

# Longitudinal Study of Loneliness, Health, and Mortality in Old Age

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# **Longitudinal Study of Loneliness, Health, and Mortality in Old Age**

## **Abstract**

This study examines the relationship between loneliness, health, and mortality using a representative sample of 2,101 adults aged 50 years and over from the 2002 to 2008 waves of the Health and Retirement Study. Our analyses allow reciprocal relationships between loneliness, depressive symptoms, and health, and thus provide more rigorous assessments of the causal directions. Feelings of loneliness are associated with increased mortality risk over a 6-year period, and this relationship is diminished when depressive symptoms and physical health are added to the model. Further analyses of the relationship between loneliness and physical health using structural equation models show that loneliness has negative 2-year cross-lagged effects on self-rated health and positive effects on functional limitations even when the reciprocal effects of self-rated health and functional limitations on loneliness are taken into account. Consistent with our theoretical model of loneliness, the effect of loneliness on self-rated health is fully explained by the effect of loneliness on depressive symptoms, and the direct effect of loneliness on functional limitations persists even when its indirect effect on functional limitations through depressive symptoms is taken into account.

**Keywords:** Loneliness, Health, Mortality, Longitudinal Study, Cross-Lagged Path Model

## **Introduction**

Loneliness is a prevalent and serious social and public health problem (Cacioppo & Patrick, 2008). At any given time, up to thirty-two percent of adults over the age of 55 report feeling lonely (De Jong Gierveld & Van Tilburg, 1999), and from five to seven percent report feeling intense or persistent loneliness (Steffick, 2000; Victor, Scambler, Bowling, & Bond, 2005). Socially isolated individuals tend to feel lonely, but loneliness is not synonymous with being socially isolated. Loneliness is more accurately defined as the distressing feeling that accompanies discrepancies between one's desired and actual social relationships (Peplau & Perlman, 1982). Number of relationships can be important, but perceived shortcomings in the quality of one's relationships are particularly closely linked to loneliness (Hawkley, Hughes, Waite, Masi, Thisted, & Cacioppo, 2008; Pinqart & Sorenson, 2003). Prospective studies have shown that feelings of loneliness predict mortality (Patterson & Veenstra, 2010; Penninx, van Tilburg, Kriegsman, Deeg, Boeke, & van Eijk, 1997; Shiovitz-Ezra & Ayalon, 2010), depressive symptoms (Cacioppo, Hawkley, & Thisted, 2010; Cacioppo, Hughes, Waite, Hawkley, & Thisted, 2006b; Heikkinen & Kauppinen, 2004), impaired sleep and daytime dysfunction (Cacioppo, Hawkley, Berntson, Ernst, Gibbs, Stickgold et al., 2002a; Hawkley, Preacher, & Cacioppo, 2010; Pressman, Cohen, Miller, Barkin, Rabin, & Treanor, 2005), reductions in physical activity (Hawkley, Thisted, & Cacioppo, 2009), impaired mental health and cognition (Wilson, Krueger, Arnold, Schneider, Kelly, Barnes et al., 2007), and nursing home admission (Russell, Cutrona, de la Mora, & Wallace, 1997). At the biological level, loneliness is associated with increased vascular resistance (Cacioppo, Hawkley, Crawford, Ernst, Burleson, Kowalewski et al., 2002b; Hawkley, Berntson, Burleson, & Cacioppo, 2003), increased systolic blood pressure (SBP) (Hawkley, Masi, Berry, & Cacioppo, 2006), increased hypothalamic pituitary

adrenocortical activity (Adam, Hawkley, Kudielka, & Cacioppo, 2006; Steptoe, Owen, Kunz-Ebrecht, & Brydon, 2004), under-expression of genes bearing anti-inflammatory glucocorticoid response elements (GREs), over-expression of genes bearing response elements for pro-inflammatory NF- $\kappa$ B/Rel transcription factors (Cole, Hawkley, Arevalo, Sung, Rose, & Cacioppo, 2007), and altered immunity (Kiecolt-Glaser, Garner, Speicher, Penn, Holliday, & Glaser, 1984; Pressman et al., 2005).

Despite growing interest in the relationship between loneliness and health, previous research has focused on specific diseases or health conditions. Studies on more general health outcomes, such as self-rated health and number of functional limitations in general populations, are rare. Longitudinal studies have become more available; however, most analyses using longitudinal data have only specified changes in either loneliness or health, not their dynamic interactions. In this study, we examine the relationship between loneliness, depressive symptoms, and physical health using a national longitudinal survey of older adults aged 50 years and older in the United States. Our analyses allow reciprocal relationships among loneliness, depressive symptoms, and physical health, and thus provide more rigorous assessments than previous studies of the causal directions between these variables. Physical health outcomes to be examined include self-rated health, functional limitations, chronic health conditions, and mortality. We begin with an analysis of the effect of loneliness on mortality. Based on prior research, we hypothesize that loneliness is associated with increased mortality risk. Moreover, we hypothesize that this effect is due to the negative effects of loneliness on emotional and physical health. Then we examine the relationships between loneliness and the physical health outcomes, and explore possible mechanisms of these relationships. We hypothesize that loneliness negatively affects each physical health outcome, and that these effects are in part due

to the negative effects of loneliness on depressive symptoms, social activities, sleep quality, and health behaviors.

Our theoretical model of loneliness provides a rationale for the mechanisms through which we expect loneliness to influence health (Cacioppo & Hawkley, 2009). The features of the model point to specific mechanisms that contribute differentially to various health outcomes. Our model is grounded in an evolutionary framework in which the health, life, and genetic legacy of social species are endangered by social isolation. In humans, simply perceiving that one is socially isolated (i.e., lonely) is sufficient to incur survival and health costs. Perceived social isolation is an adverse state that, like hunger, thirst, and pain, motivates the individual to change their behavior or their environment. Longitudinal studies indicate that loneliness leads to increases in depressive symptomatology (Cacioppo et al., 2010; Cacioppo et al., 2006b; Hagerty & Williams, 1999; Heikkinen & Kauppinen, 2004; Wei, Russell, & Zakalik, 2005). Experimental research has also shown loneliness to change affective states, increasing feelings of sadness, anxiety, and low self-esteem (Cacioppo, Hawkley, Ernst, Burleson, Berntson, Nouriani et al., 2006a). Because self-ratings of health are colored by one's depressive frame of mind (Blazer, 2008), we hypothesize that the effects of loneliness on self-rated health may be explained, in part, by feelings of depressive symptoms.

Loneliness not only makes people feel unhappy, it makes them feel unsafe and it activates implicit hypervigilance for social threat in the environment (Cacioppo et al., 2006a). Chronic activation of social threat surveillance diminishes executive functioning (Blazer, 2008), and heightened impulsivity influences the tendency of individuals to engage in health behaviors that require self-control (e.g., physical activity; Hawkley, Thisted, & Cacioppo, 2009). Physical activity is important in maintaining higher levels of physical functioning (Keysor, 2003; Lee &

Park, 2006; Netuveli, Wiggins, Montgomery, Hildon, & Blane, 2008). Cognitive resources spent defending the self from perceived social threat diminish the likelihood that individuals will exert the self-control necessary to remain active, and increase the likelihood that functional limitations will worsen more quickly over time in lonely individuals. Feeling unsafe is also detrimental to sleep. A sense of safety and security in the social surround is crucial for restful, restorative sleep, and implicit vigilance for danger results in impaired sleep quality in lonelier individuals (Cacioppo et al., 2002a; Hawkley et al., 2010). Sleep deprivation and nonrestorative sleep are increasingly recognized as health risk factors (Mullington, Haack, Toth, Serrador, & Meier-Ewert, 2009; Ohayon, 2005), and poor sleep has been associated with greater functional limitations in older women (Goldman, Stone, Ancoli-Israel, Blackwell, Ewing, Boudreau et al., 2007). Sleep quality thus represents another mechanism through which loneliness may result in adverse health consequences.

Unconscious social threat surveillance also produces cognitive biases in which lonely individuals tend to preferentially perceive, remember, and expect negative social information. Negative social expectations, in turn, tend to elicit negative behaviors from others, thereby setting in motion a self-fulfilling prophecy in which lonely people actively distance themselves from would-be social partners in self-protection believing that the cause of the social distance is out of their control (Blazer, 2008). Evidence has shown that lonely individuals are less socially active, whether measured in terms of social network size or the frequency of interactions with others (Hawkley et al., 2008), and lower levels of social activity also exacerbate feelings of loneliness, producing a loop in which loneliness is perpetuated. For our purposes, evidence that social activity influences health and mortality (House, Landis, & Umberson, 1988) suggests that

less social activity may help to account for the effect of loneliness on physical health and mortality.

## **Methods**

Data mainly come from the 2002, 2004, 2006 waves of the Health and Retirement Study (HRS) although mortality data in 2008 were also used. HRS is a nationally representative, longitudinal study of older Americans with its sample composed of five birth cohorts who entered the study in different calendar years. HRS began in 1992-93 as two separate samples: the original HRS focusing on 1931-41 birth cohorts and the AHEAD focusing on 1890-1923 birth cohorts. In 1998 the two samples were merged and two new samples--CODA (1924-30 cohorts) and War Babies (1942-47 cohorts), were added, and in 2004, another new sample--EBB (1948-53 cohorts) was added, making the sample representative of those born in 1953 or before, approximately aged over 50 in 2004. Once they have entered the study, respondents were re-interviewed every two years. The spouses were also interviewed irrespective of their age. The sample for each cohort was derived from the same stratified, multistage area probability design in which blacks, Hispanics, and Floridians were over sampled. The HRS now includes over 30,000 respondents. The initial cohort response rates ranged from 70 percent to slightly over 80 percent; re-interview rates for all cohorts at each wave have been between 92 and 95 percent (Health and Retirement Study 2007).

Since its inception in 1992, the HRS has focused on the health, economics, and demographics of aging and the retirement process. The 2002 wave of HRS included a module on loneliness and 2,190 respondents were randomly selected to answer the questions in this module. Among them, 2,023 were re-interviewed, 81 died, and 86 dropped in 2004, 1,897 were re-interviewed (including 28 who did not complete the 2004 interview), 100 more died, and 54

more dropped in 2006, and 1,760 were re-interviewed (including 26 who did not complete the 2006 interview), 112 more died, and 51 more dropped in 2008. Loneliness questions were asked again of 1,756 respondents in 2004 in mostly in-person interviews, and were asked again of 1,620 respondents in 2006 in leave-behind self-administered questionnaires which were left with the respondents upon the completion of an in-person core interview. Note that not all of the 2002 loneliness module respondents were selected to answer questions on loneliness in both 2004 and 2006. The analysis in this study is restricted to the 2,101 respondents who were aged 50 years and more and completed the loneliness module in 2002.

### *Loneliness*

In each wave, HRS asked how often the respondent feels (i) lack of companionship, (ii) left out, and (iii) isolated from others. This three-item loneliness scale was adapted from the standard measure of loneliness, the Revised UCLA Loneliness Scale, and it has been shown to have good internal consistency and both concurrent and discriminant validity (Hughes, Waite, Hawkey, & Cacioppo, 2004). The three-point response scale for each item ranges from “hardly ever or never” to “often.” A loneliness scale was created by summing scores on the three items. It ranges from 3 to 9 with higher values indicating a greater degree of loneliness; Cronbach’s alpha is .82.

### *Health Outcomes*

The study assesses mortality between 2002 and 2008, and depressive symptoms and three physical health outcomes were measured in 2002, 2004, and 2006. (1) *Depressive symptoms.* HRS includes a short version of the Center for Epidemiological Studies Depression Scale (CES-D) designed for telephone interviews with older respondents (Turvey, Wallace, & Herzog, 1999). Each item asked whether the respondent experienced a specific symptom in the past week (e.g.,

“I felt that everything I did was an effort”). Depression is conceptually related to but distinct from loneliness (Cacioppo et al., 2006a; Cacioppo et al., 2010; Cacioppo et al., 2006b). To reduce the overlap in measurement of the two concepts, we deleted the item in the CES-D that states “I felt lonely” from our depressive symptoms scale. We also deleted the item “sleep was restless” because quality of sleep was used as a separate covariate in our multivariate analysis. Number of depressive symptoms is a count of the affirmative responses from the remaining items, with two items tapping positive affect reverse coded; it ranges from 0 to 6. (2) *Self-rated health*. Each respondent was asked to rate his or her physical health on a five-point scale from poor to excellent, providing a subjective assessment of his or her health status. (3) *Functional limitations*. Number of functional limitations is calculated by summing responses to eleven items assessing whether the respondent has any difficulty with specific forms of ambulation, such as walking a block and climbing a flight of stairs, or muscle movements, such as moving a large chair or picking up a dime. It ranges from 0 to 11. (4) *Chronic conditions*. Respondents were asked if a doctor had ever told them that they had diabetes, heart disease, lung disease, cancer, hypertension, or a stroke. Number of chronic conditions is the total number of conditions reported; it ranges from 0 to 6.

#### *Social Network Characteristics*

We include three social network characteristics. (1) *Marital status and spousal health*. We compare respondents who are currently married with those who are separated, divorced, widowed, or never married. Research has shown that if the spouse is ill and requires extensive care, the marital relationship could become a physical and emotional burden to the caregiving spouse that negatively affects the caregiver's felt connectedness to the spouse and his or her own health and mortality (Schultz & Beach, 1999). Therefore, among those who are married, we

further separate those with a spouse whose self-rated health is “poor” or “fair” from those with a spouse whose self-reported health is “excellent,” “very good,” or “good.” (2) *Relatives living nearby*. This variable is coded 1 if the answer is yes to the question: “Besides the people living here with you, do you have any relative in your neighborhood?” and 0 if the answer is no. (3) *Friends living nearby*. It is coded 1 if the answer is yes to the question: “Do you have any good friends living in your neighborhood?” and 0 if the answer is no.

### *Social Activities*

Respondents were asked whether they have spent any time in the past 12 months (i) “doing volunteer work for religious, educational, health-related or other charitable organizations,” and (ii) “helping friends, neighbors, or relatives who did not live with you and did not pay you for the help?” Social activities index is a count of the affirmative answers to the two questions and it ranges from 0 to 2.

### *Sleep Quality*

Respondents were asked how often they (i) “have trouble falling asleep,” (ii) “have trouble with waking up during the night,” (iii) “have trouble with waking up too early and not being able to fall asleep again,” and (iv) “feel really rested when you wake up in the morning.” The three-point response options to each item range “most of the time” to “rarely or never.” With the first three items reverse coded, the sleep quality scale is the sum of responses to the four items. It ranges from 4 to 12 with higher scores indicating poorer sleep quality; Cronbach’s alpha is .65.

### *Health Behaviors*

Health behaviors include physical exercise and smoking. (1) *Physical exercise*. It was coded 1 if the answer is yes to the question whether on average over the last 12 months the

respondent has participated in vigorous physical activity or exercise three times a week or more, and 0 if the answer is no. (2) *Smoking*. Respondents were asked whether they ever smoked cigarettes in their life time and for those who answered yes, whether they smoke cigarettes now. Based on this information, we grouped respondents into three categories: never smoked, past smoker, and current smoker.

### *Sociodemographic Covariates*

We control for age, gender, race/ethnicity, education, household income and household assets in our multivariate analysis. Age is measured in years. We distinguish three race/ethnicity categories: black, Hispanic, and white/others. Education is measured with the years of schooling completed. We use the total household income and household assets with missing data imputed by the HRS staff. Household income and household assets are log transformed to adjust for skewness.

### *Statistical Procedures*

First, we conducted survival analysis to examine the effect of loneliness in 2002 on mortality between 2002 and 2008. A series of six hierarchical Weibull hazard models were estimated using Stata Version 11. The first model includes loneliness and sociodemographic covariates in 2002, the next four models each add social network characteristics, social activities, sleep quality, and health behaviors, and the last model adds physical and emotional health. These additive models allow us to examine whether the effect of loneliness on mortality risk is explained by its associations with social network characteristics, social activities, health behaviors, and physical and emotional health.

Next, we used structural equation modeling methods to examine the relationships between loneliness and physical and emotional health. The survival analysis tells us whether

loneliness affects mortality risk and whether this effect is through the associations of loneliness with physical and emotional health. However, because loneliness and health status were measured at the same time, the causal directions between them cannot be established. Cross-lagged path analysis is widely used to infer causal associations in data from longitudinal research designs. We therefore used cross-lagged analyses and estimated autoregressive and cross-lagged paths, which allowed us to simultaneously address reciprocal influences of loneliness and health (Curran, 2000). These models were estimated with MPlus Version 5 (Muthén & Muthén, 1998-2007). Missing data were not imputed; rather, available data from all 2,101 respondents were used in analyses. All models were estimated using full information maximum likelihood estimation with robust standard errors. The degree of model fit was assessed with the chi-square goodness of fit statistic and the root-mean-square error of approximation (RMSEA).

MacCallum, Browne, & Sugawara (1996) characterized a model with an RMSEA of .08 or less as an adequate fit; Hu & Bentler (1999) characterized a model with an RMSEA of .05 or less as a good fit and .10 or more as a poor fit.

We estimated three cross-lagged path models for each physical health outcome: self-rated health and functional limitations. In the first model, we examined the cross-lagged relationship between loneliness and physical health with only sociodemographic variables as covariates. In the second model, we added social network characteristics, social activities, sleep quality, and health behaviors as covariates. In the third model, we added the cross-lagged relationships between loneliness and depressive symptoms, and between depressive symptoms and the physical health measures to examine whether the reciprocal effects of loneliness on physical health and physical health on loneliness are mediated by depressive symptoms.

## **Results**

### *Descriptive Statistics*

Descriptive statistics of the variables are presented in Table 1. The average score of the loneliness scale did not change much from 2002 to 2004, but increased between 2004 and 2006 ( $t = 9.56, p < .001$ ). The latter increase may be in part due to the change in data collection method from in-person interviews in 2004 to self-administered questionnaires in 2006 for loneliness questions. There are no significant changes in the average number of depressive symptoms over the four-year period. Physical health status of the respondents deteriorated from 2002 to 2006 as indicated in all three outcomes: self-rated health ( $t = -3.85, p < .001$ ), number of functional limitations ( $t = 4.45, p < .001$ ), and number of chronic conditions ( $t = 7.43, p < .001$ ). Intraclass correlation which indicates within-subject stability is .67 for self-related health, .76 for functional limitations, and .88 for chronic conditions. These stability estimates indicate that number of chronic conditions is the least sensitive outcome for this sample over this time frame.

“Table 1 about here”

### *Loneliness and Mortality*

Of the 2,101 respondents who responded to loneliness questions in 2002, 303 died by 2008. Results from survival analysis showed that net of sociodemographic characteristics, feeling lonely in 2002 is associated with increased mortality risk between 2002 and 2008 (OR = 1.14, 95% CI = [1.06, 1.23]) (Table 2, Model I). When social network characteristics are added in Model II, the change in the effect of loneliness is not significant, and none of the social network characteristics are associated with mortality risk. When social activities are added (Model III), social activities are associated with decreased risk of mortality (OR = .74, 95% CI = [.63, .88]), and the effect of loneliness on mortality is attenuated but remains statistically significant (OR = 1.12, 95% CI = [1.02, 1.21]). In Model IV, sleep quality is not significantly

associated with mortality risk independently of other variables in the model. When health behaviors are added in Model V, the effect of loneliness does not decrease significantly although both physical exercise and smoking are associated with mortality risk. The effect of social activities on mortality is somewhat attenuated when health behaviors are added.

The effect of loneliness becomes only marginally significant when physical and emotional health measures are added in Model VI (OR = 1.08, 95% CI = [.99, 1.18]). Among these health measures, self-rated health, functional limitations, and chronic conditions each have a significant independent effect on mortality risk. When physical health measures are not included in the model, number of depressive symptoms has a marginally significant association with mortality risk (OR = 1.08, 95% CI = [.99, 1.17]; not shown), and loneliness has a nonsignificant effect (OR = 1.07, 95% CI = [0.98, 1.17]). However, depressive symptoms no longer have an independent effect once physical health measures are also added as shown in Model VI; thus the effect of depressive symptoms on mortality seems to be mediated by the effect of depressive symptoms on physical health. Also noticeable in Model VI are the changes in the effects of behavioral characteristics on mortality risk; they are all substantially attenuated and are no longer significant or are only marginally significant once physical and emotional health are added.

Not surprisingly, mortality risk is higher for the elderly who are older, male, with lower household income and assets. Education is negatively correlated with mortality risk, but its effect on mortality risk becomes positive once household income, household wealth, and health measures are added, suggesting that the lower risk of mortality among the better educated is mainly due to the effects of education on income, wealth, and physical and emotional health.

“Table 2 about here”

### *Loneliness and Physical and Emotional Health*

The results on mortality suggest that loneliness affects mortality through its direct and indirect associations with emotional and physical health. However, in the survival analysis, loneliness and health variables were measured at the same time point, thus their causal directions cannot be established. To better establish the causal directions between loneliness and health, we conducted cross-lagged path analysis using SEM methods and the results are presented in Figures 1 to 3. Our theoretical models assume that prospective relationships between variables are stable over time. These assumptions were modeled by applying equality constraints to the autoregressive and cross-lagged paths, thereby imposing “stationarity” on the relationships among variables in the model. In these figures, autoregressive effects are represented as single-headed arrows running from a given variable at one time point to the same variable at the next time point. The cross-lagged effects of a variable at one time point to another variable at the next time point are illustrated by diagonal single-headed arrows. We also assumed that the 2-year prospective effects of covariates on loneliness, depressive symptoms, and physical health did not differ from one time point to another time point, and therefore equality constraints were applied to each of these covariates over the two 2-year intervals. The effects of covariates are illustrated by diagonal single-headed arrows. Correlations between variables and residuals at a given time are illustrated by double-headed arrows.

Table 3 presents bivariate correlations between variables at the baseline (Year 2002). Loneliness is correlated with most sociodemographic, relational, behavioral, and health variables with the exception of age, relatives living nearby and past smoking. Level of loneliness is positively associated with poor spousal health, depressive symptoms, poorer self-rated health, more functional limitations, and more chronic conditions. Being female, being black or

Hispanic, having no spouse/partner or having a spouse with poor health, having lower levels of education, less household income and assets, poor sleep quality and, current smoker are also positively associated with loneliness, while having friends nearby, physical exercise, and social activities are negatively associated with loneliness. Sociodemographics, marital status and spousal health, physical exercise, social activities, and sleep quality are correlated similarly with depressive symptoms, self-rated health, functional limitations, and chronic conditions.

“Table 3 about here”

Cross-lagged models linking loneliness and chronic health conditions revealed no significant associations, likely due to the high stability of chronic conditions over the course of the study. Chronic conditions are therefore not considered further. Figure 1 shows the cross-lagged relationship between loneliness and self-rated health and between loneliness and functional limitations while controlling only for sociodemographic covariates. The results support the stationary process and fit the data adequately. The RMSEA is .078 (90% CI = [.071, .086]) for self-rated health, and .068 (90% CI = [.060, .076]) for functional limitations. The 2-year cross-lagged effect of loneliness on self-rated health is significant ( $B = -.027, p < .01$ ), and the 2-year cross-lagged effect of self-rated health on loneliness is also significant ( $B = -.114, p < .001$ ), and thus these results provide evidence for a reciprocal relationship between loneliness and self-rated health. We also see a similar reciprocal relationship between loneliness and functional limitations; the 2-year cross-lagged effect of loneliness on functional limitations is significant ( $B = .090, p < .001$ ), and the 2-year cross-lagged effect of functional limitations on loneliness is also significant ( $B = .055, p < .001$ ).

“Figure 1 about here”

Figure 2 shows the cross-lagged relationship between loneliness and self-rated health and between loneliness and functional limitations while controlling for sociodemographic covariates, social network characteristics, social activities, sleep quality, and health behaviors. The results support the stationary process and show significantly improved model fit for both outcomes as gauged by lack of overlap in the confidence intervals between these models and the models in Figure 1. The RMSEA is .057 (90% CI = [.051, .063]) for self-rated health, and .048 (90% CI = [.043, .054]) for functional limitations. The 2-year cross-lagged effect of loneliness on self-rated health is attenuated and becomes marginally significant ( $B = -.017, p < .1$ ), and the 2-year cross-lagged effect of self-rated health on loneliness remains significant ( $B = -.061, p < .001$ ). We also see a similar change in the reciprocal relationship between loneliness and functional limitations although both the 2-year cross-lagged effect of loneliness on functional limitations ( $B = .084, p < .01$ ), and the 2-year cross-lagged effect of functional limitations on loneliness ( $B = .034, p < .001$ ) remain significant. These results indicate that part of the reciprocal relationship between loneliness and physical health in Figure 1 is explained by the associations of loneliness with social network characteristics, social activities, sleep quality, and health behaviors.

“Figure 2 about here”

The mortality findings suggested that the effect of loneliness on mortality risk is explained in part by the indirect effect of depressive symptoms on physical health. Figure 3 presents results from the cross-lagged models adding to the models in Figure 2 the cross-lagged relationships between loneliness and depressive symptoms, and between depressive symptoms and the physical health variables. These models show good model fit: RMSEA is .049 (90% CI = [.044, .053]) for self-rated health and .043 (90% CI = [.038, .048]) for functional limitations. The 2-year cross-lagged effect of loneliness on self-rated health is no longer statistically

significant. The 2-year cross-lagged effect of self-rated health on loneliness is no longer statistically significant. Both the cross-lagged effect of loneliness on depressive symptoms and the cross-lagged effect of depressive symptoms on loneliness are significant ( $B = .128, p < .001$  and  $B = .104, p < .001$  respectively). Both the cross-lagged effect of depressive symptoms on self-rated health and the cross-lagged effect of self-rated health on depressive symptoms are significant ( $B = -.035, p < .001$  and  $B = -.143, p < .001$  respectively). These results suggest that there is a reciprocal relationship between loneliness and depressive symptoms and depressive symptoms mediate the relationship between loneliness and self-rated health.

“Figure 3 about here”

Both the cross-lagged effect of functional limitations on depressive symptoms and the cross-lagged effect of depressive symptoms on functional limitations are significant ( $B = .070, p < .001$  and  $B = .058, p < .01$  respectively). Despite this, the cross-lagged effect of loneliness on functional limitations and the cross-lagged effect of functional limitations on loneliness remain statistically significant ( $B = .064, p < .05$  and  $B = .020, p < .01$  respectively).

## **Discussion**

A growing body of prospective research indicates that loneliness predicts a wide range of physiological, cognitive, behavioral, and health problems in middle-aged and older adults. In this study, we focused on general health outcomes, such as self-rated health, functional limitations, and mortality. The longitudinal data and the structural equation modeling techniques allowed us to conduct more rigorous assessments of the causal relationship between loneliness and health. Our study extends previous research on loneliness and health by incorporating detailed analyses of the potential mechanisms of the effects of loneliness on self-rated health,

functional limitations, and mortality. Because our findings are based on a national probability sample they are more generalizable to the older adult population.

Our hypothesis that loneliness is associated with increased mortality risk was supported by the data. We found that net of sociodemographic covariates feeling lonely is associated with increased mortality risk over a six-year period; older adults with the highest level of loneliness are 2.21 times more likely to die within six years than those with the lowest level of loneliness. This finding is consistent with previous research (Patterson & Veenstra, 2010; Penninx et al., 1997; Shiovitz-Ezra & Ayalon, 2010). In addition, our results showed that the effect of loneliness on mortality is largely mediated by the effects of loneliness on social activities, health behaviors, and physical and emotional health. Comparable results were reported by Sugisawa et al. (1994), who found that the effect of loneliness on mortality over a three-year period among the elderly in Japan was fully explained by chronic diseases, functional status, and self-rated health. Patterson & Veenstra (2010) found that physical activities and depression explained the relationship between loneliness and mortality. Shiovitz-Ezra & Ayalon (2010) found that the effect of loneliness on mortality remained statistically significant after controlling for medical status, functional impairment, and depression, but their study did not include health behaviors and social activities. Taken together, these findings strengthen support for the conjecture that loneliness affects mortality through its effects on physical and emotional health, and suggest that social activities and health behaviors may play an additional indirect role through their effects on physical health. The sizable, albeit marginally significant, effect of loneliness on mortality after controlling for these mediating factors in our study suggests that future research on biological and physiological mechanisms may shed additional light on loneliness-mortality relationship (Hawkey & Cacioppo, 2010).

Mortality analysis showed that self-rated health, functional limitations, and chronic conditions assessed at the same time as loneliness helped to explain the effect of loneliness on mortality, but did not permit evaluation of the causal direction between loneliness and health. Using cross-lagged models, we found that loneliness predicted increases in self-rated health and decreases in functional limitations over two years even when the reciprocal effects of self-rated health and functional limitations on loneliness were taken into account. These findings are consistent with a causal direction that implicates loneliness in decrements in physical health.

What explains the effect of loneliness on physical health? Our theoretical model of loneliness suggested several distinct mechanisms whose effects could differ depending on the aspect of health in question. For self-rated health, we posited that loneliness could contribute to lower health ratings in part through its influence on depressive symptoms and the effect of sadness on self-perceptions. Consistent with this hypothesis, depressive symptoms reduced to nonsignificance the lagged effect of loneliness on self-rated health in a model that also included social network characteristics, social activities, sleep quality, and health behaviors. In addition, the reciprocal path from self-rated health to loneliness was not significant when depressive symptoms were included in the model, but depressive symptoms had a significant reciprocal association with self-rated health over two-year intervals, suggesting that altered health perceptions both influence and are influenced by depressive symptoms.

For functional limitations, we posited that the effect of loneliness on executive functioning and self-control could contribute to greater functional limitations in part through its influence on health behaviors. Implied in our hypothesis was that the affective frame of mind accompanying depressive symptoms would have less of an impact on the relationship between loneliness and functional limitations (a relatively affect-free evaluation) than on the relationship

between loneliness and self-rated health. Indeed, our data showed that although depressive symptoms had significant relationships with loneliness and functional limitations, the effect of loneliness on functional limitations over a two-year interval remained significant when depressive symptoms were modeled as mediators of the cross-lagged association between loneliness and functional limitations. Functional limitations also retained a significant reciprocal effect on loneliness, suggesting that functional limitations may have an impact on people's ability to find or develop social relationships in or out of the home. This hypothesis warrants additional research. Changes in functional limitations have been shown to predict changes in self-rated health that predicted mortality independent of negative affect (Mora, DiBonaventura, Idler, Leventhal, & Leventhal, 2008), a finding that is consistent with the indirect role posited for functional limitations in loneliness-related mortality in our sample.

In additional analyses (not shown), we further explored several potential mechanisms that may explain the remaining effect of loneliness on functional limitations. Previous research shows that loneliness predicts reduced physical activity (Hawkley et al., 2009), and physical activity predicts recovery from functional limitations (Lee & Park, 2006). Previous research has also shown that loneliness predicts poor sleep quality (Cacioppo et al., 2002a; Hawkley et al., 2010; Pressman et al., 2005), and poor sleep quality has been associated with more functional limitations (Goldman et al., 2007). Although the baseline measures of these variables were included in the analyses discussed above, we also tested models that specified social activities, physical exercise, and sleep quality as having cross-lagged relationships with functional limitations and with depressive symptoms. The effect of loneliness on functional limitations remained significant when these variables and relationships were added.

What might account for the residual effect of loneliness on functional limitations?

Physical activity cannot be ruled out; the type, intensity, and duration of activity could matter in terms of maintaining high levels of physical functioning, as could whether physical exercise is done in isolation versus with others. It should be noted that loneliness had significant lagged effects on social activities, sleep quality and physical exercise when functional limitations were not in the model (ancillary analyses not shown). However, in the models that specified reciprocal cross-lagged effects of social activities, physical exercise, and sleep quality with both loneliness and functional limitations, the effects of loneliness on changes in social activities and physical exercise were mainly through the effect of loneliness on functional limitations, and no significant direct effects. The direct effect of loneliness on changes in sleep quality remained significant.

This study used a three-item composite index of loneliness which has been shown to have good validity and reliability (Hughes et al., 2004). This measure is an important improvement over previous studies on the loneliness-mortality relationship which measured loneliness with a single item asking respondents whether and/or how often they felt lonely. Specifically, our three-item measure avoids use of the term “lonely” or “loneliness” and thus avoids much of the stigma associated with and consequent underestimation of loneliness. Nevertheless, the fact that mean loneliness levels were higher in 2006 than in 2002 and 2004, and that this difference corresponded to a change from an interview-based to a self-administered questionnaire leaves open the possibility that stigma may have resulted in an underestimation of loneliness in the interview-based data. Future waves of HRS, in which loneliness will continue to be assessed by self-administered questionnaire, will allow testing the degree to which the relationships reported in this study are robust to questionnaire format.

Although our data showed that number of chronic conditions is a strong predictor of mortality risk, we could not examine how loneliness predicts changes in chronic conditions because we did not see much variability within individuals in chronic conditions over the time period of this study. Future waves of HRS and a longer sampling time frame will also allow testing of the effects of loneliness on chronic conditions, and mechanisms for these effects. Furthermore, even though we analyzed the reciprocal relationships between loneliness, depressive symptoms, and self-rated health and functional limitations, arguably other factors which we theorized as mediating mechanisms, such as social activities, sleep quality, and physical exercise, could be both the cause and the effect of loneliness. Future research needs to construct more complex models to gain a better understanding of the dynamics of these relationships.

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Table 1. Descriptive statistics of the HRS sample

Variables	Year 2002			Year 2004			Year 2006		
	N	Mean/%	SD	N	Mean/%	SD	N	Mean/%	SD
Loneliness (3-9)	2,101	3.90	1.35	1,675	3.85	1.35	1,540	4.34	1.54
Depressive symptoms (0-6)	2,101	.98	1.46	1,902	.94	1.46	1,765	.93	1.43
Self-rated health (1-5)	2,101	3.30	1.08	1,936	3.22	1.09	1,813	3.16	1.06
Functional limitations (0-11)	1,730	2.49	2.73	1,595	2.67	2.84	1,536	2.94	2.96
Chronic conditions (0-6)	2,100	1.11	1.04	1,931	1.22	1.07	1,805	1.37	1.12
Spouse health poor %	2,099	19.0							
Spouse health good %	2,099	58.1							
Relatives living nearby %	2,101	31.9							
Friends living nearby %	2,101	70.8							
Social activities (0-2)	2,101	1.00	.75						
Sleep quality poor (4-12)	2,101	6.43	2.01						
Physical exercise %	2,101	44.6							
Past smoker %	2,088	42.7							
Current smoker %	2,101	12.6							
Age (50-98)	2,101	67.36	9.31						
Female %	2,101	63.0							
Black %	2,101	11.5							
Hispanic %	2,101	6.6							
Education (0-17)	2,101	12.47	2.99						
Household income (log) (0-15)	2,101	10.51	1.13						
Household assets (log) (0-17)	2,101	11.56	2.90						

Table 2. Hazard ratios of the Weibull models of mortality from 2002 to 2008

Variables	Model I		Model II		Model III		Model IV		Model V		Model VI	
	Hazard ratio	CI										
Loneliness in 2002	1.14***	[1.06, 1.23]	1.13**	[1.05, 1.23]	1.12**	[1.03, 1.21]	1.11*	[1.02, 1.20]	1.10*	[1.02, 1.20]	1.08+	[.99, 1.18]
Spouse health poor <sup>a</sup>			1.01	[.72, 1.42]	1.02	[.73, 1.43]	1.01	[.72, 1.41]	1.00	[.71, 1.40]	.87	[.61, 1.22]
Spouse health good <sup>a</sup>			.88	[.63, 1.21]	.90	[.65, 1.25]	.90	[.65, 1.25]	.92	[.67, 1.28]	.89	[.64, 1.23]
Relatives living nearby			.91	[.71, 1.17]	.92	[.71, 1.18]	.91	[.71, 1.18]	.92	[.71, 1.18]	.91	[.70, 1.17]
Friends living nearby			.85	[.65, 1.10]	.91	[.69, 1.19]	.91	[.69, 1.18]	.99	[.76, 1.30]	.92	[.70, 1.21]
Social activities					.74***	[.63, .88]	.75***	[.63, .88]	.78**	[.66, .93]	.84+	[.71, 1.00]
Sleep quality poor							1.03	[.97, 1.10]	1.03	[.97, 1.09]	.96	[.90, 1.02]
Physical exercise									.62***	[.48, .81]	.82	[.62, 1.08]
Past smoker <sup>a</sup>									1.38*	[1.05, 1.81]	1.29+	[.98, 1.70]
Current smoker <sup>a</sup>									1.59*	[1.06, 2.37]	1.46+	[.97, 2.20]
Depressive symptoms in 2002											.98	[.90, 1.08]
Self-rated health in 2002											.70***	[.60, .81]
Functional limitations in 2002											1.06*	[1.00, 1.11]
Chronic conditions in 2002											1.29***	[1.15, 1.44]
Age	1.09***	[1.08, 1.11]	1.09***	[1.08, 1.11]	1.09***	[1.07, 1.10]	1.09***	[1.07, 1.10]	1.09***	[1.07, 1.10]	1.08***	[1.07, 1.10]
Female	.50***	[.39, .63]	.48***	[.38, .62]	.48***	[.38, .61]	.48***	[.37, .61]	.51***	[.39, .66]	.52***	[.40, .68]
Black <sup>a</sup>	.89	[.60, 1.30]	.90	[.61, 1.32]	.89	[.61, 1.31]	.90	[.61, 1.33]	.90	[.61, 1.32]	.78	[.54, 1.15]
Hispanic <sup>a</sup>	1.15	[.72, 1.84]	1.16	[.72, 1.86]	1.11	[.69, 1.80]	1.14	[.71, 1.85]	1.11	[.69, 1.79]	1.14	[.71, 1.84]
Education	1.02	[.98, 1.06]	1.02	[.98, 1.06]	1.03	[.99, 1.07]	1.03	[.99, 1.08]	1.03	[.99, 1.08]	1.05*	[1.01, 1.10]
Household income (log)	.82***	[.73, .91]	.83***	[.74, .93]	.84***	[.75, .94]	.84***	[.75, .94]	.85***	[.75, .95]	.88*	[.77, .99]
Household assets (log)	.95**	[.91, .98]	.95*	[.92, .99]	.96*	[.92, 1.00]	.96*	[.92, 1.00]	.96+	[.93, 1.00]	.97	[.93, 1.01]
Chi-square	267.95		271.15		283.13		284.36		304.92		398.50	
Df	8		12		13		14		17		21	

Note: N=2,074

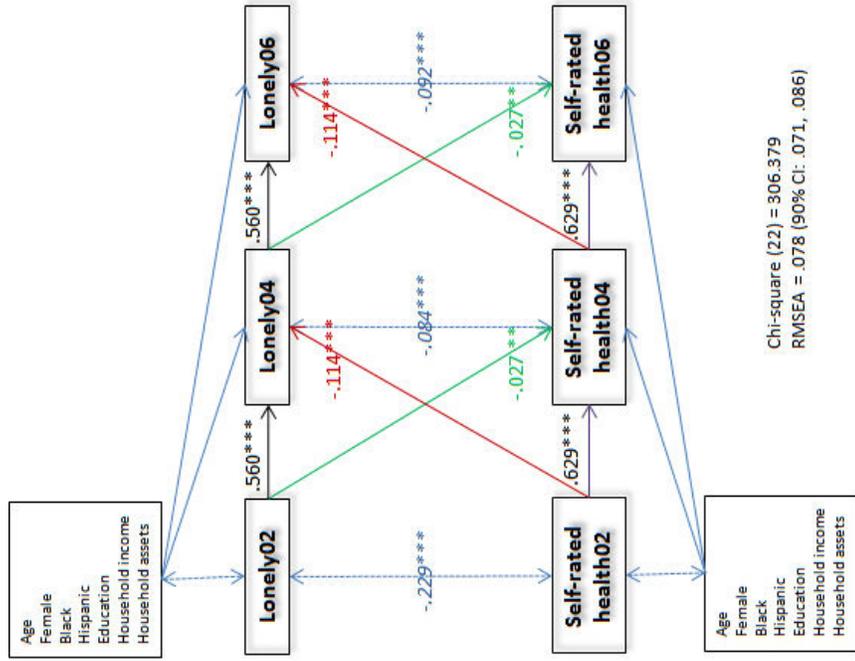
<sup>a</sup> Reference categories are “Not married,” “Never smoked,” and “White or Others”  
+ p < .1, \* p < .05, \*\* p < .01, \*\*\* p < .001

Table 3. Correlations among variables at baseline (Year 2002)

	Loneliness	Spouse health poor	Spouse health good	Relatives living nearby	Friends living nearby	Social activities	Sleep quality poor	Physical exercise	Past smoker	Current smoker	Depressive symptoms	Self-rated health	Functional limitations	Chronic conditions
Loneliness	--													
Spouse health poor <sup>a</sup>	.07**	--												
Spouse health good <sup>a</sup>	-.24***	-.57***	--											
Relatives living nearby	.00	.04*	-.02	--										
Friends living nearby	-.04+	.01	-.03	.13***	--									
Social activities	-.13***	-.08***	.18***	.02	.16***	--								
Sleep quality poor	.21***	.08***	-.08***	-.00	-.02	-.11***	--							
Physical exercise	-.08***	-.06**	.15***	.04*	.09***	.18***	-.13***	--						
Past smoker	-.02	.00	.02	-.02	.00	.02	-.02	.03	--					
Current smoker	.06*	.03	-.07**	.02	-.02	-.07**	.03	-.03	-.33***	--				
Depressive symptoms	.43***	.12***	-.18***	.01	-.04+	-.19***	.33***	-.15***	-.05*	.11***	--			
Self-rated health	-.23***	-.15***	.21***	-.02	.01	.23***	-.30***	.25***	-.02	-.04	-.37***	--		
Functional limitations	.22***	.14***	-.19***	.04+	-.01	-.22***	.34***	-.32***	.01	-.02	.39***	-.55***	--	
Chronic conditions	.07***	.06**	-.10***	.05*	.03	-.10***	.10***	-.14***	.11***	-.05*	.13***	-.40***	.37***	--
Age	.03	.04+	-.20***	.06*	.14***	-.12***	.01	-.08***	.10***	-.16***	.04+	-.15***	.17***	.25***
Female	.11***	-.01	-.13***	-.06**	-.08***	-.08***	.12***	-.09***	-.22***	-.01	.07***	-.00	.16***	-.10***
Black	.13***	.07***	-.16***	.03	-.02	-.05*	-.02	-.05*	-.00	.02	.07**	-.12***	.11***	.10***
Hispanic	.04*	.06**	-.05*	-.03	-.01	-.14***	-.01	-.07**	-.02	.01	.09***	-.13***	.03	.01
Education	-.12***	-.15***	.20***	-.12***	-.01	.29***	-.11***	.12***	.05*	-.05*	-.16***	.27***	-.21***	-.11***
Household income	-.19***	-.07***	.38***	-.06**	-.02	.21***	-.09***	.14***	-.01	-.02	-.17***	.27***	-.23***	-.15***
Household assets	-.20***	-.09***	.31***	-.02	.07***	.19***	-.10***	.18***	.05*	-.13***	-.21***	.27***	-.21***	-.13***

+  $p < .1$ , \*  $p < .05$ , \*\*  $p < .01$ , \*\*\*  $p < .001$

A. Self-Rated Health



B. Functional Limitations

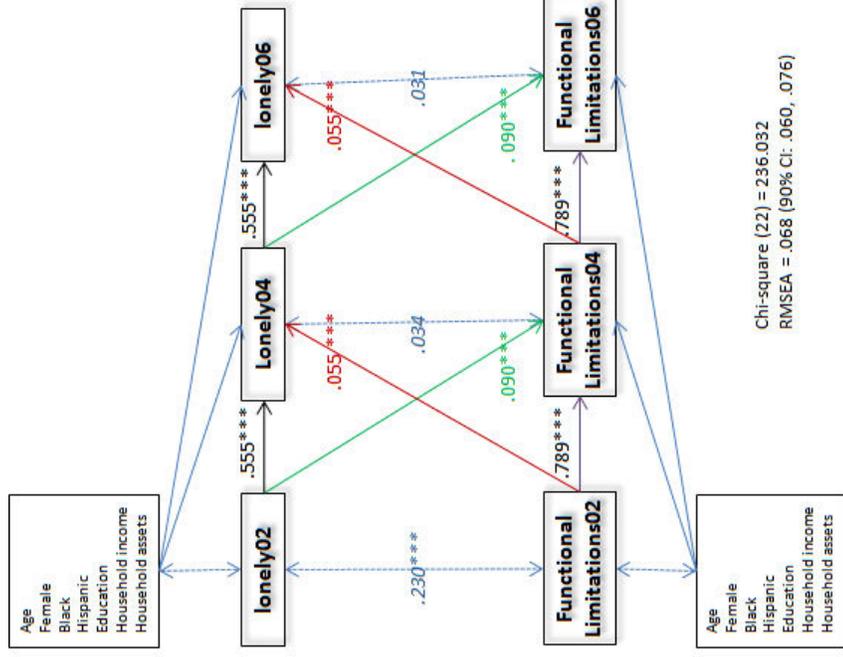
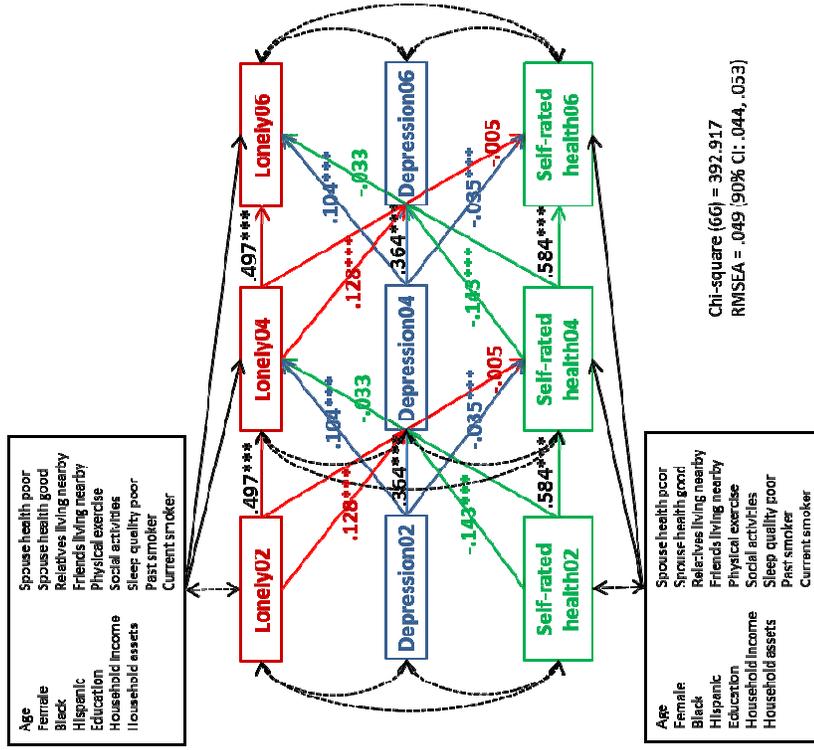


Figure 1. Structural equation models showing cross-lagged paths between loneliness and health net of demographic covariates. Italicized estimates are standardized covariances (i.e., correlations) and the remaining estimates are unstandardized coefficients. +  $p < .1$ , \*  $p < .05$ , \*\*  $p < .01$ , \*\*\*  $p < .001$ .



### A. Self-Rated Health



### B. Functional Limitations

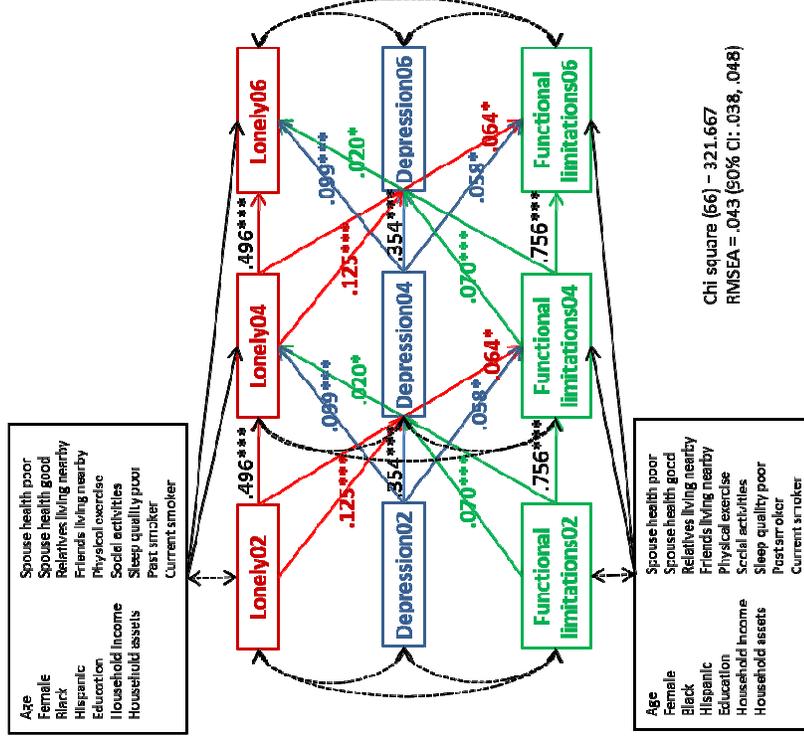


Figure 3. Structural equation models showing cross-lagged relationships between loneliness and health mediated by depressive symptoms net of demographic covariates, social relationships, and health behaviors. Numbers are unstandardized coefficients. Correlations among variables are estimated, but not shown.

+  $p < .1$ , \*  $p < .05$ , \*\*  $p < .01$ , \*\*\*  $p < .001$ .