

**Associations between changes in loneliness and social connections, and mental health
during the COVID-19 Pandemic: The Women's Health Initiative**

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ABSTRACT

Background. Older women have faced significant disruptions in social connections during the coronavirus disease 2019 pandemic. Whether loneliness increased, or whether a change in loneliness from pre- to intra-pandemic period was associated with mental health during the pandemic is unknown.

Methods. Older women (n=27,479; mean age 83.2 [SD: 5.4] years) completed surveys in mid-2020, including questions about loneliness, living arrangements, changes in social connections, and mental health. Loneliness was also previously assessed in 2014-2016. We examined whether loneliness changed from the pre- to intra-pandemic period and explored factors associated with this change. In multivariable models, we investigated the association of changes in loneliness and social connections with mental health.

Results. Loneliness increased from pre- to intra-pandemic levels. Factors associated with worsening loneliness included older age, experiencing stressful life events, bereavement, histories of vascular disease and depression, and social connection disruptions. Factors associated with a decrease in loneliness included identifying as Black, engaging in more frequent physical activity, being optimistic, and having a higher purpose in life. A 3-point increase in loneliness scores was associated with higher perceived stress, higher depressive, and higher anxiety symptoms. Social connection disruptions showed modest or no associations with mental health.

Conclusions. Loneliness increased during the pandemic in older women and was associated with higher stress, depressive and anxiety symptoms. Our findings point to opportunities for interventions targeting lifestyle behaviors, well-being, disrupted social connections, and paying closer attention to those with specific medical and mental health histories that may reduce loneliness and improve mental health.

Keywords. Loneliness, social connection, women, stress, depression, anxiety, SARS-CoV-2

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INTRODUCTION

Loneliness – the subjective feeling of being isolated – was highly prevalent among older adults even before the coronavirus disease 2019 (COVID-19) pandemic (1, 2). Pre-COVID data indicated that over 40% of Americans aged 60 and older were lonely (2-4), with one in five expressing frequent and severe feelings of loneliness (2). While loneliness decreases with age through the mid-70s, an overall increase is observed after age 75 (5). Loneliness is an important public health priority among older adults as it is associated with a myriad of long-term negative physical, cognitive, and mental health consequences, and premature all-cause mortality (2, 6-8).

Loneliness was widely anticipated to intensify among older adults during the COVID-19 pandemic, due to the national and self-imposed physical distancing and stay-at-home measures. However, studies of loneliness that included older cohorts are limited and have produced mixed findings (9-16). While a handful of investigations reported an increase in loneliness in older adults during the earlier months of the pandemic compared with the pre-pandemic levels (12, 13), one study found no change (14). In contrast, a larger number of COVID-19 surveys in mixed-age cohorts have reported that younger individuals express greater loneliness than their older counterparts (9-11, 15, 16). Despite these discrepancies, older women consistently expressed more loneliness than older men during the pandemic (12, 17-19), though explanatory factors are unknown. Also unclear is whether the degree of loneliness changed among the oldest-old women during COVID-19 compared with their pre-pandemic levels.

Older adults, especially the oldest-old, are particularly vulnerable to becoming severely ill and succumbing to COVID-19 because of multiple factors, including having more cardiovascular risk factors and other chronic health conditions. Significant precautions are therefore taken to protect them from virus exposure, bringing unprecedented disruptions to

their daily social connections. In older women, changes in loneliness levels and disruptions in objective social connections from the pre- to intra-pandemic period may adversely influence mental health outcomes during the pandemic; however, no study has evaluated this link.

We, therefore, utilized data collected from the Women's Health Initiative (WHI) participants (age range: 71 – 104 years) who completed surveys pre-pandemic (2014-2016) and during the earlier months of the pandemic (i.e., between February and October 2020) to examine (1) the changes in loneliness scores from the pre-pandemic to intra-pandemic period; (2) factors associated with changes in loneliness from the pre- to intra-pandemic period and loneliness severity during the pandemic; and (3) the associations of changes in loneliness and social connection disruptions from the pre- to intra-pandemic period with mental health outcomes during the pandemic. We further explored if the loneliness-mental health associations were modified by specific factors (i.e., age, reported race, life events, physical activity, depression history, and disruptions in social connection). While this study is not designed to examine the impact of the pandemic on non-White, financially insecure, and poorly educated subgroups, the WHI is one of the largest and more diverse cohorts of oldest-old women available; thus, this dataset provides a unique opportunity to examine the associations as described above.

METHODS

Study population

The WHI is a longitudinal study of 161,808 postmenopausal women aged 50-79 years originally recruited between 1993 and 1998 at 40 clinical centers across the United States. WHI participants were enrolled in an observational study (OS) or randomized into one or more of three clinical trials (CT) – hormone therapy (i.e., estrogen plus progestin or estrogen alone arms), dietary modification, or calcium and vitamin D supplementation. The WHI

study design and methods are detailed elsewhere (20). In 2005, either after the completion or early termination of all WHI clinical trials, women in both OS and CT components were consented to the first (2005-2010) and second (2010-2020) extension studies, which collected health updates and outcomes annually in active participants. WHI is now in its third extension (2020-2027). All participants provided written informed consent, according to the Institutional Review Board-approved protocols.

Cohort selection for this sub-study

Women who are still participating in WHI were included in this study if they completed the (1) three-item UCLA Loneliness scale during the 2014-2016 assessment, and (2) two surveys during the COVID-19 pandemic as of October 30, 2020. The two surveys were the “Activities of Daily Life,” completed between February 6, 2020 and October 30, 2020, in which the three-item UCLA Loneliness scale was repeated; and the “COVID-19 Impact Survey,” completed between June 5, 2020 and October 29, 2020 (See **Figure 1** for details).

Loneliness measure before and during COVID-19

Loneliness was measured twice (once during 2014-2016, and then in 2020 during the COVID-19 pandemic) using the three-item version of the UCLA loneliness scale. This self-reported instrument has demonstrated good reliability and both concurrent and discriminant validity and has been used in several aging studies (3, 21-23). This scale assesses subjective feelings of loneliness on a 3-point Likert scale ranging from 1 (hardly ever) to 3 (often). The three items are: (1) How often do you feel that you lack companionship? (2) How often do you feel left out? and (3) How often do you feel isolated from others? The scores range from 3 to 9; higher scores indicate greater perceived loneliness (21, 24), with women categorized as no/minimal loneliness (score of 3); some loneliness (score of 4–5); and severe loneliness (score ≥ 6).

Psychological and mental health assessments during COVID-19

Perceived stress. The four-item perceived stress scale (25), a widely used instrument, was completed on a COVID-19 survey. The items included *in the past 4 weeks how often have you felt that* (1) you were unable to control the important things in your life; (2) confident about your ability to handle your personal problems; (3) things were going your way; and (4) difficulties were piling up so high that you could not overcome them. The total scores range from 0 to 16, with higher scores indicating greater levels of perceived stress.

Current depressive symptoms. Current depressive symptoms were assessed on a COVID-19 survey using the six-item Center for Epidemiologic Studies Depression Scale (CES-D short form) (26, 27). This scale has been widely utilized in previous aging studies (27, 28). Participants are asked about their feelings during the past week, and the scores range from 0 to 18. Higher scores indicate greater levels of depressive symptoms, with a score ≥ 5 indicative of clinically significant depressive symptoms.

Current anxiety symptoms. The PROMIS Anxiety Short Form 4a questionnaire, which included four questions related to anxious mood in the past seven days, was used to measure current anxiety symptoms in the past seven days during COVID-19 (29, 30). Participants rated each item on a five-point scale (from 1 [never] to 5 [always]), with the total score ranging from 4 to 20. Total raw scores were then converted to a standardized T-score to generate a final score. The standardized T-score on this scale ranges from 40.3 to 81.6, with a mean of 50 (standard deviation of 10) for the general population. Higher scores indicate greater anxiety symptom severity, with PROMIS T-score ≥ 60 indicative of moderate to severe anxiety.

Living arrangement and changes in objective social connections during COVID-19

Living alone status. This variable was assessed by asking the question, “Do you live alone?” with participants answering either *yes* or *no*.

Changes in living arrangements due to the COVID-19 pandemic were assessed using the question, “Has your living arrangement, including the place where you live and the people that live with you, changed since March 2020 due to the COVID-19 pandemic?” with participants answering *yes* or *no*.

Living situation restrictions were indicated as *yes* if a participant lived in a care facility where residents were either not allowed to leave their home/apartment/room, have visitors, or leave the property except for emergencies, and/or food was delivered to their home/apartment/room. No living restrictions were indicated if a participant lived in a private home or endorsed that the care facility in which they lived had no restrictions on residents.

Social communication frequency during COVID-19 was assessed by the question: “How often do you communicate with others who live outside your home?” Participants were grouped into categories of *every day or several times per week* or *1-2 times per week or less*.

Change in communication frequency during the pandemic compared with before the pandemic was assessed by the question: “Compared to months before the outbreak began, would you say this (i.e., communication with others) is (1) *about the same or more often than before*, or (2) *less often than before*.”

In addition, the methods by which the participants communicated were assessed by: “How are you staying in touch with others who do not live with you.” Since there were too few responses in certain groups (i.e., speaking by telephone/video only), participants were grouped into: speaking *in person*, or *only by telephone/video/email/social media/postal mail but not in person*.

Covariates

The following variables were assessed at the WHI baseline: race, ethnicity, and education. The 2020 WHI activities of daily life survey included life events measures over the past year (stressful life events, death or serious illness of close friend or family member, death of a pet, death of spouse or partner), optimism, the purpose in life construct (31, 32)), and history of depression (using the two-item National Institute of Mental Health's Diagnostic Interview Schedule). The 2020 COVID-19 survey assessed lifestyle variables, including current walking/physical activity, alcohol intake, and smoking history. The annual WHI medical history updates included vascular risk factor variables (i.e., cerebrovascular/cardiovascular disease [CVD], cancer, treated diabetes, treated hypertension, and body mass index [BMI]). The vascular risk factors score is a composite of treated diabetes, treated hypertension, current smoker, and $BMI \geq 30$. The presence of each risk factor contributes one point to the score (range: 0 to 4). These variables came from the annual medical history assessment closest to the time of collection of the two 2020 WHI surveys during COVID-19.

Statistical analysis

We used a paired t-test to evaluate within-participant changes in the loneliness score between 2014-2016 to 2020. We used linear regression to examine changes in the loneliness scores using the participants' age group at the 2014-2016 assessment (<70, 70-74, 75-79, 80-89, and ≥ 90 years).

We explored the factors related to (1) within-participant change in pre- to intra-pandemic loneliness scores, as well as (2) the loneliness score during the pandemic. Estimates of the associations were presented as beta coefficients and 95% confidence intervals (95% CI), calculated from separate unadjusted linear regressions where the change

in loneliness scores and the loneliness score during the pandemic were separately modeled as functions of each of the factors.

We conducted multivariable linear regression analyses to examine the associations of living alone during the pandemic, changes in loneliness and social connectedness from the pre- to intra-pandemic period, and each mental health outcome (perceived stress, depressive symptoms, and anxiety symptoms) as separately modeled as a dependent variable. Loneliness change and all social connection variables were included in the same model and all models were adjusted for sociodemographic factors (age, education, race, and ethnicity), lifestyle factors (physical activity, alcohol intake, number of life events), and medical history: CVD, cancer, vascular factors risk score, history of depression. Estimates, including beta coefficients (representing the strength of the association) and 95% CI from these models are presented. Odds ratio estimates from logistic regression models were also calculated where clinically significant depressive symptoms (i.e., CES-D \geq 5) and moderate to severe anxiety (i.e., PROMIS T-score \geq 60) were separately modeled as functions of change in loneliness score (intra-pandemic minus pre-pandemic) and social connection variables, after adjusting for above-mentioned covariates.

Finally, we evaluated effect modification by age, race, objective social connection variables, physical activity, past depression history, and stressful life events. Models included main effects for change in loneliness score and the effect modifier variables further adjusted for education, Hispanic/Latina ethnicity, alcohol intake, and medical history (CVD history, cancer history, and vascular factors risk score). Interaction terms were created by multiplying the change in loneliness score by the potential effect modifier.

The p-value was set *a priori* at <0.0001 for statistical significance to minimize Type 1 error. Analyses were conducted using SAS version 9.4 (SAS Institute Inc., Cary, NC, USA).

RESULTS

Figure 1 is the STROBE flow diagram that outlines the methods used to arrive at the final sample (n=27,479) for this WHI sub-study.

The descriptive characteristics (frequencies and percentages) of the final WHI sample of participants (n=27,479) who completed the loneliness questionnaire during the 2014-2016 and 2020 assessments respectively are summarized in **Table 1**. The mean age (SD) of the participants was 83.2 (5.4) years during the 2020 surveys. On the COVID-19 survey, most women reported being nonsmokers (97.7%), 12% reported a history of CVD, 25.8% cancer, 20% diabetes, 71% hypertension, and 4.6% a history of depression, and the mean (SD) BMI of the full cohort was 26.0 (5.2). Most women reported walking for at least 5 minutes without stopping 2-3 times or more per week (67.5%) and consuming 4 or fewer alcoholic drinks per week (81.4%). During the one year before completing the 2020 surveys, 37.6% of women either experienced death or serious illness of a close friend or family member, and about 5% experienced bereavement of a spouse or partner (**Table 1**).

During the earlier months of the COVID-19 pandemic, 46.8% reported living alone. 82% of women reported no changes in their living alone status in 2020 compared with their 2014-2016 status (i.e., those who answered “yes” to living alone in 2014-2016 reported the same in 2020, and those who reported “no” answered the same at both assessments). Due to the pandemic, 6.1% reported changes in their living arrangement, and 13.8% reported restrictions in their living situation. Although a vast majority (80%) reported communicating every day or several times per week with others outside their home, 25.7% reported that the communication frequency occurred less often than before the pandemic, and only 39% were staying in touch with others during the pandemic by physically speaking *in person*. During the pandemic, 19% of women reported clinically significant depressive symptoms (i.e., CES-

D score ≥ 5) and 12% endorsed moderate to severe anxiety symptoms (i.e., PROMIS Anxiety score ≥ 60) (**Table 1**).

Loneliness changes from before to during the COVID-19 pandemic

While only 10% reported severe loneliness scores (i.e., UCLA 3-item loneliness score ≥ 6) pre-pandemic, approximately 19% reported severe loneliness during the pandemic (**Table 2a**). Compared with the pre-pandemic levels, the overall loneliness scores were higher during COVID-19 (mean change [SD]: 0.46 [1.4]; $p < 0.0001$). In the linear regression model with loneliness score changes modeled as a function of age in 2014-2016, feelings of loneliness were significantly higher during the pandemic than pre-pandemic in all age categories, except the youngest age group (< 70 years) (**Table 2b**).

Factors associated with loneliness changes

The factors associated with an intra-participant change in loneliness scores from pre-pandemic to intra-pandemic (**Figure 2a**), and (b) loneliness scores during the pandemic were similar (**Figure 2b** and **Supplementary Table S1**).

Older age (i.e., ≥ 80 years of age), reporting more stressful life events, experiencing death or serious illness of a close friend or family member, experiencing the death of a spouse or partner, history of CVD, and depression history were associated with worsening of loneliness scores over time.

Living alone during the pandemic and changes in the objective social connection factors (i.e., change in living arrangement, living situation restrictions, and less communication with others outside the home during the pandemic) were also associated with worsening of loneliness scores (**Figure 2a**; **Supplementary Table S1**).

Identifying as Black/African American (compared with White), walking continuously for at least five minutes 4 or more times per week (versus ≤ 3 times/week), drinking ≤ 4

alcoholic drinks per week, being more optimistic, and having a higher sense of purpose in life score were associated with a decrease in loneliness scores from the pre- to intra-pandemic period.

We further explored whether the month when and the region in the U.S. where the COVID survey was completed were associated with changes in loneliness from the pre-pandemic to the intra-pandemic period. We found no significant associations between the region or month of survey and change in loneliness.

Associations of changes in loneliness and objective social connection with mental health

In multivariable models, changes in loneliness showed a stronger association than living alone and changes in objective social connections, with all three dependent variables, after full covariate adjustment: During the pandemic, a 3-point increase in feelings of loneliness from pre- to intra-pandemic scores was associated with mean 0.56-point *higher* perceived stress (95% CI, 0.46, 0.65), 1.02-point *higher* depressive symptom (95% CI, 0.95, 1.09) and 1.78-point *higher* anxiety symptom (95% CI, 1.54, 2.02) scores ($p < 0.0001$) (**Table 3**). Because the rates of COVID-19 cases fluctuated on a month-to-month basis in different parts of the U.S., we conducted additional analyses to explore whether the associations between loneliness changes and mental health outcomes were different, after including the month when and the U.S. region where the COVID survey was completed as covariates. The Beta estimates and confidence intervals were not appreciably different (data not shown).

After full covariate adjustment, a 3-point increase in loneliness score from pre- to intra-pandemic period was associated with two-fold increased odds of clinically significant depressive symptoms (odds ratio = 2.37 [95% CI: 2.18, 2.57]; $p < 0.0001$) and 55% increased odds of moderate to severe anxiety (odds ratio = 1.55 [95% CI: 1.42, 1.70]; $p < 0.0001$) during the pandemic (**Supplementary Table S2**).

While changes in living arrangement due to COVID-19 were significantly associated with 0.43-point *higher* perceived stress (95% CI, 0.26, 0.60), 0.29-point *higher* depressive symptom (95% CI, 0.15, 0.42), and 1.66-point *higher* anxiety symptom (95% CI, 1.19, 2.13) scores ($p < 0.0001$), living alone did not significantly correlate with perceived stress or mental health measures. However, lack of in-person communication was associated with modestly higher perceived stress, depressive and anxiety symptoms. Lower frequency of communication during COVID-19, relative to pre-pandemic levels, was associated with modestly higher perceived stress and anxiety, but not depressive symptoms (**Table 3**).

Associations of changes in loneliness and social connection measures and mental health during the pandemic did not significantly vary by age and racial subgroups, physical activity, history of depression, stressful life events, living alone, or social connection measures (**Supplementary Table S3**). Changes in living arrangement showed a trend toward modifying the association between loneliness and depressive symptoms: In participants who reported a change in living arrangement due to COVID-19, increases in loneliness over time were associated with a mean 1.45-point increase in depressive symptoms versus a mean 0.99-point increase in those who did not report a change (interaction p -value=0.0005).

DISCUSSION

In a large sample of older women, significant increases in loneliness were observed during the earlier pandemic months, relative to pre-pandemic levels; this increase was more pronounced in those 70 years of age and older. Factors associated with increasing loneliness scores included older age, experiencing a greater number of life stressors (especially death of a spouse/partner) during the past year, having a history of CVD, a history of depression, and reporting social connection disruptions during the pandemic. The factors associated with decreases in loneliness over time included being Black/African American, being Asian/Pacific Islander, engaging in more frequent physical activity, being more optimistic,

and having a higher purpose in life. Increasing feelings of loneliness were associated with higher perceived stress, and depressive and anxiety symptoms during the pandemic. In contrast, living alone during the pandemic was not associated with mental health, and changes in objective social connection measures showed modest or no associations with these measures during the pandemic. These novel findings provide unique insights regarding loneliness and its association with mental health during COVID-19 and underscore the importance of developing strategies that mitigate loneliness to improve mental health in older women.

Recent longitudinal studies comprising older mixed-gender samples have reported an overall increase in loneliness during the earlier pandemic months compared with the pre-pandemic period (12, 13). In a Dutch study among 1,679 community-dwelling older adults, when loneliness increased during the pandemic, overall mental health remained stable (13). In another cohort of 1,990 Swiss older adults, loneliness scores increased after their government recommended physical distancing policies to protect older adults (12). Studies comprising mixed-age samples, however, have reported variable findings. For example, data from the Health and Retirement Study of U.S. adults over age 50 years showed no change in loneliness levels despite experiencing increased physical isolation during COVID-19. Participants in that study stayed digitally connected, which may have protected them from feeling lonely (14). Large cross-sectional studies from across Europe also report higher loneliness levels in younger than older adults during the COVID-19 lockdown (9, 10, 16). In a nationwide sample of American adults, older adults also expressed less loneliness than their younger counterparts, though the former showed loneliness increases in response to the acute pandemic phase (11). In these prior investigations, few older women, especially those who belong to the oldest-old cohort, were included. This is pertinent because older women express more loneliness than older men during the pandemic (12, 17-19). Further, the National Social

Life, Health and Aging Project of health and aging conducted pre-COVID-19 demonstrated that loneliness decreases with age until the mid-70s, but then increases after age 75 (5). Our findings suggest that older women express increased feelings of loneliness, particularly during unprecedented situations like the COVID-19 pandemic, and the importance of monitoring, preventing, and managing this silent epidemic during this and future similar crises. However, older women are not a monolithic group vulnerable to loneliness; certain factors may alter the risk.

Specific factors associated with worsening loneliness in our older women sample are mostly consistent with other pre- and intra-COVID-19 data from mixed-age and -gender studies. Older subgroups who reported greater loneliness during the pandemic included those living alone, having limited social contact, experiencing changes to their daily routine, and reporting poor health (12, 18, 33, 34). Also, about two-thirds of older adults with chronic health conditions (35) and over 50% of oncology patients (36) were found to experience at least moderate loneliness during the pandemic. Prior studies have also reported that experiencing bereavement and the presence of mental disorders is associated with higher loneliness during the COVID-19 lockdown (9, 12).

Loneliness intensifies after bereavement and is a gateway symptom to subsequent depressive symptoms in grieving individuals (37). Moreover, intense loneliness is one of the main associated symptoms in the diagnostic criteria for prolonged grief disorder, a clinical condition that is diagnosed 12-months post-loss in those experiencing protracted and disabling grief symptoms. Also, chronic medical conditions, including vascular factors, and CVD are associated with increased loneliness risk; those who have these health conditions have worse outcomes especially if they are lonely (2). Our data provide important clues as to the specific older women subgroups (i.e., those experiencing disruptive life events such as bereavement, chronic medical and mental health conditions, living alone, and disruptions in

social connections) who may benefit from targeted interventions to alleviate or prevent loneliness.

Few studies have examined the association between loneliness and race in older adults. Emerging COVID-19 data suggest that older persons of color with chronic conditions report lower loneliness (35). Lower odds of depression and anxiety have also been reported during COVID-19 in those identifying as Black; similar trends were also seen in those identifying as Asian (38). Similarly, young Asian Americans were less likely to report high levels of depressive and anxiety symptoms compared to whites in another COVID-19 study (39). Our results suggest that, among older adults, identifying as Black or Asian/Pacific Islander (compared with White) is associated with decreases in loneliness from the pre- to intra-pandemic period. Plausible explanations for racial differences may include greater social connections and support available to older Black and Asian/Pacific Islander women relative to their White counterparts. For instance, a pre-COVID study found that non-Hispanic White persons are more likely to live alone, have limited social contact, and be childless than Black persons; in fact, being a Black woman was found to be associated with less social isolation (40).

We also observed that being more physically active and more optimistic, consuming moderate to no alcohol, and reporting a higher purpose in life are associated with a decrease in loneliness from the pre- to intra-pandemic period. These associations are supported in the literature across men and women of different ages (2, 41-43). Our findings raise the possibility that interventions focused on increasing physical activity, moderating alcohol intake, and cultivating positive psychological attributes such as optimism or purpose in life may serve to protect against detrimental loneliness changes in older women.

We found stronger positive associations of change in loneliness from the pre- to intra-pandemic period were associated with higher perceived stress, depressive and anxiety

symptoms during the pandemic. These findings are in line with the published cross-sectional and longitudinal pre-COVID literature (44-47). In the Chicago Health, Aging, and Social Relations Study, loneliness predicted subsequent changes in depressive symptoms in a young-old sample; however, this association did not vary based on objective social connection measures of social network and support (48). In a representative older adult sample, being lonely, but not socially isolated as determined by living alone and having no direct social contacts, were cross-sectionally associated with higher depressive symptoms during the COVID-19 lockdown (49). Consistent with these findings, living alone was not associated with mental health measures, and did not modify the longitudinal loneliness-mental health associations in our study. However, modest positive associations were observed between disruptions in living arrangement due to COVID-19, and mental health variables in our study. Furthermore, women reporting living arrangement disruptions during COVID-19 showed a stronger loneliness-depressive symptom association in our study. Collectively, these results suggest that loneliness and disruptions in living arrangements increase vulnerability to stress and mental health issues. As older women belong to an age group vulnerable to experiencing COVID-related complications and deaths, the feeling of being protected against virus exposure while living alone may have alleviated depression and anxiety risk in this age cohort.

Such social exclusion, however, has led many older adults to rely heavily on digital and other non-in-person services to stay in touch with others in society (50). Among younger and middle-aged adults, modern information and communication technologies (ICTs) including smartphones, laptops, computers, and high-speed internet services have increased social networking during the pandemic by using video call apps and video conferencing platforms. On the contrary, older adults have been slower to adapt to these communication methods, even though their access to digital technologies has increased in recent years. Older

adults use modern ICTs in more basic ways than their younger counterparts (51) and continue to prefer in-person contact and telephone communication methods as their primary modes of staying socially connected (50).

The older women in the WHI cohort are no exception to this digital gap. While over 90% of older women in our study stayed in touch via telephone, only one-third also used video calls to stay in touch with others. These data, combined with our findings that a lack of in-person communication was associated with higher mental health symptoms, shed light on yet another adverse consequence of COVID-19 afflicting older adults. Factors associated with digital inequalities among older adults require additional research. The influence of staying in touch using different modalities of modern ICTs, rather than telephone, on mental health adversities in older adults should be addressed in future studies. These lines of research may aid in designing interventions to enhance digital technology adoption and use among elders, especially in those with physical disabilities and cognitive impairment who are living alone or in long-term care facilities, to mitigate loneliness and mental health symptoms (50, 52).

Multiple lifestyle behavioral and psychological mechanisms may increase the vulnerability of older women to feel lonely, and link loneliness with poor mental health outcomes (1, 2). Moreover, several plausible biological factors, including inflammation, activation of the hypothalamus-pituitary-adrenocortical axis, neurodegeneration, and brain amyloid burden have been proposed as mechanisms linking loneliness with adverse mental health outcomes (2, 53). These and other potential biological pathways should be the focus of future investigations.

Our study has several strengths, including the availability of longitudinal loneliness assessments both before and during the pandemic, change in objective social connection measures due to the pandemic, information on psychological and mental health measures

during the pandemic, as well as several covariates in a large sample of older women. However, there are study limitations. Our study cohort is a subsample from a larger sample of women who participated in multiple WHI studies that spanned over several decades. Thus, selection bias is possible. Our sample is mostly White, highly educated and at the time of WHI study enrollment, had higher incomes; thus, our results may not be generalizable. Also, we do not have data on financial status/income during this study period. Nevertheless, we would like to highlight that the oldest old age groups in the U.S. are less diverse than the younger age subgroups (54). Moreover, the WHI is one of the largest and more diverse cohorts of older women available and major efforts were made at enrollment to recruit a diverse study population. Specifically, our sample comprised of 1324 Black/African American and 624 Asian/Pacific Islander, as well as 886 Hispanic women over the age of 70. Future studies are needed to specifically address the potential adverse impact of the pandemic on predominantly non-White, financially disadvantaged, and poorly educated oldest-old cohorts. The first loneliness measure was collected about 4-6 years before the intra-pandemic assessment. Several factors could have contributed to changes in loneliness over this extended timeframe; we attempted to address this by adjusting for a robust set of covariates in our models. One major stressor, however, deserves special mention. Older women may have experienced the death of loved ones during this period. While we do not have bereavement data for the entire 4–6-year period, we collected this data for one year before the 2020 loneliness and mental health assessments. The relationship between the death of a spouse or partner over one year before the 2020 assessment and loneliness changes were examined (see **Figure 2** and **Table S1**). The mental health variables were all self-report measures, which cannot replace clinician diagnoses of mental disorders. Also, other self-report scales that can assess depressive and anxiety symptoms in more detail than those used here are available (55, 56). Cognitive assessments were not available; the effects of cognitive

impairment on the loneliness-mental health associations remain to be elucidated. Finally, a small number of women in our study identified themselves as American Indian/Alaskan Native; however, we are unable to perform analyses or draw any conclusions in this specific racial subgroup due to the small sample size. Future studies with larger samples of Native American participants with different tribal affiliations should explore the associations between loneliness and mental health outcomes.

In summary, loneliness increased in older women during the COVID-19 pandemic. Loneliness worsening was associated with increased stress, and higher depressive and anxiety symptoms during the pandemic. Several factors were associated with worsening and decreases of loneliness during the pandemic. Our preliminary findings thus point to opportunities for possible interventions targeting lifestyle behaviors (e.g., physical activity, alcohol intake, etc.), optimism and purpose in life, disrupted social connections, and monitoring those with specific medical and mental health histories that may reduce loneliness and improve mental health in older women.

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CONFLICTS OF INTEREST

The authors report no conflicts of interest

AUTHOR CONTRIBUTIONS

Conception or design of the work: Goveas, Ray, Shumaker, and Anderson

Acquisition and analysis of data: Goveas, Ray, Manson, Kroenke, Johnson, Wactawski-Wende, Naughton, Shumaker, and Anderson

Preparation of manuscript: Goveas and Ray

Interpretation of data: All authors

Critical revision of the work for important intellectual content: All authors

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FIGURE LEGENDS

Figure 1. STROBE Flow Diagram.

Footnote. WHI activities of daily life survey were received between February 6, 2020 and October 30, 2020; WHI COVID-19 survey was received between June 5, 2020 and October 29, 2020

Figure 2a. Factors related to a within-participant change in loneliness from before the COVID-19 pandemic (2014-2016) to during the pandemic (2020).

Footnote. Estimates are the beta coefficients (slope) from unadjusted linear regression models where a change in loneliness is modeled as a function of each characteristic.

Figure 2b. Factors related to loneliness during the COVID-19 pandemic.

Footnote. Estimates are the beta coefficients (slope) from unadjusted linear regression models where loneliness is modeled as a function of each characteristic.

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Table 1. Descriptive characteristics

| Characteristic | All participants (n=27,479) | |
|--|-----------------------------|-------|
| | n | % |
| Demographics | | |
| Age at 2020 survey, mean (SD) ¹ | 83.2 | (5.4) |
| Hispanic/Latina | 886 | 2.8 |
| Race | | |
| American Indian/Alaska Native | 57 | 0.2 |
| Asian/Pacific Islander | 624 | 2.3 |
| Black/African American | 1324 | 4.8 |
| White | 24,959 | 90.8 |
| More than one race | 299 | 1.1 |
| Unknown/Not reported | 216 | 0.8 |
| Education | | |
| High school diploma or less | 4185 | 15.2 |
| School after high school | 9386 | 34.2 |
| College degree or higher | 13,724 | 49.9 |
| Lifestyle | | |
| Walking continuously for 5 minutes or more | | |
| ≤1 time each week | 8554 | 31.1 |
| 2 to 3 times each week | 6368 | 23.2 |
| 4 to 6 times per week | 6890 | 25.1 |
| 7 or more times per week | 5277 | 19.2 |
| Alcoholic drinks per week | | |
| None | 13,758 | 50.1 |
| ≤4 | 8611 | 31.3 |
| 5-7 | 3846 | 14.0 |
| >7 | 985 | 3.6 |
| Currently smoke regular or electronic cigarettes | 348 | 1.3 |
| Life events² | | |
| Number of stressful life events (0-11), mean (SD) | 1.0 | (1.1) |
| Death or serious illness of close friend or family member (other than spouse or partner) | 10,335 | 37.6 |
| Death of a pet | 1848 | 6.7 |

| Characteristic | All participants (n=27,479) | |
|---|-----------------------------|-------|
| | n | % |
| Death of spouse or partner | | |
| No | 24,183 | 88.0 |
| Yes | 1306 | 4.8 |
| Intense longing or yearning for spouse/partner who died | | |
| Did not experience death of spouse/partner | 24,183 | 88.0 |
| Never/rarely | 374 | 1.4 |
| Sometimes/often | 775 | 2.8 |
| Always | 116 | 0.4 |
| Frequent thoughts about spouse/partner who died intrude on usual activities | | |
| Did not experience death of spouse/partner | 24,183 | 88.0 |
| Never/rarely | 787 | 2.9 |
| Sometimes/often | 459 | 1.7 |
| Always | 36 | 0.1 |
| Optimism construct, mean (SD) | 23.6 | (3.6) |
| Purpose in life construct (7-item scale), mean (SD) | 19.2 | (4.8) |
| Medical history³ | | |
| CVD | 3288 | 12.0 |
| Cancer | 7078 | 25.8 |
| Treated diabetes | 5530 | 20.1 |
| Treated hypertension | 19,518 | 71.0 |
| Body mass index (BMI, kg/m ²), mean (SD) | 26.0 | (5.2) |
| Vascular risk factors score (0-4), mean (SD) ⁴ | 1.1 | (0.8) |
| History of depression (DIS) ² | 1274 | 4.6 |
| Social Connection | | |
| Lives alone ² | 12,857 | 46.8 |
| Living arrangement ² | | |
| Independently in the community | 21,584 | 78.6 |
| With family other than spouse, assisted living or skilled nursing facility, other | 5256 | 19.1 |
| Changes in living arrangement since March 2020, due to the COVID-19 pandemic | 1676 | 6.1 |
| Living situation restrictions due to the COVID-19 pandemic | 3795 | 13.8 |
| Communication with others outside the home | | |
| Every day or several times per week | 21,973 | 80.0 |
| 1-2 times per week, or less | 4612 | 16.8 |
| Frequency of communication, compared to before the pandemic | | |
| About the same, or more often than before | 19,542 | 71.1 |
| Less often than before | 7051 | 25.7 |
| Ways of staying in touch with others | | |
| Speaking in person | 10,684 | 38.9 |
| Telephone, video, social media, email or postal mail, but not in person | 16,257 | 59.2 |
| Psychological and Mental Health⁵ | | |

| Characteristic | All participants (n=27,479) | |
|--|-----------------------------|-------|
| | n | % |
| Perceived stress 4-item score, mean (SD) | 4.6 | (2.9) |
| CES-D 6-item scale, mean (SD) | 2.8 | (2.5) |
| CES-D score ≥ 5 | 5191 | 18.9 |
| PROMIS Anxiety 4-item T-score, mean (SD) | 50.7 | (8.2) |
| PROMIS Anxiety score ≥ 60 | 3262 | 11.9 |

Foot note. Numbers and percentages do not always sum to the total, due to missing data. Abbreviations: SD, standard deviation; DIS, Diagnostic Interview Schedule

¹At the 2014-2016 assessment, mean age (SD) for this cohort: 78.0 (5.4)

²Life events items and history of depression were collected on the Activities of Daily Life survey in 2020

³Medical history data (*except* history of depression) were collected as part of the ongoing WHI follow-up assessments; these variables come from the *annual* follow-up assessment closest to the time of collection of the 2020 surveys

⁴Vascular risk factors score is a composite of treated diabetes, treated hypertension, current smoker, and BMI ≥ 30 . Presence of each characteristic contributes one point to the score

⁵Perceived stress ranges from 0 (no stress) to 16 (greatest stress); Center for Epidemiologic Studies Depression Scale (CES-D) ranges from 0 to 18 (≥ 5 considered to have depressive symptoms); PROMIS Anxiety T-score ranges from 40.3 to 81.6. General population mean is 50 (SD=10). Higher score=greater anxiety.

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Table 2. Change in Loneliness between pre-pandemic and during the COVID-19 pandemic

2a. Loneliness scores as a categorical variable

| | 2014-2016 | | 2020 | | P-value ¹ |
|-------------------------------------|-----------|------|-------|------|----------------------|
| | N | % | N | % | |
| UCLA 3-item loneliness score | | | | | |
| 3 (no/minimal loneliness) | 18980 | 69.1 | 14896 | 54.2 | <0.0001 |
| 4-5 (some loneliness) | 5834 | 21.2 | 7458 | 27.1 | |
| 6-9 (severe loneliness) | 2665 | 9.7 | 5125 | 18.7 | |

2b. Loneliness scores as a continuous variable

| UCLA 3-item loneliness score | N | 2014-2016 | | 2020 | | Change | | P-value ² |
|------------------------------|------|-----------|-------|------|-------|--------|-------|----------------------|
| | | Mean | SD | Mean | SD | Mean | SD | |
| Overall | | 3.6 | (1.1) | 4.1 | (1.5) | 0.46 | (1.4) | <0.0001 |
| Age in 2014-2016 | | | | | | | | |
| <70 | 807 | 3.7 | (1.3) | 3.9 | (1.4) | 0.18 | (1.3) | 0.0002 |
| 70-74 | 7332 | 3.6 | (1.1) | 3.9 | (1.4) | 0.34 | (1.3) | <0.0001 |
| 75-79 | 9151 | 3.6 | (1.1) | 4.0 | (1.5) | 0.43 | (1.4) | <0.0001 |
| 80-89 | 9494 | 3.7 | (1.2) | 4.2 | (1.6) | 0.57 | (1.5) | <0.0001 |
| ≥90 | 695 | 3.8 | (1.2) | 4.6 | (1.8) | 0.77 | (1.7) | <0.0001 |

¹P-value is from Bowker's test of symmetry and compares categorical loneliness scores from 2014-16 and 2020, taking into account the paired data.

²P-values test change in loneliness from 2014-2016 to 2020 and are from paired t-test (overall) or linear regression model with change in loneliness score modeled as a function of age in 2014-2016.

Abbreviations: SD, standard deviation.

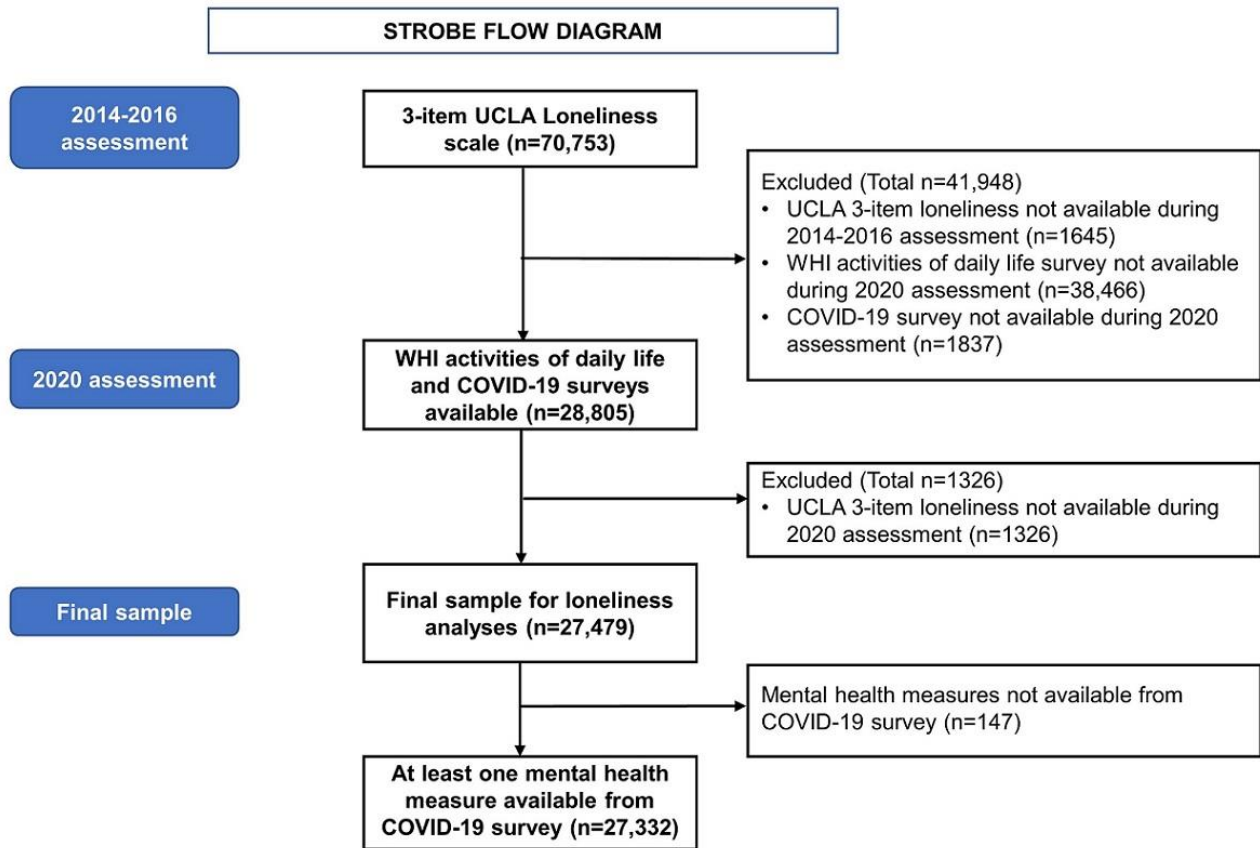
Table 3. Multivariable associations between changes in loneliness and social connection, and mental health during the COVID-19 pandemic

| Characteristic | Perceived Stress 4-item score | | CES-D Depression 6-item scale | | PROMIS Anxiety 4-item T-score | |
|---|-------------------------------|---------|-------------------------------|---------|-------------------------------|---------|
| | Estimate (95% CI) | P-value | Estimate (95% CI) | P-value | Estimate (95% CI) | P-value |
| Change in loneliness score, continuous (by increase of 3) | 0.56 (0.46, 0.65) | <0.0001 | 1.02 (0.95, 1.09) | <0.0001 | 1.78 (1.54, 2.02) | <0.0001 |
| Lives alone | -0.06 (-0.14, 0.02) | 0.1528 | -0.02 (-0.08, 0.05) | 0.6127 | -0.29 (-0.51, -0.07) | 0.0089 |
| Changes in living arrangement due to the COVID-19 pandemic | 0.43 (0.26, 0.60) | <0.0001 | 0.29 (0.15, 0.42) | <0.0001 | 1.66 (1.19, 2.13) | <0.0001 |
| Living situation restrictions due to the COVID-19 pandemic | 0.43 (0.31, 0.56) | <0.0001 | 0.13 (0.03, 0.23) | 0.0083 | 0.53 (0.20, 0.86) | 0.0018 |
| Communication with others outside the home | | | | | | |
| Every day or several times per week | Reference | | Reference | | Reference | |
| 1-2 times per week or less | 0.50 (0.38, 0.61) | <0.0001 | 0.19 (0.11, 0.28) | <0.0001 | -0.10 (-0.41, 0.20) | 0.5123 |
| Frequency of communication now, compared to before the pandemic | | | | | | |
| About the same or more often | Reference | | Reference | | Reference | |
| Less often than before | 0.30 (0.21, 0.39) | <0.0001 | 0.14 (0.07, 0.21) | 0.0001 | 1.22 (0.98, 1.47) | <0.0001 |
| Ways of staying in touch with others | | | | | | |
| Speaking in person | Reference | | Reference | | Reference | |
| Telephone, video, social media, email or postal mail, but not in person | 0.34 (0.26, 0.43) | <0.0001 | 0.21 (0.14, 0.27) | <0.0001 | 1.04 (0.82, 1.27) | <0.0001 |

Footnote. Estimates are the beta coefficients from linear regressions where stress, depression, and anxiety are separately modeled as functions of change in loneliness score (i.e., within individual intra-pandemic score minus pre-pandemic score) and social connection variables. Models include all variables shown in the table and are adjusted for sociodemographic factors (age, education, race, and ethnicity), lifestyle factors (physical activity, alcohol intake, number of stressful life events), and medical history (CVD history, cancer history, vascular factors risk score, past history of depression).

Perceived stress ranges from 0 (no stress) to 16 (greatest stress); Center for Epidemiologic Studies Depression Scale (CES-D) ranges from 0 to 18 (≥ 5 considered to have depressive symptoms); PROMIS anxiety T-score ranges from 40.3 to 81.6. General population mean is 50 (SD=10). Higher score=greater anxiety

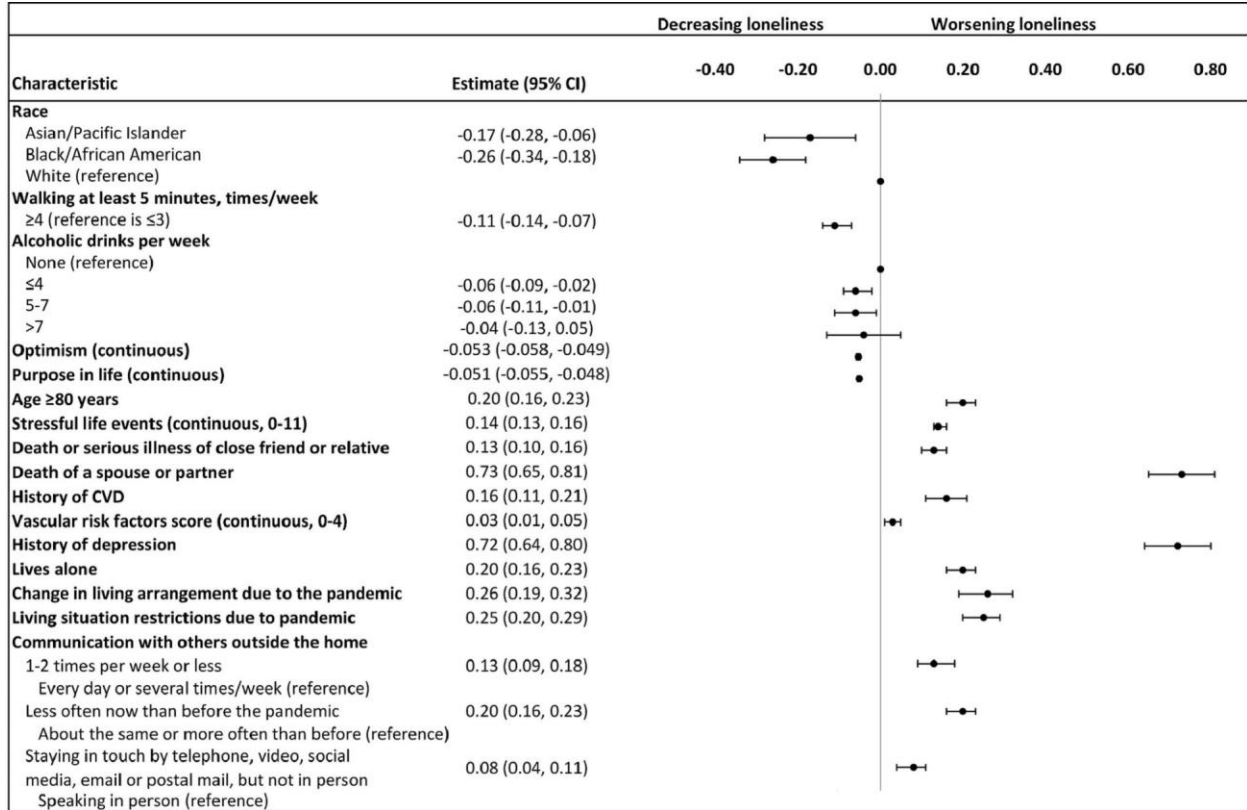
Figure 1



WHI activities of daily life survey was received between February 6, 2020 and October 30, 2020; WHI COVID-19 survey was received between June 5, 2020 and October 29, 2020.

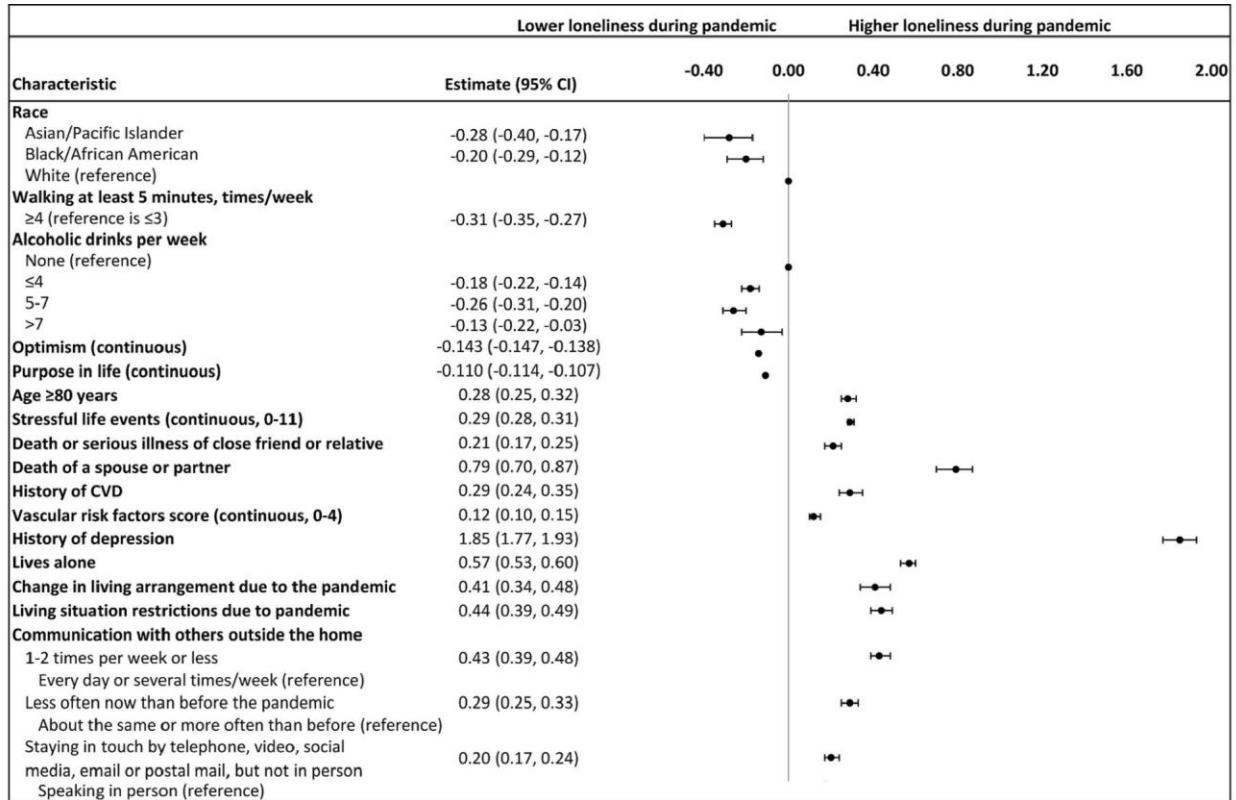
Accepted

Figure 2a



Accepted

Figure 2b



Accepted