

## Original Article

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# The silent epidemic of loneliness: identifying the antecedents of loneliness using a lagged exposure-wide approach

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**Abstract**

**Background.** A large and accumulating body of evidence shows that loneliness is detrimental for various health and well-being outcomes. However, less is known about potentially modifiable factors that lead to decreased loneliness.

**Methods.** We used data from the Health and Retirement Study to prospectively evaluate a wide array of candidate predictors of subsequent loneliness. Importantly, we examined if changes in 69 physical-, behavioral-, and psychosocial-health factors (from  $t_0$ :2006/2008 to  $t_1$ :2010/2012) were associated with subsequent loneliness 4 years later ( $t_2$ :2014/2016).

**Results.** Adjusting for a large range of covariates, changes in certain health behaviors (e.g. increased physical activity), physical health factors (e.g. fewer functioning limitations), psychological factors (e.g. increased purpose in life, decreased depression), and social factors (e.g. greater number of close friends) were associated with less subsequent loneliness.

**Conclusions.** Our findings suggest that subjective ratings of physical and psychological health and perceived social environment (e.g. chronic pain, self-rated health, purpose in life, anxiety, neighborhood cohesion) are more strongly associated with subsequent loneliness. Yet, objective ratings (e.g. specific chronic health conditions, living status) show less evidence of associations with subsequent loneliness. The current study identified potentially modifiable predictors of subsequent loneliness that may be important targets for interventions aimed at reducing loneliness.

**Introduction**

Loneliness, the subjective perception that one lacks social connection, is recognized as one of the most urgent public health threats in the United States for several reasons (Leigh-Hunt et al., 2017; Rubin, 2017). First, a large and growing body of research has documented the detrimental effects of loneliness on a wide range of health and well-being outcomes (Perissinotto, Holt-Lunstad, Periyakoil, & Covinsky, 2019; Perissinotto, Stijacic Cenzer, & Covinsky, 2012). For example, a meta-analysis of 19 longitudinal studies found that greater loneliness is associated with greater incidence of subsequent dementia (Lara et al., 2019). Further, loneliness predicts premature mortality at rates comparable to traditional physical health risk factors such as smoking, obesity, and physical inactivity (Holt-Lunstad, Smith, & Layton, 2010, 2015). Loneliness may also influence various health outcomes through multiple pathways, including (1) psychological pathways (e.g. increased negative social expectations leading to behaviors that confirm these negative expectations from others such as physical distancing) (Newall et al., 2009), (2) physiological pathways (e.g. increased sensitivity to stressors leading to maladaptive stress responses including greater inflammation, cardiovascular activation, and hyperactivity of the HPA axis) (Park et al., 2020), and (3) behavioral pathways (e.g. decreased physical activity, health care use, and poorer sleep quality) (Hawkey & Cacioppo, 2010; Hom, Chu, Rogers, & Joiner, 2020).

Second, contrary to popular belief, loneliness impacts individuals of all ages and is not limited to older adults (Victor & Yang, 2012). According to a 2018 survey of over 20 000 US adults aged >18, nearly half of the population reported sometimes or always feeling alone or left out (Polack, 2018). Third, loneliness has economic consequences. A report by the London School of Economics estimated that over a 10-year period, loneliness could add an additional >\$2000 of healthcare costs per person when comparing lonely *v.* non-lonely

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older adults (McDaid, Bauer, & Park, 2017). They also note, how loneliness costs United Kingdom employers more than \$3.5 billion dollars per year (Jeffrey, Abdallah, & Michaelson, 2017). Fourth, the COVID-19 pandemic and its accompanying physical distancing rules/recommendations have increased societal awareness about the pernicious effects of loneliness (Holt-Lunstad, 2020).

With the aim of offsetting the troublesome realities that loneliness causes, social/health organizations, educational agencies, and governments worldwide are creating interventions and policies aimed at reducing loneliness. For example, the UK and Japan recently appointed their first ‘ministers of loneliness’ to combat loneliness at a national level (Fried et al., 2020), and a growing number of British doctors are now embracing ‘social prescription’ practices (i.e. writing prescriptions for patients to engage in social activities at subsidized prices) (Harris, 2018). Similarly, China implemented a ‘must visit parents’ mandate as part of the new *Elderly Rights Law*, which requires adult children to visit their aging parents to stem the rising problem of loneliness (Hatton, 2013). In the US, the Surgeon General Vivek Murthy has repeatedly raised concerns about the potential increase in loneliness following the COVID-19 pandemic, which he termed as a ‘social recession’. Thus, identifying potential predictors that decrease loneliness can aid in this growing global effort. While an extensive literature has identified sociodemographic factors that predict subsequent loneliness (e.g. gender, age, income, widowed/divorced) (Cohen-Mansfield, Shmotkin, & Goldberg, 2009; Dahlberg, Andersson, McKee, & Lennartsson, 2015; Franssen, Stijnen, Hamers, & Schneider, 2020; Victor & Bowling, 2012), accumulating evidence shows that loneliness is predicted by other potentially modifiable factors, including some health behaviors (e.g. poor sleep quality) (Jia & Yuan, 2020; Macià et al., 2021), indicators of physical health (e.g. self-rated health) (Swader, 2019; Yang & Gu, 2020), psychological factors (e.g. depression, negative affect) (Böger & Huxhold, 2018; Dahlberg et al., 2015; Hsueh, Chen, Hsiao, & Lin, 2019), and social factors (e.g. social support) (Mann et al., 2017). Yet, other research has yielded mixed findings. For example, while some studies find that greater physical activity is associated with lower loneliness (Kim, Lee, Chun, Han, & Heo, 2017), others find no associations (McAuley et al., 2000; Tully et al., 2019).

These seminal studies have contributed greatly to the literature, yet, are limited. First, most prior research evaluates predictors of subsequent loneliness accumulated across the life-course and at one point in time, rather than evaluating how *changes* in predictors might influence *changes* in subsequent loneliness. Examining how *changes* in the predictors might influence changes in subsequent loneliness is desirable because it can strengthen causal inference by addressing confounding by all time-invariant individual characteristics, including unmeasured ones. Thus, answering the latter question produces results that are more useful for interventions (VanderWeele, Mathur, & Chen, 2020). Second, most research only examined a limited range of predictors, which (1) limits the potential pool of building blocks for developing loneliness-reducing interventions and policies, and (2) makes it challenging to compare effect sizes across candidate predictors as potential intervention targets. Third, less is known about how initial experiences of loneliness (i.e. whether people are already experiencing loneliness or not) shape associations between predictors and subsequent loneliness. The regulatory loop model of loneliness (Hawkey & Cacioppo, 2010) indicates that lonely individuals show greater surveillance for and

sensitivity to stressors (e.g. increased attention to threats, better memory of negative social experiences). This hypersensitivity leads to increased negative social expectations and elicits behaviors that confirm these negative expectations which, in turn, leads to greater loneliness. This self-reinforcing loop increases lonely individuals’ susceptibility to various risk factors for loneliness.

In a nationally representative sample of adults aged >50, we used a *lagged exposure-wide* analytic approach (see *Statistical analysis* section) (VanderWeele et al., 2020), to evaluate how *changes* in 69 predictors might lead to changes in subsequent loneliness 4 years later. The predictors were chosen for two reasons. First, they are commonly included in the conceptualization of key gerontological models that characterize the antecedents, processes, and outcomes that increase people’s ability to age well (Aldwin & Igarashi, 2015; Depp & Jeste, 2006; Kim et al., 2021; Rowe & Kahn, 1987; Ryff & Singer, 2009). Second, research indicates that several of our predictors can be modified through existing interventions and/or with further research.

## Methods

### Study population

Participants were from the Health and Retirement Study (HRS) – a nationally representative sample of adults aged >50 in the US. In 2006, approximately 50% of HRS respondents completed an enhanced face-to-face interview, whereas the other half of respondents were assessed in 2008. Following the interview, participants completed a psychosocial questionnaire which they mailed to the University of Michigan. Response rates were 88% in 2006 and 84% in 2008 (Smith, Ryan, Fisher, Sonnega, & Weir, 2017). To increase sample size and statistical power, we combined data from 2006 and 2008 to create the pre-baseline wave. All study measures were comparable between the two cohorts. Because more than half of the study predictors were measured in the psychosocial questionnaire, participants were excluded if they did not report psychosocial data in this pre-baseline wave.

This study used three waves of data collected 4 years apart ( $t_0$ , pre-baseline;  $t_1$ , baseline; and  $t_2$ , outcome). All covariates were measured in the pre-baseline wave ( $t_0$ ; 2006/2008), candidate predictors were measured in the baseline wave ( $t_1$ ; 2010/2012), and the outcome (loneliness) was measured in the outcome wave ( $t_2$ ; 2014/2016). Study documentation can be found on the HRS website (<http://hrsonline.isr.umich.edu/>). The HRS is conducted by the University of Michigan and supported by the National Institute on Aging (NIA U01AG009740). Because we used de-identified and publicly available data, the ethics review board at the University of British Columbia exempted this study from human subjects review.

### Measures

#### Loneliness

Loneliness was measured using a three-item loneliness scale, shortened from the 20-item Revised UCLA loneliness Scale (Russell, Peplau, & Cutrona, 1980). Participants indicated how much of the time they feel ‘lack of companionship’, ‘left out’, and ‘isolated from others’ on a three-point Likert scale (1 [often], 2 [some of the time], 3 [hardly ever or never]). Responses were reverse-coded, and all items were averaged to create a composite score (range: 1–3). Greater values indicated greater loneliness, and we standardized the variable (mean = 0, standard deviation = 1) so

that the results can be interpreted as a standard deviation change in loneliness ( $\alpha = 0.80$ ).

### Covariates

We included a large number of covariates that were measured in the pre-baseline wave ( $t_0$ ;2006/2008). Covariates included socio-demographic factors (age, gender, race/ethnicity, marital status, annual household income [ $< \$50\,000$ ,  $\$50\,000$ – $\$74\,999$ ,  $\$75\,000$ – $\$99\,999$ ,  $\geq \$100\,000$ ]), total wealth (based on quintiles of the score distribution for total wealth in this sample), educational attainment (no degree, GED/high school diploma,  $\geq$  college degree), geographic region (Northeast, Midwest, South, West), personality (openness, conscientiousness, extraversion, agreeableness, neuroticism; continuous), and childhood physical abuse (yes/no). Pre-baseline values of all predictors ( $t_0$ ;2006/2008) were also included as covariates to examine change in each predictor variable. We also adjusted for pre-baseline loneliness to reduce the possibility of reverse causation. The analyses can be interpreted as how a change in loneliness over 4 years, rather than prevalent loneliness, affects subsequent loneliness 4 years later; the effects of pre-baseline loneliness on subsequent loneliness is substantial but the relationship is not deterministic because loneliness may change due to a variety of factors.

### Predictors

In the baseline wave ( $t_1$ ;2010/2012), 69 candidate predictors were assessed including indicators of: health behaviors (binge drinking; smoking; physical activity; sleep problems), physical health (total number of chronic conditions; diabetes; hypertension; stroke; cancer; heart disease; lung disease; arthritis; overweight/obesity; physical functioning limitations; cognitive impairment; chronic pain; self-rated health; hearing; eyesight), psychological well-being (positive affect; life satisfaction; optimism; purpose in life; mastery; health mastery; financial mastery), psychological distress (depression; depressive symptoms; hopelessness; negative affect; perceived constraints; anxiety; trait anger; state anger; cynical hostility; stressful life events; financial strain; daily discrimination; major discrimination), and social factors (living alone; frequency of contact with children, other family, and friends; closeness with spouse; having any child, other family, and friends; number of close children, other family, and friends; positive social support from spouse, children, other family, and friends; negative social strain from spouse, children, other family, and friends; neighborhood cohesion; neighborhood disorder; social effort and reward; non-religious social activity participation; volunteer activity; religious service attendance; helping friends, neighbors, and relative social status ladder ranking; and change in social status ladder ranking), employment status, and health insurance. For further details about each of the covariates and predictor variables, see Supplementary Text 1 and HRS documentation (Fisher, Faul, Weir, & Wallace, 2005; Jenkins, Ofstedal, & Weir, 2008; Smith et al., 2013).

### Statistical analysis

We used a lagged exposure-wide analytic approach (VanderWeele et al., 2020) and conducted separate analyses for each exposure (candidate predictor). Because loneliness was a continuous variable, we used linear regression to examine how each baseline ( $t_1$ ;2010/2012) exposure variable (candidate predictor) was independently related to subsequent loneliness in the outcome wave ( $t_2$ ;2014/2016) controlling for all pre-baseline variables ( $t_0$ ;2006/

2008). The outcome (subsequent loneliness) and all other continuous exposures (predictors) were standardized (mean = 0, standard deviation = 1) so that each effect estimate could be interpreted as a standard deviation change in the exposure. When considering categorical exposures, each effect estimate corresponds to associations between the exposure at baseline ( $t_1$ ;2010/2012) subsequent loneliness in the outcome wave ( $t_2$ ;2014/2016), conditional on the exposures and covariates in the pre-baseline wave ( $t_0$ ;2006/2008). We used Bonferroni correction to account for multiple testing. In our tables, we marked multiple  $p$  value thresholds because different investigators often use different standards in interpreting evidence. For ease of reviewing results, the tables include  $p$  value thresholds of:  $p < 0.05$ ,  $p < 0.01$ , or a Bonferroni correction to account for multiple testing ( $0.05/69$  predictors =  $p < 0.00072463768$ ). In our results section, we comment on traditional 0.05  $p$  value threshold (without Bonferroni correction), but in all cases we also provide 95% confidence intervals which give what are often considered preferable assessments of uncertainty since all thresholds are ultimately arbitrary.

### Additional analyses

We conducted four additional analyses. First, we conducted  $E$ -value analyses to examine the minimum strength of unmeasured confounding associations on the risk ratio scale (with both the exposure and subsequent loneliness) needed to explain away the association between the exposure and subsequent loneliness. This analysis was conducted to assess the robustness of our results to potential unmeasured confounding (VanderWeele & Ding, 2017). Second, we repeated these analyses restricting analytic samples to: (a) non-lonely people at baseline (composite loneliness score = 1, people whose composite score indicates experiencing loneliness ‘hardly ever or never’) and (b) lonely people at baseline (baseline composite loneliness score  $> 1$ , participants whose composite scores indicate experiencing loneliness ‘some of the time’ or ‘often’). Third, we conducted these analyses again using only complete-cases to assess the impact of multiple imputation.

### Missing data

To address potential selection bias due to missing data (Hernán, Hernández-Díaz, & Robins, 2004), we imputed all missing exposures, covariates, and outcome data using multiple imputation by chained equations, which created five datasets. We performed analyses using each imputed dataset and combined estimates across imputations (Rubin, 2004).

### Results

In the pre-baseline wave ( $t_0$ ;2006/2008), when all covariates were assessed, the average age of participants was 68 years old (s.d. = 10), more likely women (58%) and married (62%). Table 1 summarizes participant characteristics. Table 2 describes changes in loneliness from the pre-baseline to the outcome wave.

Table 3 shows the associations between the candidate predictors and subsequent loneliness. When considering health behaviors, two out of four predictors were associated with subsequent loneliness. Those who engaged in more frequent physical activity ( $\beta = -0.07$ , 95% CI  $-0.11$ ,  $-0.03$ ) and binge drinking ( $\beta = -0.11$ , 95% CI  $-0.20$ ,  $-0.03$ ) reported less subsequent loneliness 4 years later. For physical health indicators, five out of 15 candidate predictors were associated with subsequent loneliness. Those with fewer physical functioning limitations ( $\beta = 0.11$ , 95% CI  $0.03$ – $0.18$ ), and better self-rated health

**Table 1.** Characteristics of participants at pre-baseline ( $N = 13\,365$ )<sup>a,b,c</sup>

Participant characteristics	Pre-baseline: non-lonely $N = 5650$		Pre-baseline: lonely $N = 7715$	
	No. (%)	Mean (s.d.)	No. (%)	Mean (s.d.)
<b>Sociodemographic factors</b>				
Age (year; range: 52–101)		69.2 (9.0)		69.0 (10.0)
Female (%)	3121 (55.2)		4653 (60.3)	
<b>Race/ethnicity (%)</b>				
White	4609 (81.6)		5791 (75.1)	
Black	565 (10.0)		1109 (14.4)	
Hispanic	365 (6.5)		657 (8.5)	
Other	110 (2.0)		158 (2.1)	
Married (%)	4190 (74.2)		4226 (54.8)	
<b>Annual household income (%)</b>				
<\$50 000	3011 (53.3)		5013 (65.0)	
\$50 000–\$74 999	969 (17.2)		1125 (14.6)	
\$75 000–\$99 999	534 (9.5)		597 (7.7)	
≥\$100 000	1136 (20.1)		980 (12.7)	
<b>Total wealth (%)</b>				
1st Quintile	747 (13.2)		1867 (24.2)	
2nd Quintile	994 (17.6)		1658 (21.5)	
3rd Quintile	1178 (20.9)		1506 (19.5)	
4th Quintile	1300 (23.0)		1409 (18.3)	
5th Quintile	1431 (25.3)		1275 (16.5)	
<b>Education (%)</b>				
<High school	892 (15.8)		1658 (21.5)	
High school	3070 (54.4)		4250 (55.2)	
≥College	1680 (29.8)		1788 (23.2)	
<b>Employment</b>				
In labor force	2055 (36.4)		2651 (34.4)	
Health insurance (%)	5464 (96.7)		7333 (95.1)	
<b>Geographic region (%)</b>				
Northeast	858 (15.2)		1158 (15.0)	
Midwest	1511 (26.8)		1999 (26.0)	
South	2206 (39.1)		3119 (40.5)	
West	1070 (19.0)		1422 (18.5)	
Childhood abuse (%)	260 (4.7)		566 (7.5)	
<b>Physical health</b>				
Diabetes (%)	965 (17.1)		1663 (21.6)	
Hypertension (%)	3093 (54.8)		4498 (58.4)	
Stroke (%)	386 (6.8)		680 (8.8)	
Cancer (%)	883 (15.7)		1161 (15.1)	
Heart disease (%)	1274 (22.6)		1963 (25.5)	
Lung disease (%)	452 (8.0)		818 (10.6)	
Arthritis (%)	3250 (57.6)		4795 (62.2)	

(Continued)

Table 1. (Continued.)

Participant characteristics	Pre-baseline: non-lonely <i>N</i> = 5650		Pre-baseline: lonely <i>N</i> = 7715	
	No. (%)	Mean (s.d.)	No. (%)	Mean (s.d.)
Overweight/obesity (%)	3853 (68.9)		5374 (70.6)	
Physical functioning limitations (%)	952 (16.9)		2227 (28.9)	
Cognitive impairment (%)	822 (14.8)		1713 (22.6)	
Chronic pain (%)	1595 (28.2)		3023 (39.2)	
Self-rated health (range: 1–5)		3.4 (1.0)		3.0 (1.1)
Hearing (range: 1–5)		3.4 (1.1)		3.3 (1.1)
Eyesight (range: 1–6)		4.3 (1.0)		4.1 (1.0)
<b>Health behaviors</b>				
Binge drinking (%)	381 (8.2)		399 (6.3)	
Smoking (%)	608 (10.9)		1075 (14.0)	
Frequent physical activity (%)	4327 (76.6)		5301 (68.8)	
Sleep problems (%)	1101 (37.0)		1893 (45.9)	
<b>Psychological well-being</b>				
Positive affect (range: 1–5)		3.9 (0.6)		3.4 (0.7)
Life satisfaction (range: 1–7)		5.6 (1.2)		4.6 (1.5)
Optimism (range: 1–6)		4.8 (0.9)		4.2 (0.9)
Purpose in life (range: 1–6)		4.9 (0.8)		4.3 (0.9)
Mastery (range: 1–6)		5.0 (1.0)		4.6 (1.1)
Health mastery (range: 0–10)		7.7 (2.1)		6.9 (2.5)
Financial mastery (range: 0–10)		7.9 (2.3)		6.9 (2.8)
<b>Psychological distress</b>				
Depression (%)	245 (4.4)		1550 (20.5)	
Depressive symptoms (range: 0–8)		0.7 (1.3)		1.9 (2.2)
Hopelessness (range: 1–6)		1.9 (1.1)		2.7 (1.3)
Negative affect (range: 1–5)		1.4 (0.4)		1.9 (0.7)
Perceived constraints (range: 1–6)		1.8 (1.0)		2.6 (1.2)
Anxiety (range: 1–4)		1.4 (0.4)		1.7 (0.6)
Trait anger (range: 1–4)		2.0 (0.6)		2.3 (0.7)
State anger (range: 1–4)		1.4 (0.4)		1.6 (0.5)
Cynical hostility (range: 1–6)		2.6 (1.1)		3.2 (1.1)
Stressful life events (range: 0–5)		0.2 (0.5)		0.3 (0.6)
Financial strain (range: 1–5)		1.7 (0.9)		2.1 (1.0)
Daily discrimination (range: 1–6)		1.4 (0.5)		1.8 (0.8)
Major discrimination (range: 0–6)		0.3 (0.7)		0.6 (1.0)
<b>Social factors</b>				
Living alone (%)	1214 (22.0)		3176 (42.4)	
Contact children (%)				
<Every few months	608 (11.0)		1170 (15.6)	
1–2×/Month	563 (10.2)		912 (12.2)	
1–2×/Week	1824 (32.9)		2209 (29.5)	
≥3×/Week	2552 (46.0)		3206 (42.8)	

(Continued)

**Table 1.** (Continued.)

Participant characteristics	Pre-baseline: non-lonely <i>N</i> = 5650		Pre-baseline: lonely <i>N</i> = 7715	
	No. (%)	Mean (s.d.)	No. (%)	Mean (s.d.)
Contact other family (%)				
<Every few months	1196 (21.5)		1990 (26.3)	
1–2×/Month	1380 (24.7)		1701 (22.5)	
1–2×/Week	1614 (28.9)		1997 (26.4)	
≥3×/Week	1387 (24.9)		1876 (24.8)	
Contact friends (%)				
<Every few months	693 (12.4)		1506 (19.8)	
1–2×/Month	986 (17.6)		1452 (19.1)	
1–2×/Week	2108 (37.7)		2607 (34.2)	
≥3×/Week	1811 (32.4)		2056 (27.0)	
Closeness with spouse		3.7 (0.5)		3.3 (0.8)
Any children (%)	5100 (92.9)		6708 (90.1)	
Any other family (%)	5330 (95.0)		7117 (93.3)	
Any friends (%)	5313 (95.5)		6872 (90.8)	
Number of close children (range: 0–6)		2.6 (1.4)		2.4 (1.5)
Number of close other family(range: 0–11)		3.6 (3.0)		3.2 (2.8)
Number of close friends (range: 0–12)		4.6 (3.3)		3.6 (2.9)
Positive social support from spouse (range: 1–4)		3.7 (0.5)		3.2 (0.7)
Positive social support from children (range: 1–4)		3.4 (0.7)		3.2 (0.7)
Positive social support from other family (range: 1–4)		3.0 (0.9)		2.8 (0.9)
Positive social support from friends (range: 1–4)		3.2 (0.7)		3.0 (0.7)
Social strain from spouse (range: 1–4)		1.7 (0.6)		2.2 (0.7)
Social strain from children (range: 1–4)		1.5 (0.5)		1.8 (0.7)
Social strain from other family (range: 1–4)		1.4 (0.5)		1.7 (0.7)
Social strain from friends (range: 1–4)		1.8 (0.4)		1.9 (0.5)
Neighborhood cohesion (range: 1–7)		5.9 (1.3)		5.3 (1.4)
Neighborhood disorder (range: 1–7)		3.6 (1.7)		3.7 (1.6)
Social effort/reward (range: 1–5)		4.3 (0.8)		3.8 (0.9)
Non-religious social activity (%)	726 (13.2)		884(11.9)	
Religious service attendance (%)				
Not at all	1306 (23.1)		2052 (26.6)	
<1×/Week	1703 (30.2)		2490 (32.3)	
≥1×/Week	2638 (46.7)		3168 (41.1)	
Volunteer (%)				
0 h	3352 (59.4)		5259 (68.2)	
1–49 h	660 (11.7)		830 (10.8)	
50–99 h	515 (9.1)		551 (7.2)	
100–199 h	573 (10.2)		599 (7.8)	
≥200 h	542 (9.6)		468 (6.1)	
Helping friends/neighbors/relatives (%)				
0 h	2372 (42.1)		3987 (51.8)	

(Continued)



Table 1. (Continued.)

Participant characteristics	Pre-baseline: non-lonely <i>N</i> = 5650		Pre-baseline: lonely <i>N</i> = 7715	
	No. (%)	Mean (s.d.)	No. (%)	Mean (s.d.)
1–49 h	1396 (24.8)		1749 (22.7)	
50–99 h	881 (15.6)		916 (11.9)	
100–199 h	581 (10.3)		594 (7.7)	
≥200 h	402 (7.1)		446 (5.8)	
Social status ladder (range: 1–10)		6.9 (1.6)		6.2 (1.8)
Change in social status ladder (%)				
Moved down	332 (6.1)		902 (12.1)	
No change	4507 (82.1)		5557 (74.7)	
Moved up	651 (11.9)		980 (13.2)	
Personality				
Openness (range: 1–4)		3.0 (0.5)		2.9 (0.6)
Conscientiousness (range: 1–4)		3.5 (0.4)		3.3 (0.5)
Extraversion (range: 1–4)		3.3 (0.5)		3.1 (0.6)
Agreeableness (range: 1–4)		3.6 (0.4)		3.5 (0.5)
Neuroticism (range: 1–4)		1.8 (0.5)		2.2 (0.6)

<sup>a</sup>This table was created based on non-imputed data.

<sup>b</sup>All variables in Table 1 were used as covariates, and assessed in the pre-baseline wave ( $t_0$ ; 2006/2008).

<sup>c</sup>The percentages in some sections may not add up to 100% due to rounding.

( $\beta = -0.09$ , 95% CI  $-0.13$  to  $-0.05$ ) were most strongly associated with lower subsequent loneliness in comparison to other physical health factors.

All psychological factors (20 out of 20 predictors) were associated with subsequent loneliness. For example, among psychological well-being factors, life satisfaction ( $\beta = -0.16$ , 95% CI  $-0.20$  to  $-0.11$ ) and purpose in life ( $\beta = -0.16$ , 95% CI  $-0.19$  to  $-0.13$ ) were most strongly associated with lower subsequent loneliness in comparison to other psychological well-being factors. Among psychological distress factors, depression ( $\beta = 0.33$ , 95% CI  $0.25$ – $0.41$ ) and negative affect ( $\beta = 0.23$ , 95% CI  $0.18$ – $0.27$ ) were most strongly associated with greater subsequent loneliness. For social factors, 19 out of 28 predictors were associated with subsequent loneliness. Having friends ( $>1\times/\text{week}$ ;  $\beta = -0.23$ , 95% CI  $-0.34$  to  $-0.13$ ) and frequent interactions with friends ( $>3\times/\text{week}$ ;  $\beta = -0.22$ , 95% CI  $-0.31$  to  $-0.14$ ) were most strongly associated with lower subsequent loneliness.

Table 2. Change in loneliness from the pre-baseline wave ( $t_0$ ) to the outcome wave ( $t_2$ )<sup>a</sup>

	Outcome wave ( $t_2$ )	
	Non-lonely %	Lonely %
Baseline wave ( $t_0$ )		
Non-lonely	66.1	33.9
Lonely	25.8	74.2

<sup>a</sup>The percent of lonely and non-lonely individuals in the pre-baseline wave ( $t_0$ ) who were lonely or non-lonely in the outcome wave ( $t_2$ ).

### Additional analyses

We conducted several additional analyses. First, *E*-values indicated that many of the observed associations were potentially somewhat robust to unmeasured confounding (Table 4), though for some estimates, a combination of unmeasured confounding and statistical uncertainty might explain away the results. For example, for purpose in life, an unmeasured confounder would have to be associated with both loneliness and purpose in life by risk ratios of 1.58 each (above and beyond the covariates already adjusted for) to explain away the association. Further, to shift the CI to include the null, an unmeasured confounder would have to be associated with both loneliness and purpose in life by risk ratios of 1.51. Second, results varied when comparing candidate predictors among the subpopulations of people who were not lonely at baseline compared to who were lonely at baseline (Supplementary Table S1). Most associations between many candidate predictors and subsequent loneliness were observed more strongly among individuals who were lonely at baseline compared to those not lonely at baseline. Third, results from the complete-case analyses showed weaker associations between the candidate predictors and subsequent loneliness compared to results from the imputed analyses (Supplementary Table S2).

### Discussion

In a diverse, large, prospective, and nationally representative sample of US adults aged  $>50$ , we examined how changes in 69 candidate predictors (e.g. physical health, health behaviors, and psychosocial factors) were associated with subsequent loneliness 4 years later. Results identified some health behaviors (e.g. physical activity), physical health conditions (e.g. physical functioning limitations), psychological factors (e.g. purpose in life, life

**Table 3.** Candidate predictors of loneliness (Health and Retirement Study [HRS]:  $N = 13\,771$ )<sup>a,b,c,d</sup>

Candidate predictor	$\beta$	95% CI
Health behaviors		
Frequent physical activity	-0.07	-0.11 to -0.03**
Smoking	0.04	-0.18 to 0.26
Binge drinking	-0.11	-0.20 to -0.03*
Sleep problems	-0.00	-0.04 to 0.03
Physical health		
Number of physical conditions	0.02	-0.03 to 0.08
Diabetes	0.01	-0.10 to 0.11
Hypertension	0.05	-0.04 to 0.14
Stroke	0.14	-0.05 to 0.33
Cancer	0.00	-0.09 to 0.09
Heart disease	0.01	-0.07 to 0.08
Lung disease	0.02	-0.14 to 0.18
Arthritis	0.01	-0.06 to 0.09
Overweight/obese	-0.03	-0.12 to 0.05
Physical functioning limitations	0.11	0.03-0.18*
Cognitive impairment	0.11	0.02-0.19*
Chronic pain	0.07	0.01-0.13*
Self-rated health	-0.09	-0.13 to -0.05**
Hearing	-0.03	-0.06 to -0.00*
Eyesight	-0.05	-0.10 to 0.00
Psychological well-being		
Positive affect	-0.15	-0.18 to -0.12***
Life satisfaction	-0.16	-0.20 to -0.11***
Optimism	-0.13	-0.16 to -0.10***
Purpose in life	-0.16	-0.19 to -0.13***
Mastery	-0.09	-0.12 to -0.07***
Health mastery	-0.11	-0.14 to -0.07***
Financial mastery	-0.09	-0.12 to -0.07***
Psychological distress		
Depression	0.33	0.25-0.41***
Depressive symptoms	0.17	0.12-0.21***
Hopelessness	0.13	0.11-0.15***
Negative affect	0.23	0.18-0.27***
Constraints	0.17	0.14-0.20***
Anxiety	0.16	0.10-0.23**
Trait anger	0.11	0.08-0.13***
State anger	0.08	0.05-0.10***
Cynical hostility	0.08	0.06-0.11***
Stressful life events	0.04	0.03-0.06***
Financial strain	0.06	0.03-0.08***
Daily discrimination	0.11	0.09-0.14***

(Continued)

**Table 3.** (Continued.)

Candidate predictor	$\beta$	95% CI
Major discrimination	0.05	0.02-0.08**
Social factors		
Living alone	0.16	-0.01 to 0.32
Contact children		
<Every few months	Reference	Reference
1-2×/Month	-0.03	-0.14 to 0.09
1-2×/Week	-0.07	-0.18 to 0.04
≥3×/Week	-0.09	-0.20 to 0.02
Contact other family		
<Every few months	Reference	Reference
1-2×/Month	-0.02	-0.11 to 0.07
1-2×/Week	-0.03	-0.11 to 0.06
≥3×/Week	-0.02	-0.10 to 0.07
Contact friends		
<Every few months	Reference	Reference
1-2×/Month	-0.09	-0.17 to -0.01*
1-2×/Week	-0.16	-0.24 to -0.09***
≥3×/Week	-0.22	-0.31 to -0.14***
Closeness with spouse	-0.12	-0.19 to -0.06**
Any child	-0.05	-0.28 to 0.17
Any other family	0.03	-0.14 to 0.20
Any friends	-0.23	-0.34 to -0.13***
Number of close children	-0.04	-0.08 to -0.00*
Number of close other family	-0.03	-0.06 to -0.01*
Number of close friends	-0.08	-0.11 to -0.05***
Positive social support from spouse	-0.16	-0.22 to -0.11***
Positive social support from children	-0.07	-0.10 to -0.04***
Positive social support from other family	-0.04	-0.07 to -0.01*
Positive social support from friends	-0.05	-0.07 to -0.03***
Social strain from spouse	0.22	0.14-0.29***
Social strain from children	0.10	0.03-0.16*
Social strain from other family	0.07	0.03-0.11**
Social strain from friends	0.03	0.01-0.05**
Neighborhood cohesion	-0.08	-0.10 to -0.05***
Neighborhood disorder	0.04	0.02-0.06***
Social effort/reward	-0.07	-0.09 to -0.05***
Non-religious social activity	0.05	-0.11 to 0.21
Volunteer		
0 h	Reference	Reference
0-49 h	-0.05	-0.12 to 0.02
50-99 h	-0.08	-0.15 to 0.00
100-199 h	-0.12	-0.19 to -0.05**

(Continued)



Table 3. (Continued.)

Candidate predictor	$\beta$	95% CI
$\geq 200$ h	-0.09	-0.17 to -0.02*
Religious service attendance		
Not at all	Reference	Reference
<1×/Week	-0.06	-0.12 to 0.00
$\geq 1$ ×/Week	-0.11	-0.18 to -0.05**
Helping friends/neighbors/relatives		
0 h	Reference	Reference
1–49 h	-0.04	-0.10 to 0.01
50–99 h	-0.07	-0.14 to 0.01
100–199 h	-0.02	-0.11 to 0.06
$\geq 200$ h	-0.04	-0.12 to 0.04
Health insurance	-0.16	-0.26 to -0.06**
Employment status	-0.01	-0.08 to 0.06
Social status ladder	-0.06	-0.12 to -0.01*
Change in social status ladder		
Moved down	Reference	Reference
No change	-0.16	-0.26 to -0.07**
Moved up	-0.12	-0.28 to 0.03

CI, confidence interval.

\* $p < 0.05$  before Bonferroni correction; \*\* $p < 0.01$  before Bonferroni correction; \*\*\* $p < 0.05$  after Bonferroni correction (the  $p$  value cutoff for Bonferroni correction is  $p = 0.05/69$  predictors =  $p < 0.00072463768$ ).

<sup>a</sup>The analytic sample was restricted to those who had participated in the pre-baseline wave (2006 or 2008). Multiple imputation was performed to impute missing data on the exposures, covariates, and outcome. Candidate antecedents were assessed, one at a time, in wave 2 (2010/2012), and the outcome (loneliness) was assessed in wave 3 (2014/2016). The following covariates were controlled for at wave 1 (2006/2008): sociodemographic characteristics (age, sex, race/ethnicity, marital status, income, total wealth, level of education, employment status, health insurance, geographic region), childhood abuse, personality factors (openness, conscientiousness, extraversion, agreeableness, neuroticism), and all of the predictor variables, including health behaviors (physical activity, smoking, binge drinking, sleep problems), physical health (total number of physical conditions, heart disease, cancer, stroke, arthritis, hypertension, overweight/obese, diabetes, lung disease, chronic pain, hearing, eyesight, self-rated health, physical functioning limitations, cognitive impairment), social factors (live with spouse, frequency of contact with children, frequency of contact with other family, frequency of contact with friends, closeness with spouse, having any children, other family, friends, number of close children, number of close other family, number of close friends, positive social support from spouse, positive social support from children, positive social support from friends, positive social support from other family, social strain from spouse, social strain from children, social strain from other family, social strain from friends, volunteering, neighborhood cohesion, neighborhood disorder, social effort/reward, non-religious social activity, religious service attendance, helping friends/neighbors/relatives, employment status, perceived social status, change in perceived social status, loneliness), psychological well-being factors (life satisfaction, positive affect, purpose in life, optimism, health mastery, financial mastery, mastery), and psychological distress (depressive symptoms, hopelessness, negative affect, constraints, anxiety, trait anger, state anger, daily discrimination, major discrimination, cynical hostility, stressful life events, financial strain), health insurance.

<sup>b</sup>All continuous candidate antecedents were standardized (mean = 0; standard deviation = 1).

<sup>c</sup>An exposure-wide analytic approach was used, and a separate model for each exposure was run. Because loneliness was a continuous outcome, we ran linear regressions.

<sup>d</sup>The final estimates of the predictors reflect changes in these values from pre-baseline to baseline waves.

satisfaction, depression), and social factors (e.g. frequency of contact with friends, attending religious services) as candidate predictors of subsequent loneliness. However, there was little evidence of associations with subsequent loneliness for other factors. This study is among one of the few to consider such a broad array of predictors of subsequent loneliness – moving us closer to a fuller understanding of the antecedents of a major public health concern

and possible intervention targets. All models used the same analytic method and adjusted for the same covariates to allow for comparison of effect sizes among all variables in the same sample.

Our findings converge with some previous studies, indicating that being more active (Boekhout, Berendsen, Peels, Bolman, & Lechner, 2019), having fewer functional limitations (Theeke, 2009), less chronic pain (Loeffler & Steptoe, 2021; Smith, Dainty, Williamson, & Martin, 2019), and better self-rated health (Cohen-Mansfield et al., 2009; Theeke, 2009), psychological well-being (Aartsen & Jylhä, 2011; Dahlberg et al., 2015; VanderWeele, Hawkey, & Cacioppo, 2012), and more protective social factors (e.g. greater contact with friends, number of close friends, less strain from others, volunteering, and attending religious services) (Aartsen & Jylhä, 2011; Cohen-Mansfield et al., 2009; Petersen et al., 2016; Yang & Gu, 2020) are associated with decreased subsequent loneliness. For example, our findings align with previous study which found that increasing subjective well-being by one standard deviation is associated with decreased subsequent loneliness both 1 and 2 years later (VanderWeele et al., 2012). However, our results also diverged from the results of previous studies, which found associations between other factors and subsequent lower loneliness. For example, past research found that living with others (Theeke, 2009), fewer sleep problems (Hom et al., 2020), less cognitive impairment (Zhong, Chen, Tu, & Conwell, 2017), improved hearing (Maharani, Pendleton, & Leroi, 2019; Strawbridge, Wallhagen, Shema, & Kaplan, 2000), and fewer physical health conditions (Cohen-Mansfield et al., 2009) were related to less loneliness, but we did not find evidence of the association between these factors and subsequent loneliness in this study. Several potential reasons may explain our diverging results, including (1) differences in study design (e.g. varying follow-up periods, simultaneous controlling/covarying of predictors), (2) composition of the study sample, (3) measurement/categorization of exposures (e.g. stable levels of predictors *v.* changes in predictors) and outcomes (e.g. different types of loneliness scales, using 3 *v.* 11 *v.* 20 item UCLA loneliness scales), (4) number of covariates (e.g. differences in specific questionnaires/items, including fewer *v.* a larger range of covariates) and measurement of covariates (e.g. while some studies used self-reported ratings of physical activity [Macià et al., 2021] others used objective measurement tools such as accelerometers), or another reason entirely (Schrepff, Jackowska, Hamer, & Steptoe, 2019; Tully et al., 2019).

Importantly, our results corroborate previous research that loneliness is a *subjective* phenomenon, conceptualized as the *perceived* discrepancy between desired and experienced social connectedness (Perlman & Peplau, 1981). People can feel lonely even when with others, and research consistently finds that loneliness is only weakly associated with objective social isolation (Cacioppo & Cacioppo, 2018; Larson, 1990). Accordingly, our findings showed that *subjective* ratings of physical and psychological health (e.g. self-rated health, pain, purpose in life, negative affect) and the perceived social environment (strain from others, perceptions of positive social support from others, subjective rating of one status on a social ladder) were most strongly associated with subsequent loneliness. In contrast, we observed less evidence for associations between more objective indicators of individuals' physical health (e.g. specific health conditions) and subsequent loneliness.

Despite the acknowledgment that loneliness is a subjective evaluation, more objective social factor characteristics also predicted declines in subsequent loneliness (e.g. contact with friends, religious service attendance, volunteering, and the number of close friends). Improving people's objective social environment (e.g. increasing

**Table 4.** Robustness to unmeasured confounding (*E*-values) for the associations between candidate predictors and subsequent loneliness (*N* = 13 771)<sup>a</sup>

	Effect estimate <sup>b</sup>	Confidence interval limit <sup>c</sup>
Health behaviors		
Frequent physical activity	1.33	1.19
Smoking	1.23	1.00
Binge drinking	1.46	1.20
Sleep problems	1.07	1.00
Physical health		
Number of physical conditions		
Diabetes	1.08	1.00
Hypertension	1.26	1.00
Stroke	1.53	1.00
Cancer	1.07	1.00
Heart disease	1.08	1.00
Lung disease	1.15	1.00
Arthritis	1.12	1.00
Overweight/obese	1.20	1.00
Physical functioning limitations	1.44	1.24
Cognitive impairment	1.44	1.22
Chronic pain	1.33	1.14
Self-rated health	1.38	1.28
Hearing	1.20	1.08
Eyesight	1.26	1.09
Psychological well-being		
Positive affect	1.56	1.49
Life satisfaction	1.57	1.47
Optimism	1.51	1.43
Purpose in life	1.58	1.51
Mastery	1.40	1.34
Health mastery	1.43	1.35
Financial mastery	1.40	1.33
Psychological distress		
Depression	2.04	1.85
Depressive symptoms	1.60	1.50
Hopelessness	1.51	1.45
Negative affect	1.76	1.65
Constraints	1.61	1.54
Anxiety	1.59	1.45
Trait anger	1.43	1.36
State anger	1.36	1.28
Cynical hostility	1.37	1.30
Stressful life events	1.25	1.19
Financial strain	1.28	1.20

(Continued)

**Table 4.** (Continued.)

	Effect estimate <sup>b</sup>	Confidence interval limit <sup>c</sup>
Daily discrimination	1.45	1.39
Major discrimination	1.27	1.17
Social factors		
Living alone	1.58	1.19
Contact children		
<Every few months	Reference	Reference
1–2×/Month	1.19	1.00
1–2×/Week	1.34	1.00
≥3×/Week	1.39	1.00
Contact other family		
<Every few months	Reference	Reference
1–2×/Month	1.16	1.00
1–2×/Week	1.18	1.00
≥3×/Week	1.14	1.00
Contact friends		
<Every few months	Reference	Reference
1–2×/Month	1.40	1.16
1–2×/Week	1.59	1.42
≥3×/Week	1.75	1.55
Closeness with spouse	1.48	1.33
Any children	1.27	1.00
Any other family	1.20	1.00
Any friends	1.78	1.54
Number of close children	1.24	1.08
Number of close other family	1.21	1.09
Number of close friends	1.36	1.27
Positive social support from spouse	1.59	1.48
Positive social support from children	1.33	1.24
Positive social support from other family	1.24	1.13
Positive social support from friends	1.25	1.18
Social strain from spouse	1.74	1.57
Social strain from children	1.42	1.27
Social strain from other family	1.33	1.23
Social strain from friends	1.19	1.09
Neighborhood cohesion	1.35	1.27
Neighborhood disorder	1.23	1.15
Social effort/reward	1.34	1.27
Non-religious social activity	1.26	1.00
Volunteer		
0 h	Reference	Reference
0–49 h	1.26	1.00
50–99 h	1.35	1.05

(Continued)

Table 4. (Continued.)

	Effect estimate <sup>b</sup>	Confidence interval limit <sup>c</sup>
100–199 h	1.47	1.27
≥200 h	1.40	1.15
Religious service attendance		
Not at all	Reference	Reference
<1×/Week	1.30	1.03
≥1×/Week	1.46	1.27
Helping friends/neighbors/relatives		
0 h	Reference	Reference
0–49 h	1.24	1.00
50–99 h	1.32	1.00
100–199 h	1.17	1.00
≥200 h	1.25	1.00
Health insurance	1.58	1.30
Social status ladder	1.31	1.15
Change in social status ladder		
Moved down	Reference	Reference
No change	1.59	1.37
Moved up	1.48	1.00
Employment status	1.12	1.00

<sup>a</sup>See VanderWeele and Ding (2017) for the formula for calculating *E*-values.

<sup>b</sup>The *E*-values for effect estimates are the minimum strength of association on the risk ratio scale that an unmeasured confounder would need to have with both the exposure and the outcome to fully explain away the observed association between the exposure and outcome, conditional on the measured covariates.

<sup>c</sup>The *E*-values for the limit of the 95% confidence interval (CI) closest to the null denote the minimum strength of association on the risk ratio scale that an unmeasured confounder would need to have with both the exposure and the outcome to shift the confidence interval to include the null value, conditional on the measured covariates.

the size of one's network and increasing frequency of contact) is often proposed as ostensibly the only 'cure' for loneliness (Burholt & Scharf, 2014; Rokach, Orzeck, & Neto, 2004). Although this is a valuable effort (also supported by the current study), our findings indicate that fostering people's subjective assessments of psychological well-being and social relationships may be an equally powerful and complementary pathway to decreasing subsequent loneliness. However, there is no one-size-fits-all approach to combatting loneliness. Interventions should use both psychological (e.g. cognitive-therapy) and objective intervention methods (e.g. increasing social engagement through improved transportation, access to technology) to meet the specific needs of individuals (Mann et al., 2017).

Overall, the effect sizes of the various exposures examined were relatively modest, often corresponding to only a 0.05 or a 0.15 standard deviation reduction in subsequent loneliness. This was true for both the more psychological and the more objective social exposures; no single exposure seemed dominant. On the other hand, there was a wide range of physical, psychological, and social exposures associated with lower subsequent loneliness, which suggests that a multi-faceted intervention approach might be most effective in trying to alleviate loneliness.

The effects of a change in loneliness can differ for individuals who are initially lonely (*v.* are not), as is the case for the other

factors. By adjusting for pre-baseline loneliness in the analysis using the overall sample, we estimated the population-average effects of the predictors on loneliness among the whole sample that included both those who were initially lonely and those who were not. Our supplementary analyses revealed that effect sizes of most predictors were greater for those who were lonely (*v.* not lonely) at baseline (Supplementary Table S1). Importantly, these patterns were particularly evident among psychological well-being, psychological distress, and social factors. Further, the mere presence of a friendship (regardless of the amount or closeness to a friend) was associated with less subsequent loneliness only for those lonely (*v.* not lonely) at baseline. Thus, friendships may play an important role in reducing subsequent loneliness, particularly for those who are already experiencing loneliness.

Results from the sensitivity analysis that stratify by lonely and non-lonely individuals at baseline should be interpreted cautiously. Stronger associations between various predictors and subsequent loneliness among those lonely at baseline (*v.* those not lonely) may be explained by the regulatory loop model of loneliness, which posits that lonely individuals are more likely to continue experiencing loneliness due to their increased susceptibility to stressors (Hawkey & Cacioppo, 2010) or less variability in loneliness among those who are already lonely. Notably, growing research suggests that many predictors identified in the current study are modifiable through various intervention efforts. These predictors include but are not limited to behavioral (e.g. increasing physical activity) (Conn, Hafdahl, & Mehr, 2011) and psychosocial factors (e.g. positive affect, purpose, mastery, number of friends, depression, negative affect, anxiety) (Moskowitz et al., 2012; Stewart, Craig, MacPherson, & Alexander, 2001). For example, a meta-analysis of over 358 reports found that interventions using behavioral strategies (e.g. physical activity behavior feedback, goal-setting, self-monitoring) increase physical activity (Conn et al., 2011). Studies also indicate that various skills-based training improves positive affect (e.g. noticing minor positive events, mindfulness, positive reappraisal, acts of kindness) (Moskowitz et al., 2012). Similarly, cognitive behavioral therapy that focuses on reshaping misconceptions and biases about one's mastery and control over a situation/task improves a sense of mastery. Research also indicates that cognitive-behavioral therapy and mindfulness practices reduce depression and anxiety (Hong et al., 2021). Further, accumulating research also indicates that friendships can also be expanded. Various friendship interventions including, Friendship Enrichment Programs, The Fast Friend (FF) Procedure, and Befriending Interventions help individuals develop and maintain positive and close friendships (Stevens, Martina, & Westerhof, 2006; via enhancing: [1] listening, [2] self-disclosure, [3] expressing gratitude, [4] setting relationship boundaries, [5] increasing self-esteem) (Aron, Melinat, Aron, Vallone, & Bator, 1997; Hong et al., 2022; Siette, Cassidy, & Priebe, 2017). Finally, studies have identified building-blocks that can be potentially intervened upon (e.g. volunteering, physical activity) to enhance a sense of purpose in life (Nakamura, Chen, VanderWeele, & Kim, 2022).

There are important future directions for loneliness research. First, future research should examine how the mechanisms that explain the associations between candidate predictors and subsequent loneliness may vary by key social structural factors. Previous research indicates that loneliness varies by gender, age, socioeconomic status, and race/ethnicity. For example, greater loneliness is often reported by men (*v.* women) (Barreto et al.,

2021), among younger adults (*v.* older adults) (Franssen et al., 2020), people in lower socioeconomic positions (*v.* people in higher socioeconomic positions) (De Koning, Stathi, & Richards, 2017), and in the US and UK (*v.* Japan) (DiJulio, Hamel, Muñana, & Brodie, 2018). Examining these underlying pathways may help reduce loneliness among the most vulnerable populations (e.g. low SES). Second, growing research suggests that various health and well-being factors are differentially associated with transient *v.* chronic loneliness. For example, one study among older adults found that living alone and higher socioeconomic status are associated only with transient loneliness. In contrast, the death of a spouse within the past year is associated only with trait loneliness (Hector-Taylor & Adams, 1996). Thus, future research should further examine how a wide range of factors are associated with transient and chronic loneliness. Our study also had several limitations. First, many physical health outcomes and health behaviors were self-reported and thus are vulnerable to self-report bias. Study participants, however, were not aware of the study's hypothesis at the time of data collection. Second, a longer scale may more accurately assess loneliness. However, only the three-item loneliness scale was available in the 2006 wave of the HRS. The three-item loneliness scale, however, has shown strong reliability and validity when used in large population-based surveys (Hughes, Waite, Hawkey, & Cacioppo, 2004). Third, there is potentially unmeasured confounding. Yet, we were able to evaluate this concern specifically with robust covariate adjustment, use of a prospective design, and *E*-value analyses. Fourth, temporal factors should be taken into consideration when interpreting findings. Some factors that were associated with subsequent loneliness in our study (e.g. depression) are subject to acute intra-individual changes, and their impact on loneliness could be transitory. Thus, a 4-year interval between measurements may be too long to capture such phenomenon. The current study also had several strengths, such as the use of a prospective, large, diverse, and nationally representative sample of US adults who were 50 years and older. Third, although we adjusted for baseline loneliness to address potential reverse causation, this adjustment may have led to conservative associations between predictors and subsequent loneliness because baseline loneliness can be a mediator of associations.

Meeting the unique needs of our rapidly growing older adult population is expected to be one of the next major global public health challenges. Despite substantial gains in life expectancy, the number of years lost to disability has also increased. Thus, as populations rapidly age, identifying modifiable risk factors that reduce disease risk is important for stemming the rising tide of chronic conditions and associated healthcare costs. The COVID-19 pandemic, with its accompanying social distancing rules, further highlighted the growing concerns over the adverse health outcomes associated with loneliness. Our results highlight potential factors that can be targeted as we continue efforts to develop, refine, and deploy scalable loneliness interventions. Implementing individual- and community-level interventions and policies aimed at combatting loneliness may be a promising and innovative way to improve a wide range of health and well-being outcomes for our rapidly growing older adult population.

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**Ethical standards.** The ethics review board at the University of British Columbia exempted this study from human subjects review because we used de-identified and publicly available data.

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