



# HHS Public Access

Author manuscript

*J Aging Health*. Author manuscript; available in PMC 2017 August 01.

Published in final edited form as:

*J Aging Health*. 2016 August ; 28(5): 775–795. doi:10.1177/0898264315611664.

## Longitudinal Relationship Between Loneliness and Social Isolation in Older Adults: Results From the Cardiovascular Health Study

Johanna Petersen, PhD<sup>1</sup>, Jeffrey Kaye, MD<sup>1</sup>, Peter G. Jacobs, PhD<sup>1</sup>, Ana Quinones, PhD<sup>1</sup>, Hiroko Dodge, PhD<sup>1</sup>, Alice Arnold, PhD<sup>2</sup>, and Stephen Thielke, MD<sup>2</sup>

<sup>1</sup>Oregon Health & Science University, Portland, USA

<sup>2</sup>University of Washington, Seattle, USA

### Abstract

**Objective**—To understand the longitudinal relationship between loneliness and isolation.

**Method**—Participants included 5,870 adults 65 years and older ( $M = 72.89 \pm 5.59$  years) from the first 5 years of the Cardiovascular Health Study. Loneliness was assessed using a dichotomized loneliness question. Social isolation was assessed using six items from the Lubben Social Network Scale. Yearly life events were included to assess abrupt social network changes. Mixed effects logistic regression was employed to analyze the relationship between isolation and loneliness.

**Results**—Higher levels of social isolation were associated with higher odds of loneliness, as was an increase (from median) in level of social isolation. Life events such as a friend dying were also associated with increased odds of loneliness.

**Discussion**—These results suggest that average level of isolation and increases in the level of isolation are closely tied to loneliness, which has implications for future assessment or monitoring of loneliness in older adult populations.

### Keywords

loneliness; social isolation; longitudinal methods; Cardiovascular Health Study

### Introduction

Social relationships are important at all ages and are considered a key element in successful aging (Chaves, Camozzato, Eizirik, & Kaye, 2009). Many older adults have diminished opportunities for social relationships and may become lonely. Loneliness has been defined

Reprints and permissions: [sagepub.com/journalsPermissions.nav](http://sagepub.com/journalsPermissions.nav)

**Corresponding Author:** Johanna Petersen, Department of Biomedical Engineering, Oregon Health & Science University, 3303 SW Bond Ave. CH13B, Portland, OR 97239, USA. [peterjo@ohsu.edu](mailto:peterjo@ohsu.edu).

A full list of principal CHS investigators and institutions can be found at [CHS-NHLBI.org](http://CHS-NHLBI.org). The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health. The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the article.

### Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

as a subjective state resulting from a deficiency in social contacts (Peplau & Perlman, 1982). A large body of literature has focused on understanding the relationship between loneliness and health among older adults (Antonucci, Ajrouch, & Birditt, 2014). Loneliness has been associated with poor sleep quality (Hawkley, Preacher, & Cacioppo, 2010), decreased mobility (Buchman et al., 2010), and increased risk of placement in nursing home facilities (Tinetti & Williams, 1997). Loneliness has frequently been shown to predict morbidity and mortality (Luo, Hawkley, Waite, & Cacioppo, 2012; Perissinotto, Stijacic Cenzer, & Covinsky, 2012; Tilvis, Laitala, Routasalo, & Pitkala, 2011), and is associated with decreased cognitive function (Wilson et al., 2007).

Another important aspect of the social lives of older adults is their level of social isolation. While loneliness is a subjective state, social isolation is a quantitative construct arising from a deficit in social contact. Like loneliness, social isolation has significant consequences for health: Individuals who are socially isolated exhibit increased morbidity and mortality (Holt-Lunstad, Smith, & Layton, 2010), poor sleep quality (Friedman et al., 2005), and increased risk of cognitive decline (Barnes, Mendes de Leon, Wilson, Bienias, & Evans, 2004). Social isolation is typically defined as one end of a continuum encompassing the objective size of the network and the frequency of contact (E. Y. Cornwell & Waite, 2009; Wenger, Davies, Shahtahmasebi, & Scott, 1996). However, by reducing the continuum to a binary state (isolated or not), it is possible to lose relevant information regarding the level of isolation. Thus, in this article, we will not dichotomize the continuum but instead use overall level of isolation, a measure of both the size of the social network and the frequency of contact.

Although it might seem self-evident that social isolation co-occurs with loneliness, they are in fact distinct constructs (Peplau & Perlman, 1982). Several studies have examined the relationship between social isolation and loneliness (Pinquart & Sorensen, 2001; Routasalo, Savikko, Tilvis, Strandberg, & Pitkala, 2006), many of which focus on the relationship between loneliness and the size of the social network (one aspect of social isolation). For example, Berkman, Glass, Brissette, and Seeman (2000) suggested that the social network lays the foundation for support, arguing that although one may perceive a lack of support despite a large social network, without any social network, one cannot have support. Peplau and Perlman (1982) also argue that the size of the social network is one of the key determinants of loneliness. Other studies have found that individuals with no friends or children were most likely to report loneliness (Mullins, Elston, & Gutkowski, 1996) and that having small social network was significantly associated with loneliness (Hawkley et al., 2008), especially among those suffering from “social” loneliness (Dykstra & Fokkema, 2007).

Despite findings suggesting a relationship between loneliness and social isolation, only a handful of objective, longitudinal studies on this relationship exist. In 2002, Holmen and Furukawa (2002) found that loneliness was closely tied to not having a good friend to talk to in a longitudinal study of residents of Stockholm. Social network was also found to be associated with loneliness among Israeli populations (Cohen-Mansfield, Shmotkin, & Goldberg, 2009). More recently, loneliness was found to be associated with social network score among British populations (Victor & Bowling, 2012), although this study only had two time points spaced 8 years apart. Because the manifestation of loneliness may be influenced

by culture (Johnson & Mullins, 1987; Victor, Scambler, & Bond, 2008), the results from non-U.S. cohorts cannot be generalized to the U.S. older adult population. In the United States, a single study by Cacioppo, Hawkley, and Thisted (2010) found social isolation was associated with both loneliness and depression. However, the main outcome of this study was to understand the relationship between loneliness and depression, not to understand the complex relationship between loneliness and social isolation.

Remarkably, none of the longitudinal studies investigated the relationship between *change* in isolation (measured either via life events that directly or indirectly impact the social network or a deviation in social network score) and loneliness—a particularly important relationship to understand given that changes in social network (which would manifest as changes in the level of isolation) are related to health outcomes independent of baseline network size (B. Cornwell & Laumann, 2015). Still, a qualitative study on the causes of loneliness in older adults found that the greatest causes of loneliness were “life events” that cause changes in either one’s ability to interact with the available social network or in the social network itself (Savikko, Routasalo, Tilvis, Strandberg, & Pitkala, 2005).

In this article, we examine the relationship between isolation and self-reported loneliness among a large group of U.S. older adults surveyed yearly for 5 years. We examine several variables designed to assess both overall level of isolation and changes in the level of isolation over time. These include life events that may cause a change in the level of isolation (e.g., the death of a spouse), the median social isolation score for a given individual (calculated across all available years of data), and yearly deviations from the median isolation score for a given individual. By separating social isolation into the median across years and the individual deviation from the median for a given year, we can elucidate the impact that general isolation levels have on loneliness (across individuals) and the effect of deviations in the level of isolation (within the same individual). We hypothesize that individuals who have recently experienced a life event that would cause a change in the level of isolation will be more likely to report feelings of loneliness. We also hypothesize that both higher median levels of isolation (across individuals) and increases in the level of isolation from the median (within the same individual) will be associated with a higher probability of reporting loneliness.

## Design and Method

### Study Design

Data for this study came from the first 5 years of the Cardiovascular Health Study (CHS), an ongoing observational study on the risk factors for cardiovascular disease in U.S. adults aged 65 and older. A total of 5,888 participants were enrolled from Medicare eligibility lists in four different communities. In 1989–1990, 5,201 participants were enrolled and an additional 687 African American participants were enrolled in 1992–1993. Exclusion criteria at baseline included institutionalization, receiving hospice care or radiation chemotherapy for cancer, and not expecting to stay in the area for the next 3 years. Participants were also excluded if they were not ambulatory at home or if they were not able to be interviewed. All participants received up to 10 annual in-person interviews and 6-month telephone calls until 1999 when they started receiving telephone calls twice per year.

Demographics collected at baseline include age, sex, race, and education. The institutional review board (IRB) of each of the sites and the coordinating center approved the study. In addition, the IRB at Oregon Health & Science University approved the reanalysis of the data set described here (IRB 10006). Details of the study design and sampling methods have been described elsewhere (Fried et al., 1991; Tell et al., 1993).

## Participants

During the first 5 years of the study, participants were asked questions regarding social network and life events, which were subsequently discontinued. The current study uses these social data to examine the relationship between change in isolation and loneliness. A complete descriptive summary of the demographic characteristics of the cohort at baseline and during the 4 years of follow-up is provided in Table 1. Only those participants who answered the loneliness question (described in the section “Measures”) are included in tables or analyses.

## Measures

**Loneliness**—Subjective loneliness was assessed using a question from the Center for Epidemiological Studies Depression (CES-D) scale (Radloff, 1977). The question asks, “In the last week, I felt lonely” with answer options (i) rarely/none of the time, (ii) some or a little of the time, (iii) a moderate amount of time, and (iv) most of the time. We dichotomized loneliness to “not lonely” (i) versus “lonely” (ii, iii, and iv).

**Social isolation**—Social isolation was measured using 6 items from Lubben’s Social Network Scale (Lubben, 1988), which was developed as a modification to the Berkman–Syme social network index to specifically target older adults (Berkman & Syme, 1979). This questionnaire asks 10 questions: three questions regarding family relationships, three targeting friend relationships, three looking at independent social support, and one identifying living situation (with others or alone). Each question is answered categorically and converted to a score ranging from 0 to 5. The scores on the six questions regarding friend and family relationships were summed to give a summary “network score” between 0 and 30. Because this analysis is specifically looking at the relationship between the level of isolation and loneliness, the three questions targeting social support were not included in the summary isolation score. This ensures that any observed relationship between loneliness and social isolation is due to changes in the level of social isolation, not changes in perceived support. In addition, living situation was included in the analysis separately as a binary variable.

To understand how both overall social isolation and change in social isolation affect loneliness, we included two variables. For the first, we calculated each individual’s median isolation score over the time period as a measure of average level of social isolation. For each individual, we then calculated each year’s offset from the median as a representation of *deviation* in the level of isolation from the individual’s median (Figure 1). We used difference in level of isolation from the median level instead of from the previous year because this captures longer term trends in isolation levels (not simply the previous year, but the average over the time period).

**Life events**—Five questions were included in the model regarding major life events: (a) Did somebody close to you die? (b) Did a significant relationship become considerably worse? (c) Did someone close to you have an illness? (d) Was a grandchild born? and (e) Have you been caring for a sick or disabled person? Each year, participants indicated whether any of the life events had occurred within the last 6 months (“yes” or “no”). Each question was included in the model independently to understand the specific influence of each type of life event on the perception of loneliness.

**Additional covariates**—We included variables in the models that might confound the relationship between loneliness and social isolation. Because cognitive function has been shown to impact one’s ability to form and maintain relationships (Barnes et al., 2004), it was important to control for cognitive function in the model. Cognitive function was measured using the Modified Mini-Mental State Examination (3MSE; Teng & Chui, 1987) in Years 1 to 4. Because the 3MSE was not used at baseline, values from Year 1 were lagged backward to the baseline year as scores on sequential years were highly correlated ( $\rho = .80$ ). Scores on the 3MSE range from 0 to 100. The average 3MSE score in this cohort was  $90.6 \pm 8.6$  at Year 1. Health status at each year was determined by calculating whether or not a participant had any prior report of cardiovascular disease, cancer, chronic obstructive pulmonary disease, kidney disease, or was taking any medication for diabetes.

## Data Analysis

**Descriptive analysis**—We first computed descriptive statistics for all variables included in the model. Because the scores on the social network questionnaires are highly skewed to the left (large social network), we computed the median and interquartile range (IQR), a robust measure of variability, for the Social Network Scale. These are computed yearly on the available data for all participants who completed the corresponding year’s CES-D loneliness item. We also computed the percent of positive responses for all life events variables for all years.

**Transition probability analysis**—To understand the stability of loneliness, we created a transition probability graph describing the probability of transitioning between lonely and non-lonely states. Transition probabilities were computed between adjoining years (e.g., from Year 2 to Year 3) by calculating the total number of participants who transitioned between states (e.g., lonely to not lonely) and dividing that number by the total number of participants who were in the starting state (e.g., lonely) in the first of the two adjoining years *and* answered the CES-D loneliness question both years. For each possible state change (e.g., lonely to non-lonely), a total of four transition probabilities were computed: one for each year pair. The overall transition probability across years was computed as the average transition probability across the 4 years of follow-up data.

**Logistic regression mixed effects models**—Longitudinal mixed effects logistic regression models were employed in Stata (StataCorp, Texas, Version 13) to examine the relationship between loneliness and the level of isolation over time. The mixed effects regression framework allows for repeated measures of the same individual by including individual-specific offset terms. Thus, all available data from all years (those shown in Table

1) are included in the model together, allowing the model to fit both group and individual effects over time. The variables used in the first model were missing an average of 2% of cases each year (max = 7.6%, min = 0%). To avoid biases associated with list-wise deletion and to maximize efficiency, chained multiple imputation (Stata command: *mi impute chained*) was employed on all variables used in the first model with missing data due to non-response (imputation was not employed on participants who died or were lost to follow-up). The outcome variable was not imputed. Ten imputed data sets were generated to ensure reliability and consistency of the imputed results. The average number of observations included in the model per individual was four, and the minimum number of observations was one. To ensure coefficient estimates were not biased by multicollinearity, the variance inflation factor (VIF), a standard diagnostic tool for assessing the level of collinearity of the independent variables, was computed for all independent variables. The VIF for all variables was below 2.5, indicating any bias from multicollinearity can reasonably be ignored (Allison, 2012). Because of the number of prior analyses that have been performed using this data set, *p* value of .01 was considered significant.

## Results

### Descriptive Statistics

As shown in Table 1, the mean participant age was  $72.8 \pm 5.6$  years at baseline; 57% of the cohort was female, and 70% was married. By the end of the analysis period, the mean age was  $75.9 \pm 5.3$  years, the proportion of females was 59%, and the proportion of married individuals was 67%. An average of 23% of the participants (averaged across years) reported feeling lonely at least some of the time. Only an average of 3.8% of the participants reported feeling lonely most of the time in the previous week. The median social network score was 20 (of 30 possible points) with an IQR of 6 at baseline, and increased to 21 (IQR = 5) by the last year of the analysis.

An average of 27.54% of the cohort reported that somebody close died within the last 6 months (averaged across years), and an average of 27.52% of the cohort reported that somebody close had an illness. Having a significant relationship become worse was relatively uncommon, with only an average of 4.7% of the cohort reporting this each year. Only 11% of the cohort reported the birth of a grandchild each year. Finally, an average of 9.2% of the cohort reported they had been caring for a sick or disabled person during the last 6 months.

### Transition Probability

Figure 2 shows the average annual probability (*p*) of transitioning between states of loneliness from one year to the next. Only an average of 13% of individuals who were not lonely one year transitioned to feeling lonely at least sometimes in the next year, while 87% of those who were not lonely one year remained non-lonely the next year. In contrast, an average of 40% of individuals reporting loneliness one year transitioned to non-lonely by the next year, while 60% of the individuals reporting loneliness one year remained lonely in the next year. Although there was a greater probability of resolving than developing loneliness,



overall there was a slight increase in loneliness over time (from 22% to 25% of the cohort) because of the larger number of individuals in the non-lonely group.

### Loneliness and Social Isolation

The results of the longitudinal logistic regression between loneliness and social isolation are shown in Table 2. The variable most strongly associated with loneliness was living alone, which was associated with 79% higher odds of reporting loneliness. Loneliness was also significantly related to the median level of social isolation across years (between-person effect) and the yearly deviation in the level of social isolation relative to the individual's median (within-person effect). These variables are shown in Table 2 as “median social network score” and “deviation in social network score,” respectively. Across individuals, those with one additional point in their median social network score (which corresponds to a lower level of social isolation) had 11% lower odds of reporting loneliness. Thus, compared with those who are fully connected (score of 30 on the social network score), those who are completely isolated (score of 0 on the social network score) have 97% higher odds of reporting at least some loneliness.

Within the same individual, years where the social network score was higher than that individual's median social network score across years (indicating lower than normal levels of social isolation) had 3% lower odds of reporting loneliness per unit increase in social network score relative to the median—a small yet significant change in the odds of reporting loneliness. Thus, for the individual shown in Figure 1, the odds of reporting loneliness in Year 1 are 6% lower than that in Year 2 (social network score is 2 points higher than the median in Year 1), and 3% higher in Year 3 as compared with Year 2. The most any participant deviated from their median was 17 points in either direction, indicating the maximum effect of this variable was a 40% change in the odds of reporting loneliness.

Among the life events variables, the variable most strongly associated with loneliness was reporting that a significant relationship became considerably worse, which was associated with a 125% higher odds of reporting loneliness (Table 2). Caring for a sick or disabled person was also associated with 54% higher odds of reporting loneliness, although reporting that somebody close had an illness was not a significant predictor of loneliness levels. Reporting that someone close died was associated with 22% higher odds of reporting loneliness. Surprisingly, those who reported a grandchild had been born in the last year also had 17% higher odds of reporting loneliness, although this result was not significant ( $p > .01$ ).

Consistent with other studies on factors associated with loneliness, widowhood was associated with 61% higher odds of reporting loneliness relative to being married (shown in Table 2). Marital status was assessed at baseline and considered constant across the monitoring period; thus, the effect of widowhood represents the differential odds of reporting loneliness for widows compared with married participants and does not represent the change in the odds of reporting loneliness at the onset of widowhood. Men had 46% lower odds of reporting loneliness relative to females, and each unit increase in 3MSE score (associated with higher cognitive function) was associated with 2% lower odds of reporting loneliness. Having significant chronic diseases was also associated with 45% higher odds of

reporting loneliness, and each increase in years of education was associated with 3% lower odds of reporting loneliness. In this full model, age was not significantly related to loneliness. This result was not consistent with prior studies on loneliness, leading to a post hoc analysis investigating the univariate association between age and loneliness. In this analysis, age was significantly associated with loneliness (results not shown).

## Discussion

In this article, we have shown that loneliness is closely tied to both the median level of isolation, and deviations from an individual's normal level of isolation. We found that life events that would affect the level of isolation are closely related to the probability of reporting loneliness. In our first analysis, we presented a transition probability graph of loneliness, showing that loneliness is a relatively stable state: 60% of participants who report loneliness one year will also report it the following year. We also found the percentage of participants reporting loneliness was gradually increasing each year, ending at nearly 25% reporting at least some loneliness in the final year of the analysis.

Both the median social isolation and *deviations* from an individual's median level of isolation were significantly related to loneliness. We found that relative to those experiencing the highest level of isolation, those with the largest possible social network score had 97% lower odds of reporting loneliness. In addition, a decrease in social network score relative to an individual's median score (which may arise due to changes in the number of connections or the frequency of seeing the available connections) significantly increased the odds of reporting loneliness. Thus, individuals who began at a low level of isolation and then became highly isolated over the time period are more likely to report loneliness than those who began at a high level of isolation and remained there for the entire monitoring period (holding all other variables constant). Still, the effect of being very isolated was larger than the effect of *becoming* isolated over the monitoring period. This may be because participants exhibiting low social network scores have limited ability to become more isolated but may be more impacted by changes in social isolation. Future studies should investigate the relationship between changes in social isolation and loneliness among those who are already experiencing social isolation. It may also be that the effect of the deviation variable is smaller because some changes in the social network such as the loss of a close friend who is then replaced by a new friend would not show up in this measure of social isolation. This is highlighted in the significance of the life events variables, which dramatically affected the odds of reporting loneliness. These results are consistent with previous longitudinal studies on the relationship between loneliness and social isolation (Cacioppo et al., 2010; Tjshuis, De Jong-Gierveld, Feskens, & Kromhout, 1999), and suggest that future studies investigating the relationship between health and loneliness or social isolation should account for the correlation between these two variables.

It should be noted that although the model considers deviations in social isolation as a predictor of loneliness, the causality of the relationship cannot be inferred from this observational study. Hawkey et al. demonstrate that lonely individuals have more negative social interactions than their nonlonely counterparts (Hawkey, Preacher, & Cacioppo, 2007), and that these negative social interactions lead to additional future negative



interactions. Thus, as loneliness progresses, individuals engage with others more negatively and may also perceive more negative emotions from others causing them to retract further from social relationships, thereby furthering their isolation and loneliness (Cacioppo & Hawkley, 2009).

In addition to finding the level of isolation was associated with loneliness, we also discovered that participants who experienced a life event that impacted their level of isolation were considerably more likely to report loneliness. This included events that would directly affect the social network such as having a significant relationship become worse or losing a close friend or family member as well as those that may indirectly affect the level of social isolation such as caring for a sick or disabled person (although this is more like a state change than a life event). Of course, it is natural and even healthy to mourn the loss of a close friend or family member. However, given the close relationship between loneliness and health, it is important to help individuals suffering from loss to engage in their community and build new relationships. Methods to identify and help such individuals may become increasingly important as the number of older adults continues to rise. Some interventions have been designed which specifically target individuals suffering from bereavement (Stewart, Craig, MacPherson, & Alexander, 2001); still, a better understanding of loneliness and its causes may help in the design and implementation of such interventions.

Caring for a sick or disabled person may hamper the frequency with which one can interact with the available social networks. Many studies have investigated the relationship between caregiving and health, and have found that caregiving, especially for a friend or family member, reduces well-being (Verbakel, 2014) and increases stress (Gallagher-Thompson et al., 2006) and depression (Butler, Turner, Kaye, Ruffin, & Downey, 2005). The results presented here also suggest that caregiving increases the likelihood of feeling lonely, which is consistent with qualitative studies on loneliness and caregiving (Tunstall, 1966). This highlights the need to provide resources and support for those who are caring for a family member or loved one.

Consistent with previous work, gender, cognitive status, marital status, education, and health status were all associated with the probability of reporting loneliness. In the full model, age was not a significant predictor of loneliness. However, in a univariate model of age and loneliness, increased age was associated with higher odds of reporting loneliness. This suggests that the relationship between loneliness and age that has been found in previous studies may be due to changes in health status, social network, or life events that are more likely to accrue with increased age.

This study has some limitations. First, the data included in the analysis are from 1989 to 1992: more than 20 years old. An entirely new generation has moved into old age, with possibly different values, beliefs, and means of socializing (e.g., online communities). It is possible that the results reported here will not generalize to the new generation of older adults. As noted, the study also included only 5 years of data, and therefore may not have been sensitive to the full relationship between loneliness and changes in isolation. Future studies should investigate these relationships over longer time periods. In addition, the Social Network Scale used as part of the CHS only has six questions on social isolation and

does not include measures such as community involvement or church attendance which are frequently included in measures of social isolation. Future studies should investigate how changes in these aspects of isolation affect loneliness.

Finally, loneliness was assessed using a direct question regarding the perception of loneliness in the last week. Although this loneliness assessment technique has excellent face validity and has been employed in numerous studies, it also has several drawbacks. First, individuals experiencing loneliness are frequently perceived as weaker, less attractive, and more passive than their non-lonely counterparts. Due to these social stigmas associated with loneliness, it is possible that many participants will avoid reporting loneliness even when they are quite lonely, leading to an underestimate of loneliness in the population and erroneous estimation of the association between loneliness and health outcomes. In addition, assessing loneliness via a single question assumes that loneliness is a unidimensional construct so the only difference between individuals is the frequency or intensity of perceived loneliness (Victor, Grenade, & Boldy, 2005). Weiss argued that loneliness is in fact multidimensional, encompassing both an emotional loneliness (the loneliness for significant attachment figure such as a spouse) and a social loneliness (the loneliness for close friends; Weiss, 1973). Assessing loneliness via a single question cannot capture these differences in the type of loneliness experienced, or the differences in the relationship between loneliness and isolation in these two types of loneliness. Previous work by Dykstra and Fokkema noted that individuals who were experiencing social loneliness were affected by the size of their social network, while those experiencing emotional loneliness felt lonely independent of the social network (Dykstra & Fokkema, 2007). Future studies are required to fully understand the relationship between changes in social isolation and the experience of emotional and social loneliness.

In this article, we have shown that loneliness is associated with both the level of isolation and deviations in an individual's level of isolation. These results have important consequences for future studies on loneliness, especially on the identification of lonely individuals. Because loneliness may change in response to many life events and is closely related to social isolation, it may be more timely and informative to identify lonely individuals by tracking changes in the social network or other daily behaviors using unobtrusive monitoring techniques (Kaye et al., 2010; Petersen, Austin, Kaye, Pavel, & Hayes, 2014). For example, tracking call history would enable assessment of social network size and frequency of contact—the two major components of social isolation scales (Petersen, Thielke, Austin, & Kaye, 2015). Other behaviors that may relate to loneliness that can be tracked unobtrusively include time spent outside the home (Petersen et al., 2014; Petersen, Austin, Mattek, & Kaye, 2015), computer use (Amichai-Hamburger & Ben-Artzi, 2003), and sleep quality (Hawkey et al., 2010). Such approaches to loneliness identification would have dramatic consequences for the understanding of loneliness, enabling researchers to monitor and assess loneliness levels on smaller timescales such as daily or even hourly.

## Acknowledgments

### Funding

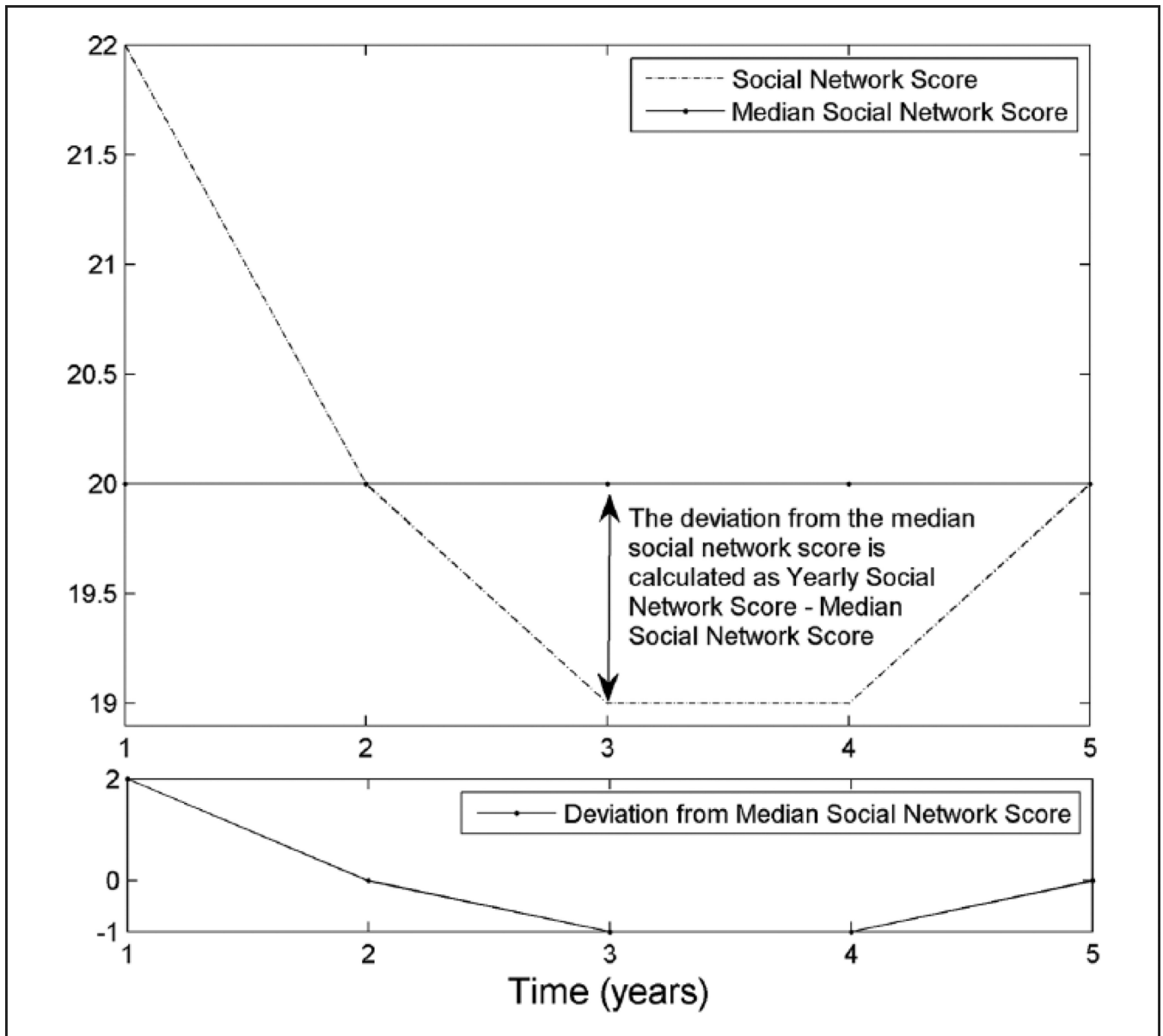
The authors disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This research was supported by Contracts HHSN268201200036C, HHSN268200800007C, N01HC55222, N01HC85079, N01HC85080, N01HC85081, N01HC85082, N01HC85083, N01HC85086, and Grant U01HL080295 from the National Heart, Lung, and Blood Institute (NHLBI), with additional contribution from the National Institute of Neurological Disorders and Stroke (NINDS). Additional support was provided by R01AG023629 from the National Institute on Aging (NIA). Dr. Quiñones is supported by the American Diabetes Foundation (ADA 7-13-CD-08).

## References

- Allison P. When can you safely ignore multicollinearity?. 2012 Retrieved from <http://www.statisticalhorizons.com/multicollinearity>.
- Amichai-Hamburger Y, Ben-Artzi E. Loneliness and Internet use. *Computers in Human Behavior*. 2003; 19:71–80.
- Antonucci TC, Ajrouch KJ, Birditt KS. The convoy model: Explaining social relations from a multidisciplinary perspective. *Gerontologist*. 2014; 54:82–92. [PubMed: 24142914]
- Barnes LL, Mendes de Leon CF, Wilson RS, Bienias JL, Evans DA. Social resources and cognitive decline in a population of older African Americans and whites. *Neurology*. 2004; 63:2322–2326. [PubMed: 15623694]
- Berkman LF, Glass T, Brissette I, Seeman TE. From social integration to health: Durkheim in the new millennium. *Social Science & Medicine*. 2000; 51:843–857. [PubMed: 10972429]
- Berkman LF, Syme SL. Social networks, host resistance, and mortality: A nine-year follow-up study of Alameda County residents. *American Journal of Epidemiology*. 1979; 109:186–204. [PubMed: 425958]
- Buchman AS, Boyle PA, Wilson RS, James BD, Leurgans SE, Arnold SE, Bennett DA. Loneliness and the rate of motor decline in old age: The Rush Memory and Aging Project, a community-based cohort study. *BMC Geriatrics*. 2010; 10:77–84. [PubMed: 20969786]
- Butler SS, Turner W, Kaye LW, Ruffin L, Downey R. Depression and caregiver burden among rural elder caregivers. *Journal of Gerontological Social Work*. 2005; 46(1):47–63. [PubMed: 16338884]
- Cacioppo JT, Hawley LC. Perceived social isolation and cognition. *Trends in Cognitive Sciences*. 2009; 13:447–454. [PubMed: 19726219]
- Cacioppo JT, Hawley LC, Thisted RA. Perceived social isolation makes me sad: 5-year cross-lagged analyses of loneliness and depressive symptomatology in the Chicago Health, Aging, and Social Relations Study. *Psychology and Aging*. 2010; 25:453–463. [PubMed: 20545429]
- Chaves ML, Camozzato AL, Eizirik CL, Kaye J. Predictors of normal and successful aging among urban-dwelling elderly Brazilians. *The Journals of Gerontology, Series B: Psychological Sciences & Social Sciences*. 2009; 64:597–602.
- Cohen-Mansfield J, Shmotkin D, Goldberg S. Loneliness in old age: Longitudinal changes and their determinants in an Israeli sample. *International Psychogeriatrics*. 2009; 21:1160–1170. [PubMed: 19785916]
- Cornwell B, Laumann EO. The health benefits of network growth: New evidence from a national survey of older adults. *Social Science & Medicine*. 2015; 125:94–106. [PubMed: 24128674]
- Cornwell EY, Waite LJ. Measuring social isolation among older adults using multiple indicators from the NSHAP study. *The Journals of Gerontology, Series B: Psychological Sciences & Social Sciences*. 2009; 64(Suppl. 1):i38–i46.
- Dykstra PA, Fokkema T. Social and emotional loneliness among divorced and married men and women: Comparing the deficit and cognitive perspectives. *Basic and Applied Social Psychology*. 2007; 29:1–12.
- Fried LP, Borhani NO, Enright P, Furberg CD, Gardin JM, Kronmal RA, Newman A. The Cardiovascular Health Study: Design and rationale. *Annals of Epidemiology*. 1991; 1:263–276. [PubMed: 1669507]
- Friedman EM, Hayney MS, Love GD, Urry HL, Rosenkranz MA, Davidson RJ, Ryff CD. Social relationships, sleep quality, and interleukin-6 in aging women. *Proceedings of the National Academy of Sciences of the United States of America*. 2005; 102:18757–18762. [PubMed: 16339311]

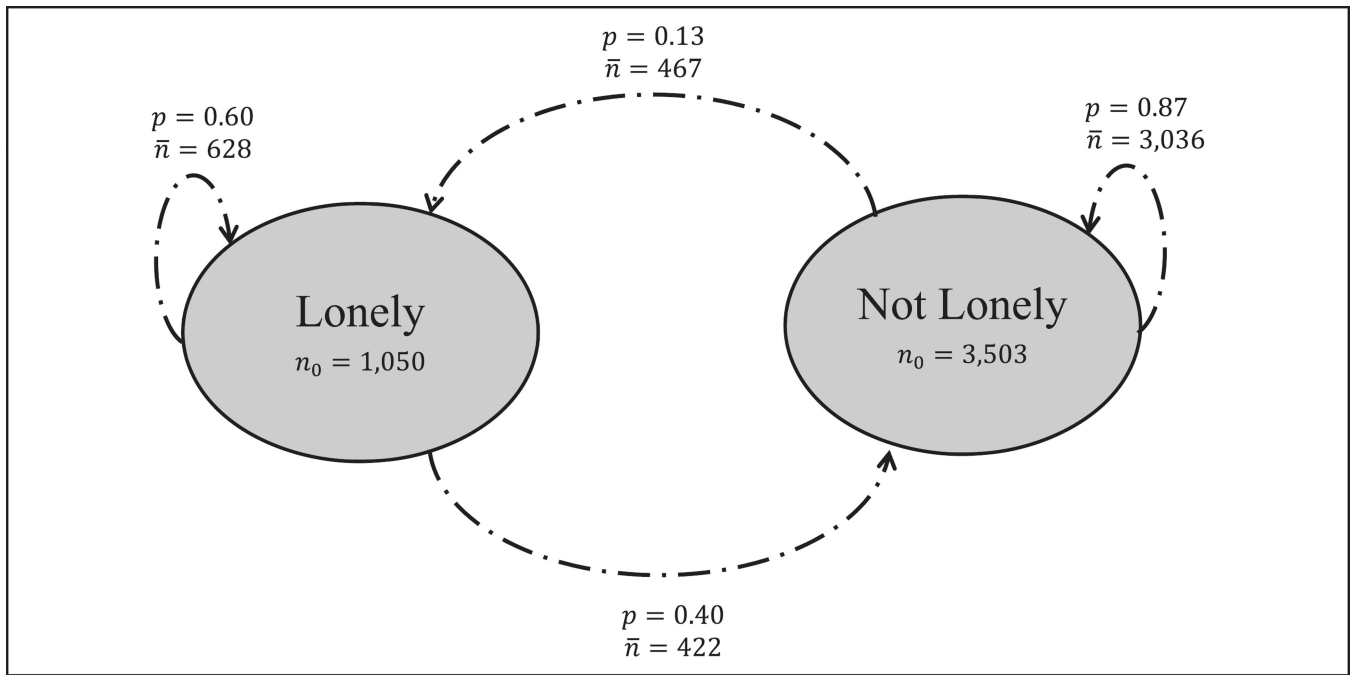
- Gallagher-Thompson D, Shurgot GR, Rider K, Gray HL, McKibbin CL, Kraemer HC, Thompson LW. Ethnicity, stress, and cortisol function in Hispanic and non-Hispanic white women: A preliminary study of family dementia caregivers and noncaregivers. *The American Journal of Geriatric Psychiatry*. 2006; 14:334–342. [PubMed: 16582042]
- Hawkey LC, Hughes ME, Waite LJ, Masi CM, Thisted RA, Cacioppo JT. From social structural factors to perceptions of relationship quality and loneliness: The Chicago health, aging, and social relations study. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*. 2008; 63:S375–S384.
- Hawkey, LC.; Preacher, KJ.; Cacioppo, JT. Multilevel modeling of social interactions and mood in lonely and socially connected individuals: The MacArthur social neuroscience studies. In: Ong, AD.; Van Dulmen, MHM., editors. *Oxford handbook of methods in positive psychology*. New York, NY: Oxford University Press; 2007. p. 559-575.
- Hawkey LC, Preacher KJ, Cacioppo JT. Loneliness impairs daytime functioning but not sleep duration. *Health Psychology*. 2010; 29:124–129. [PubMed: 20230084]
- Holmen K, Furukawa H. Loneliness, health and social network among elderly people—A follow-up study. *Archives of Gerontology and Geriatrics*. 2002; 35:261–274. [PubMed: 14764365]
- Holt-Lunstad J, Smith TB, Layton JB. Social relationships and mortality risk: A meta-analytic review. *PLoS Medicine*. 2010; 7(7):e1000316. [PubMed: 20668659]
- Johnson DP, Mullins LC. Growing old and lonely in different societies: Toward a comparative perspective. *Journal of Cross-Cultural Gerontology*. 1987; 2:257–275. [PubMed: 24389861]
- Kaye JA, Maxwell SA, Mattek N, Hayes TL, Dodge H, Pavel M, Zitzelberger TA. Intelligent systems for assessing aging changes: Home-based, unobtrusive, and continuous assessment of aging. *The Journals of Gerontology, Series B: Psychological Sciences & Social Sciences*. 2010; 66(Suppl. 1):i180–i190.
- Lubben JE. Assessing social networks among elderly populations. *Family & Community Health*. 1988; 11(3):42–52.
- Luo Y, Hawkey LC, Waite LJ, Cacioppo JT. Loneliness, health, and mortality in old age: A national longitudinal study. *Social Science & Medicine*. 2012; 74:907–914. [PubMed: 22326307]
- Mullins LC, Elston CH, Gutkowski SM. Social determinants of loneliness among older Americans. *Genetic, Social, and General Psychology Monographs*. 1996; 122:453–473.
- Peplau, LA.; Perlman, D. Perspectives on loneliness. In: Peplau, LA.; Perlman, D., editors. *Loneliness: A sourcebook of current theory, research, and therapy*. New York, NY: Wiley; 1982. p. 1-18.
- Perissinotto CM, Stijacic Cenzer I, Covinsky KE. Loneliness in older persons: A predictor of functional decline and death. *Archives of Internal Medicine*. 2012; 172:1078–1083. [PubMed: 22710744]
- Petersen J, Austin D, Kaye J, Pavel M, Hayes T. Unobtrusive in-home detection of time spent out-of-home with applications to loneliness and physical activity. *IEEE Journal of Biomedical and Health Informatics*. 2014; 18:1590–1596. [PubMed: 25192570]
- Petersen J, Austin D, Mattek N, Kaye J. Time out-of-home and cognitive, physical, and emotional wellbeing of older adults: A longitudinal mixed effects model. *PLoS One*. 2015; 10(10):e0139643. [PubMed: 26437228]
- Petersen J, Thielke S, Austin D, Kaye J. Phone behaviour and its relationship to loneliness in older adults. *Aging & Mental Health*. 2015 Advance online publication.
- Pinquart M, Sorensen S. Influences on loneliness in older adults: A meta-analysis. *Basic and Applied Social Psychology*. 2001; 23:245–266.
- Radloff LS. The CES-D scale a self-report depression scale for research in the general population. *Applied Psychological Measurement*. 1977; 1:385–401.
- Routasalo PE, Savikko N, Tilvis RS, Strandberg TE, Pitkala KH. Social contacts and their relationship to loneliness among aged people—A population- based study. *Gerontology*. 2006; 52(3):181–187. [PubMed: 16645299]
- Savikko N, Routasalo P, Tilvis RS, Strandberg TE, Pitkala KH. Predictors and subjective causes of loneliness in an aged population. *Archives of Gerontology and Geriatrics*. 2005; 41:223–233. [PubMed: 15908025]

- Stewart M, Craig D, MacPherson K, Alexander S. Promoting positive affect and diminishing loneliness of widowed seniors through a support intervention. *Public Health Nursing*. 2001; 18:54–63. [PubMed: 11251874]
- Tell GS, Fried LP, Hermanson B, Manolio TA, Newman AB, Borhani NO. Recruitment of adults 65 years and older as participants in the Cardiovascular Health Study. *Annals of Epidemiology*. 1993; 3:358–366. [PubMed: 8275211]
- Teng EL, Chui HC. The Modified Mini-Mental State (3MS) examination. *Journal of Clinical Psychiatry*. 1987; 48:314–318. [PubMed: 3611032]
- Tijhuis MA, De Jong-Gierveld J, Feskens EJ, Kromhout D. Changes in and factors related to loneliness in older men. The Zutphen Elderly Study. *Age Ageing*. 1999; 28:491–495. [PubMed: 10529046]
- Tilvis RS, Laitala V, Routasalo PE, Pitkala KH. Suffering from loneliness indicates significant mortality risk of older people. *Journal of Aging Research*. 2011; 2011:1–5.
- Tinetti ME, Williams CS. Falls, injuries due to falls, and the risk of admission to a nursing home. *New England Journal of Medicine*. 1997; 337:1279–1284. [PubMed: 9345078]
- Tunstall, J. *Old and alone: A sociological study of old people*. London, England: Routledge & Kegan Paul; 1966.
- Verbakel E. Informal caregiving and well-being in Europe: What can ease the negative consequences for caregivers? *Journal of European Social Policy*. 2014; 24:424–441.
- Victor CR, Bowling A. A longitudinal analysis of loneliness among older people in Great Britain. *The Journal of Psychology: Interdisciplinary and Applied*. 2012; 146:313–331. [PubMed: 22574423]
- Victor CR, Grenade L, Boldy D. Measuring loneliness in later life: A comparison of differing measures. *Reviews in Clinical Gerontology*. 2005; 15:63–70.
- Victor, CR.; Scambler, S.; Bond, J. *The social world of older people: Understanding loneliness and social isolation in later life*. New York, NY: McGraw-Hill; 2008.
- Weiss, RS. *Loneliness: The experience of emotional and social isolation*. Cambridge, MA: The MIT Press; 1973.
- Wenger GC, Davies R, Shahtahmasebi S, Scott A. Social isolation and loneliness in old age: Review and model refinement. *Ageing & Society*. 1996; 16:333–358.
- Wilson RS, Krueger KR, Arnold SE, Schneider JA, Kelly JF, Barnes LL, Bennett DA. Loneliness and risk of Alzheimer disease. *Archives of General Psychiatry*. 2007; 64:234–240. [PubMed: 17283291]



**Figure 1.** Example data from one participant showing the social network score for each time point, the calculated median social network score (per participant), and the calculated deviation from the median social network score (calculated for each year).





**Figure 2.**

Graph of the average annual transition probability ( $p$ ) between states of loneliness.

*Note.* The variable,  $n_0$ , represents the number of people in each category at baseline, while  $\bar{n}$  represents the average number of people transitioning between each category across years.

**Table 1**  
 Descriptive Statistics of the Variables Included in the Model of Loneliness and Social Isolation at Each Assessment Year.

	Baseline (n = 5,194)	Year 1 (n = 4,894)	Year 2 (n = 4,659)	Year 3 (n = 5,059)	Year 4 (n = 4,600)
Age (years) <sup>a</sup>	72.8 (5.6)	73.6 (5.4)	74.54 (5.4)	75.06 (5.4)	75.92 (5.3)
Gender (%) <sup>b</sup>					
Male	43.0	42.9	42.4	41.3	40.7
Female	57.0	57.1	57.6	58.7	59.3
Marital status (%) <sup>b</sup>					
Married	69.1	69.7	69.2	66.5	66.7
Widowed	23.0	22.5	22.7	24.2	24.1
Divorced/separated	3.8	3.6	3.7	5.2	5.2
Never married	4.1	4.2	4.3	4.1	4.0
Education (years) <sup>a</sup>	13.9 (4.7)	14.0 (4.7)	14.0 (4.7)	13.9 (4.7)	14.0 (4.7)
Race (%) <sup>b</sup>					
Black	4.7	4.3	4.4	17.3	16.0
Non-Black	95.3	95.7	95.6	82.7	84.0
3MSE score <sup>a</sup>	—	90.6 (8.6)	90.8 (9.5)	89.7 (10.0)	90.6 (10.3)
Living situation (%) <sup>b</sup>					
Alone	9.8	22.2	25.1	27.8	28.8
With others	76.7	75.6	74.8	72.1	69.6
Felt lonely (%) <sup>b</sup>					
Most of the time	3.0	3.9	3.8	4.2	3.9
Moderate amount of time	4.3	4.9	4.8	4.8	4.9
At least some of the time	14.5	15.2	15.1	16.4	15.7
Rarely/never	78.2	76.0	76.4	74.6	75.5
Social network score <sup>c</sup>	20 (6)	20 (6)	20 (6)	21 (5)	21 (5)
Somebody close died <sup>b</sup>					
Yes	30.6	25.4	26.3	27.9	27.5
No	69.2	74.5	73.5	72.1	72.3

	Baseline (n = 5,194)	Year 1 (n = 4,894)	Year 2 (n = 4,659)	Year 3 (n = 5,059)	Year 4 (n = 4,600)
A significant relationship became considerably worse <sup>b</sup>					
Yes	6.6	4.1	3.8	4.8	4.3
No	93.2	95.8	95.9	95.1	95.5
Somebody close had illness <sup>b</sup>					
Yes	30.9	25.4	29.3	26.6	25.4
No	69.0	74.6	70.6	73.3	74.3
A grandchild was born <sup>b</sup>					
Yes	9.2	11.2	10.8	12.6	12.0
No	90.7	81.2	89.0	87.3	87.6
Been caring for a sick/disabled person <sup>b</sup>					
Yes	14.5	7.6	7.7	9.5	6.8
No	85.3	92.1	92.1	90.3	93.1

*Note.* Only individuals who answered the yearly CES-D loneliness question are included in the table each year.

3MSE = Modified Mini-Mental State Examination; CES-D = Center for Epidemiological Studies Depression; IQR = interquartile range.

<sup>a</sup>Continuous variables are presented as the mean and standard deviation.

<sup>b</sup>Categorical and binary variables are presented as percent in each category. The remaining percent of 100 for these variables corresponds to the percent missing.

<sup>c</sup>The social network score is presented as the median and IQR due to the skewness in the responses.

**Table 2**

Longitudinal Association of Loneliness and Social Isolation.

	Odds ratio	z	95% Confidence interval
Median social network score (per unit; 30 points total)	0.89**	-12.75	[0.87, 0.90]
Deviation in social network score (per unit)	0.97*	-3.48	[0.96, 0.99]
Someone close died in last year	1.22**	3.87	[1.10, 1.35]
A significant relationship became considerably worse	2.25**	8.37	[1.86, 2.72]
Somebody close had illness in last 6 months	1.14	2.46	[1.03, 1.26]
A grandchild was born in the last 6 months	1.17	2.16	[1.02, 1.36]
Been caring for a sick/disabled person	1.54**	5.58	[1.33, 1.80]
Not living alone	0.21**	-18.33	[0.18, 0.25]
3MSE score	0.98**	-6.42	[0.97, 0.98]
Health status	1.45**	5.62	[1.27, 1.65]
Male	0.46**	-9.35	[0.40, 0.55]
Education (years)	0.97*	-3.35	[0.95, 0.99]
Marital status (married)			
Widowed	1.61**	4.56	[1.31, 1.98]
Divorced/separated	1.01	0.03	[0.71, 1.41]
Never married	0.74	-1.61	[0.51, 1.07]
Race (non-Black)			
Black	0.88	-1.06	[0.70, 1.11]
Age	1.006	0.92	[0.99, 1.02]

Note. Based on 24,323 observations from 5,870 individuals.

3MSE = Modified Mini-Mental State Examination.

\*  $p < .01$ .

\*\*  $p < .001$