home modifications” was 34% among those aged 70–79 years, 47% among those aged 80–89 years, and 60% among those older than 90 years (Kutty, 1999). As expected, presence of health conditions, older age, and living alone were strongly associated with having baseline residential modifications. However, we did not find evidence that having low household income was associated with decreased likelihood of home modification. Previous studies have offered contradictory reports of the association between income and presence of home modifications (Newman, 2003; Tabbarah et al., 2000). Although not a specific goal of the current study, the comparability observed between participants who did

and did not have residential modifications suggests that reexamining assumptions regarding affordability driving the decision of implementing home modifications would be prudent.

In addition, the wide range of quintile-specific risk difference in our propensity score model suggests that the benefit of having residential modifications may differ according to subgroup and time interval. The largest risk difference was noted in Quintile 4, which suggests that 2 years may be too short of a time interval to assess the effects of residential decline for participants grouped in Quintiles 1 through 3. Quintiles 1 through 3 had lower risk differences than Quintile 4. A larger proportion of participants grouped in Quintiles 1 through 3 are younger and in better health at baseline than those grouped in Quintiles 4 and 5. Similarly, the smaller risk difference in Quintile 5 compared with Quintile 4 may indicate that participants who have passed a threshold in terms of baseline health or disability may reap a limited benefit from having residential modifications compared with their peers without residential modifications. This difference in subpopulation sociodemographics may have contributed to the intraquintile variability in risk differences. This is further supported by the results from our adjusted regression model. Sample persons in propensity score Quintiles 4 and 5 were more likely to have experienced decline in physical function at follow-up compared with those in propensity score Quintile 1 after adjusting for the presence of residential modification. More importantly, we found that the odds of experiencing subsequent decline in physical health were significantly lower among respondents with a baseline residential modification compared with those without baseline residential modification after adjusting for the propensity score quintile.

Table 1. Comparison of Participant Characteristics by Presence of Baseline Residential Modifications, Second Longitudinal Study on Aging

Characteristic	Baseline modifications		Total
	Yes	No	
Sample <i>n</i>	3,582	5,865	9,447
Weighted <i>n</i>	8,198,233	13,557,616	21,755,849
Sociodemographics (%)			
70–74 years old	34	43	39
75–79 years old	28	30	29
80–84 years old	22	17	19
≥85 years old	16	10	12
More than HS	26	25	25
Male	36	42	40
At or above poverty	73	76	75
Medicaid coverage in the past month	11	8	9
Married	49	56	53
White	91	89	90
Lives alone	40	31	35
Lives in a retirement community	81	88	11
Geographical (%)			
Population 1 million or more	37	39	39
Lived in present residence for <1 year	6	4	4
Northeast	22	22	22
Midwest	28	24	26
South	32	33	33
West	18	20	19
Health (%)			
Excellent/very good health	33	40	37
Frequently depressed/anxious	10	6	8
Frequently confused/disoriented/forgetful	9	5	7
Ever had arthritis	63	53	57
Ever had broken hip	7	3	4
Ever had cancer	20	18	19
Ever had diabetes	14	11	12
Heart disease	23	20	21
Hypertension	50	41	44
Other heart disease	9	7	7
Osteoporosis	11	7	9
Stroke or CVA	12	7	9
Trouble with sight	18	11	14
No lower body limitations	35	52	46
No upper body limitations	46	63	57
Services (%)			
Home health care services in past 12 months	5	1	2
Planning to move to receive services	2	1	1
Equipment assistance (%)			
Uses special aides	36	14	22
Behavioral (%)			
Has a regular exercise routine	37	40	39
0–1 social activity	7	8	6

Notes: CVA = cerebrovascular accident; HS = high school.

Strengths and Limitations

Our study has several data limitations. The operational expression of the outcome measure relied on self-reported difficulty and individual's interpretation of what the task entails. Self-reports might be inconsistent with actual ability. In addition, cur-

rent ADL measures are known to be located on the easier end of the ability continuum and therefore subject to floor and ceiling effects (McHorney, 1997). Nevertheless, our population-based estimates of these estimates were consistent with previous studies (Naik & Gill, 2005; Newman, 2003;

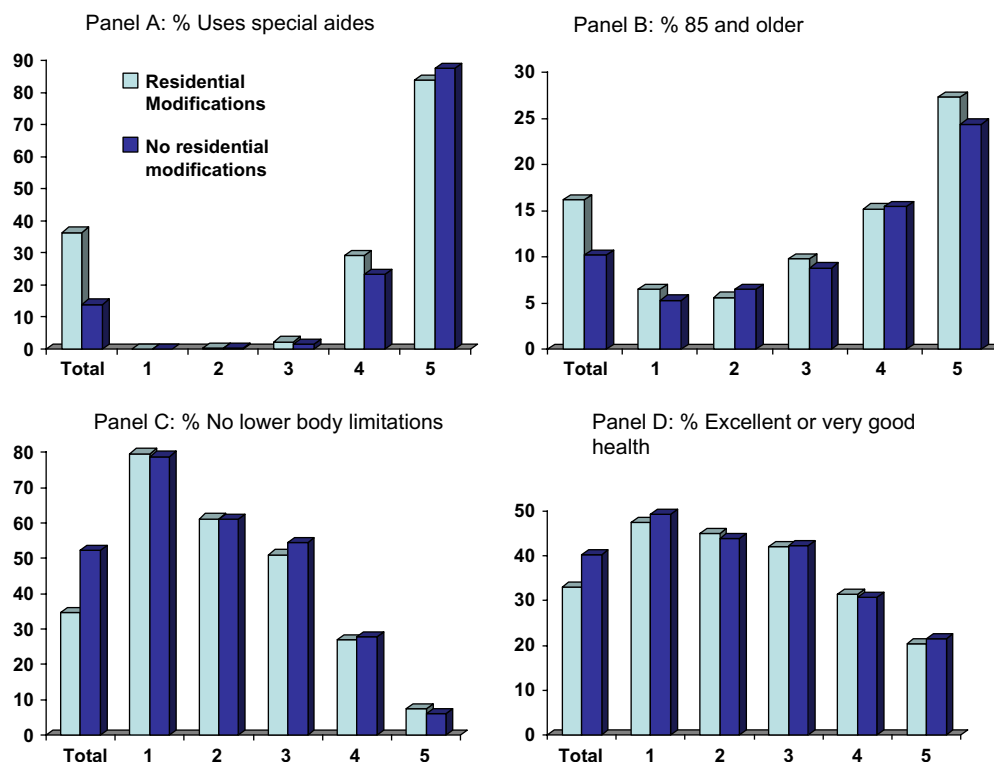


Figure 2. Comparison of selected potential confounders between those with and without baseline residential modifications within each quintile of propensity score.

Tabbarah et al., 2000). Because our study was not concerned with quantifying the level of physical impairment but whether or not the participant ex-

perienced any decline in functional ability, the sensitivity of ADL measures to floor and ceiling effects should have minimal impact on our findings.

Table 2. Effect of Residential Modifications on Decline in Risk for Physical Function in 2 Years Among a Nationally Representative Sample of Community-Dwelling Elders Aged 70 Years and Older, Second Longitudinal Study on Aging

Model	Has residential modification	Unweighted <i>n</i>	Weighted <i>n</i>	% With residential modification	% Decline	Risk difference (95% CI)
Crude	Yes	3,582	8,198,233	37.7	44.1	-0.5
	No	5,865	13,557,616		43.7	
Propensity score ^a						
Quintile 1	Yes	358	—	19.0	39.4	1.8 (-3.83 to 7.43)
	No	1,531	—		41.2	
Quintile 2	Yes	527	—	27.0	36.2	2.8 (-2.05 to 7.65)
	No	1,363	—		39.0	
Quintile 3	Yes	621	—	32.9	39.1	2.6 (-2.10 to 7.30)
	No	1,268	—		41.7	
Quintile 4	Yes	816	—	43.2	44.4	5.1 (0.57-9.63)
	No	1,074	—		49.5	
Quintile 5	Yes	1,260	—	66.7	50.6	2.5 (-2.28 to 7.28)
	No	629	—		53.1	
Overall	Yes	3,582	—	37.9	41.9	3.1
	No	5,865	—		44.9	
Survey-weighted propensity score model ^b	Yes	—	—	—	43.9	3.1
	No	—	—	—	47.0	

Notes: CI = confidence interval.

^aWald's interval for binomial proportion.

^bClosed-form formulas to derive 95% CIs using this method were not available.

Table 3. Odds of Decline Among a Nationally Representative Sample of Community-Dwelling Elders Aged 70 Years and Older, Second Longitudinal Study on Aging^a

Model	Crude OR (95% CI)	Adjusted OR (95% CI)
Residential modification— one or more at baseline vs. none	1.02 (0.93–1.19)	0.88 (0.79–0.97)
PS Quintile 1	—	—
PS Quintile 2	—	0.93 (0.81–1.07)
PS Quintile 3	—	1.07 (0.90–1.26)
PS Quintile 4	—	1.39 (1.19–1.62)
PS Quintile 5	—	1.70 (1.46–1.98)

Notes: CI = confidence interval; OR = odds ratio; PS = propensity score.

^aWeights accounted for complex survey design and nonresponse.

Second, the time interval between the two surveys, 2 years, might be too broad to capture disability transitions that occurred between waves or too short to evaluate the impact of physical function decline amenable to prevention by residential modifications. The data used in this study were collected in the 1990s, which may limit the generalizability of these findings to the current population of older adults. Finally, we assume that presence of a residential modification at baseline indicates safe and correct use of such a modification. Although the presence of a modification is associated with use, people may still be unsafe in how they perform tasks (Murphy, Nyquist, Strassburg, & Alexander, 2006). Such an assumption would attenuate the effect estimate. Therefore, our results are a conservative estimate of short-term decline in functional ability among older adults.

Most importantly, there may be residual confounding from assistive technology and other potential confounders. The definition of assistive device used in LSOA may not be inclusive of all assistive technology. Furthermore, some may argue that our definition of environmental modifications overlaps with assistive technology. Studies differ in what modifications or devices are recorded as well as how such items are grouped together (Cornman, Freedman, & Agree, 2005). Previous studies have used definitions of environmental modifications and assistive technology that range from broadly defined (e.g., environmental modifications considered to be a component of assistive technology; Kitchener, Ng, Lee, & Harrington, 2008) to more narrowly focused (Cornman et al.,

2005). As previously used in the literature, we defined an environmental modification as any change in the physical residence that reduces the demands of the physical environment and an assistive device as any equipment that enhances an individual's capabilities (Agree, 1999). Therefore, assistive devices are transferable, whereas environmental modifications are site specific. However, there may still be residual confounding from assistive devices if the above-mentioned question does not completely cover all usage of assistive technology. In addition, we also recognize that the lack of a standard definition for what constitutes an environmental modification or assistive device may prevent comparisons with previously published studies.

Nevertheless, we feel our study has several important strengths. By incorporating a survey-weighted propensity score in the analysis, we are able to estimate a causal treatment effect parameter that adjusts for selection bias. Previously, research using the HEI model found that the perception of unmet needs for accessibility features in the home among community-dwelling adults with physical limitations was significantly associated with an increased likelihood of ADL difficulty (Stineman et al., 2007). Our results suggest that lack of residential modifications increases the likelihood of functional decline as measured by increasing ADL limitation. This finding supports the expanded biopsychosocial framework outlined in the HEI model. In addition, we estimated measures of effect on a nationwide scale because our study sample is nationally representative. To the best of our knowledge, LSOA II is the only publicly available longitudinal data set that is nationally representative with extensive questions about health status, health condition, sociodemographics, and presence of residential modifications necessary for deriving our propensity score model.

Recent legislative acts have reshaped the built environment. The Fair Housing Amendments Act of 1988 required all newly constructed multifamily dwellings to have an accessible route into and through each dwelling, accessible environmental controls (e.g., light switches), reinforcements in the bathroom walls to allow installation of grab bars, and kitchens and bathrooms with enough floor space to accommodate wheelchairs. The Americans with Disabilities Act of 1990 included enforceable standards for design to ensure accessibility (Welch & Palames, 1995). Since the late 1990s, several states such as Texas, Vermont, and Kansas have also passed legislation that required basic disability-friendly

architectural features (e.g., wider doorways and hallways) for specific types of newly built housing (Kochera, 2002). For existing housing, housing providers are required to allow persons with disabilities to make reasonable modifications, but such reasonable modifications are usually made at the resident's expense (U.S. Department of Housing and Urban Development, 2006). Although such ordinances and legislation were enacted with the goal of increasing accessibility for people with disability, policies encouraging these design policies may be the first steps in raising the threshold for disability and contribute to the lower prevalence of disability in future cohorts.

Old age does not necessarily lead to drastic decline in functional ability (Mor, Murphy, & Masterson-Allen, 1998), and even those who experience decline may recover from disability (Beckett et al., 1996). Additional efforts could extend the recovery and independence of older subjects at high risk of decline. Given the enormous impact of decreasing disability in elderly adults, a better understanding of the role of residential modifications will have serious implications for the individual and the society at large. Health care professionals might want to include questions about home architectural factors when assessing their patients. At the societal level, housing policy should continue to promote widespread provision of such modifications. Our results showing modest decrease in likelihood of decline suggest that widespread adoption of residential modifications among older adults could potentially reduce the overall population estimates of decline in ADLs in the short term.

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