Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.
Short communication

Acute relationships between mental health and cognitive function during the COVID-19 pandemic: Longitudinal evidence from middle-aged and older US adults

Lindsay C. Kobayashi a,b,*, Brendan Q. O'Shea a, Carly Joseph a,c, Jessica M. Finlay d

a Center for Social Epidemiology and Population Health, Department of Epidemiology, University of Michigan School of Public Health, Ann Arbor, MI, USA
b MRC/Wits Rural Health and Health Transitions Research Unit (Agincourt), School of Public Health, University of the Witwatersrand, Johannesburg, South Africa
c Central Michigan University College of Medicine, Mount Pleasant, MI, USA
d Social Environment and Health Program, Survey Research Center, Institute for Social Research, University of Michigan, Ann Arbor, MI, USA

ARTICLE INFO

Keywords: COVID-19, Cognitive function, Mental health, Anxiety, Loneliness, Older adults

ABSTRACT

Background: The acute impacts of COVID-19-related mental health concerns on cognitive function among middle-aged and older adults are unknown. We investigated whether between-person (BP) differences and within-person (WP) changes in loneliness, anxiety, and worry about COVID-19 were related to cognitive function and abilities in a longitudinal cohort of middle-aged and older United States (US) adults over a nine-month period during the COVID-19 pandemic.

Methods: Data were from bimonthly questionnaires in the nationwide COVID-19 Coping Study from August/September 2020 through April/May 2021 (N = 2262 adults aged ≥55). Loneliness was assessed with the 3-item UCLA Loneliness Scale, anxiety with the 5-item Beck Anxiety Inventory, and COVID-19 worry on a 5-point Likert-type scale. Cognitive outcomes were assessed with the 6-item Patient Reported Outcomes Measurement Information System (PROMIS®) Cognitive Function and Abilities scales. Marginal structural models incorporating inverse probability of treatment and attrition weights as well as sampling weights estimated the BP and WP relationships between the mental health predictors and PROMIS® cognitive scores over time.

Results: In any given month, experiencing a loneliness or anxiety symptom score higher than the sample mean (BP difference) or higher than one's personal mean across the nine-month period (WP change) was negatively associated with cognitive function and abilities in that month. The observed magnitudes of associations were stronger for BP differences than for WP changes and were the strongest for anxiety symptom scale scores.

Conclusions: Elevated loneliness and anxiety symptoms, both relative to other adults and to one's usual levels, were acutely associated with worse perceived cognitive function and abilities over a nine-month period during the COVID-19 pandemic in the United States. The long-term impacts of mental health symptoms experienced during the pandemic for population cognitive health should be explored.

1. Introduction

The coronavirus disease 2019 (COVID-19) pandemic has had far-reaching impacts on the mental health of populations worldwide (Kola et al., 2021; Xiong et al., 2020; Pfefferbaum and North, 2020; Pierce et al., 2020). Middle-aged and older adults are typically at higher risk of severe COVID-19 morbidity and mortality, making social distancing, vaccination, and other preventive measures important for this population. Middle-aged and older adults may also experience unique worries and mental health impacts of the pandemic (Armitage and Nellums, 2020; Kotwal et al., 2021; Galea et al., 2020). From March through June 2020, the US National Poll on Healthy Aging identified that 41% of US adults aged 50–80 years felt a lack of companionship, and 56% felt isolated from others (National Poll on Healthy Aging, 2020). In June 2020, a national survey conducted by the US Centers for Disease Control and Prevention (CDC) identified that 20.3% of adults aged 45–64 and 8.1% of adults aged ≥65 had an anxiety or depressive disorder, and 29.5% of those aged 45–64 and 15.1% of those aged ≥65 had at least one mental or...
Participants were excluded from this analysis if they were missing any baseline covariate data (N = 252/4,401, 6%), if they had more than two missing follow-up questionnaires (N = 1861/4,149, 45%), if they had more than two missing observations for any of the mental health exposure variables over the follow-up (N = 62, 3% for loneliness; N = 9, <1% for anxiety; N = 1, <1% for worry about COVID-19), or if they were missing inverse probability of treatment weights (N = 22, 1% for loneliness; N = 26, 1% for anxiety; N = 27, 2% for worry about COVID-19). The final analytical sample sizes were N = 2204 for the loneliness model, N = 2253 for the anxiety model, and N = 2260 for the worry about COVID-19 model, with a total of 2262 unique individuals contributing data to at least one model.

2.2. Exposures: loneliness, anxiety, and worry about COVID-19

Loneliness in the past week was assessed with the 3-item UCLA Loneliness Scale (Russell, 1996), which included the items: “How often did you feel you lacked companionship?”, “How often did you feel left out?”, and “How often did you feel isolated from others?”, with response options of “hardly ever” (1 point), “some of the time” (2 points), and “often” (3 points). The scale had a range of 3–9, with higher scores indicating higher loneliness.

Anxiety symptoms in the past week were assessed with the 5-item Beck Anxiety Inventory, adapted from the US Health and Retirement Study (Smith et al., 2017), which included the items: “I had fear of the worst happening”, “I was nervous”, “I felt my hands trembling”, “I had a fear of dying”, and “I felt faint”, with response options of “never” (1 point), “hardly ever” (2 points), “some of the time” (3 points), and “mostly of the time” (4 points). Scores on the scale were summed across all items and averaged, to give a range of 1–4, with higher scores indicating greater anxiety symptomatology.

Current worry about the COVID-19 pandemic was assessed on a 5-point Likert-type scale, consistent with existing measures of worry about health conditions including cancer (Deimling et al., 2006), Zika virus infection (Blakely and Abramowitiz, 2017), dementia (Kessler et al., 2012), and general health (Blakely and Abramowitiz, 2017). This scale was newly developed for the current study, given the novelty of the COVID-19 pandemic in 2020. The scale is intended to capture the construct of worry, which is a functional psychological response to a perceived threat (e.g., COVID-19) that can keep the body in a prolonged state of physiological arousal, especially when reduction or avoidance of the threat is not possible (Dijkstra and Brosschot, 2003). The scale was developed with survey methodologists and pilot-tested for comprehension and appropriateness with a group of adults aged ≥55 years who did not become part of the study sample, as described in detail elsewhere (Kobayashi et al., 2021). Response options were “not at all worried” (0 points), “slightly worried” (1 point), “somewhat worried” (2 points), “moderately worried” (3 points), and “extremely worried” (4 points), for a range of 0–4 with higher scores indicating greater worry (Kobayashi et al., 2021).

All three variables were analysed continuously, to capture symptom burden while avoiding loss of information through categorisation. To differentiate between between-person (BP) and within-person (WP) relationships, we derived two variables for each mental health exposure for each person. To create the BP exposure variables, we first calculated the sample grand means for the loneliness, anxiety, and worry scales across all time points. Then, for each scale, we centred each person’s score at each time point to the sample grand mean. To create the WP exposure variables, we first calculated the person-specific grand means for the loneliness, anxiety, and worry scales across all time points. Then, for each scale, we centred each person’s score at each time point to their personal grand mean.

2.3. Outcomes: cognitive function and abilities

Cognitive outcomes were assessed with the 6-item Patient Reported Outcomes Measurement Information System (PROMIS®) Cognitive Function and Abilities scales (HealthMeasures, 2019). The Cognitive...
Function scale captures negative sentiments about cognition, while the Cognitive Abilities scale captures positive sentiments about cognition, both as applied to scenarios of daily life (HealthMeasures, 2019; Terwee et al., 2021). Both scales give a series of statements about cognitive function or abilities in the past 7 days, with statements such as “My thinking has been slow” and “I have had trouble concentrating” (Cognitive Function scale), and “My mind has been as sharp as usual” and “My memory has been as good as usual” (Cognitive Abilities scale). Response options were “Never”, “Rarely (once)”, “Sometimes (two or three times)”, “Often (about once a day)”, “Very often (several times a day)” for the Cognitive Function scale and “Not at all”, “A little bit”, “Somewhat”, “Quite a bit”, and “Very much” for the Cognitive Abilities scale. The Cognitive Function scale was reverse-coded, so that higher scores indicate better cognitive outcomes.

Scores on the PROMIS® scales have been validated against clinical diagnoses, they are considered relevant to assessing daily quality of life as affected by perceived cognitive function and abilities, and they have been recommended for use in COVID-19 research to harmonize measures and data across studies of older adults (HealthMeasures, 2019). The PROMIS® Cognitive Function and Abilities raw scores were converted to T-scores using the HealthMeasures Scoring Service, which is the most accurate method for scoring a PROMIS® instrument (HealthMeasures, 2019). The T-score is a standardized score calibrated to the US general population with a mean of 50 and standard deviation of 10 (HealthMeasures, 2019). A higher T-score represents greater cognitive function or abilities. Within-person changes in PROMIS® T-scores of 2–6 points are thought to represent the minimal degree of change that patients perceive as important or meaningful (HealthMeasures, 2021). More information about the HealthMeasures calibration and interpretation of the T-scores can be found elsewhere (HealthMeasures, 2019).

2.4. Covariates

Potential confounders of the relationships between the mental health exposures and cognitive outcomes were: age (continuous, in years), sex (male; female), race/ethnicity (non-Hispanic white; other racial/ethnic group), highest educational attainment (high school or less; some college or two-year associate’s degree; four-year college or university degree; postgraduate or professional degree), pre-COVID-19 employment status (employed; unemployed; retired), relationship status (single, never married; single, divorced/separated; single, widowed; married or in a relationship), previous physician diagnosis of hypertension, diabetes, heart disease, asthma, chronic obstructive pulmonary disease, cancer, other physical or mental health condition (all yes; no), use of a mobility aid (yes; no), pre-COVID-19 social isolation (score out of five on the English Longitudinal Study of Ageing social isolation index, with one point assigned for each of: less than monthly contact with each of children, other family, or friends; living alone; and not belonging to any social organizations or clubs) (Kobayashi and Steptoe, 2018), and number of depressive symptoms according to the 8-item Center for Epidemiologic Studies Depression (CES-D) scale (Radloff, 1977). The covariates were measured at the initial cohort baseline (April/May 2020), except for depressive symptoms, which was assessed one month prior to each analytical time point and treated as a time-varying confounder.

2.5. Statistical analysis

As we aimed to estimate the time-varying BP and WP relationships between anxiety, loneliness, and worry about COVID-19 with perceived cognitive function and abilities, we considered depressive symptoms to be a potential time-varying confounder and mediator of the relationships under study. In this scenario, antecedent depressive symptoms would predict both the current mental health exposure and cognitive outcome under study (i.e., the confounding effect), while current depressive symptoms could mediate any effects of the prior mental health exposures on the cognitive outcomes (i.e., the mediating effect).

To address this potential time-varying confounding structure in our longitudinal data, we fit marginal structural models using inverse probability of treatment weights (IPTWs) (Hernán and Robins, 2020). The IPTWs were constructed with the goal of making the time-varying mental health exposure variables independent of the prior values of the time-varying depressive symptom variable, by balancing the previous depressive symptoms variable across levels of each mental health exposure at each time point (Hernán and Robins, 2020). First, at each analytical time point, we fit logistic regression models to estimate the predicted probabilities of each dichotomized mental health exposure variable. For these models, loneliness was dichotomised at <6 vs. ≥6 (80th percentile of the baseline distribution), anxiety was dichotomised at <2 vs. ≥2 (80th percentile of the baseline distribution), and COVID-19 worry was dichotomised at <3 vs. ≥3 (3 points corresponds to “moderately worried”). The numerator of each IPTW was the predicted probability of the dichotomized mental health exposure variable, conditional on baseline confounders, at the analytical time point. The denominator of each IPTW was the predicted probability of the dichotomized mental health exposure variable at the analytical time point, T. The denominator of each IPTW was the predicted probability of the dichotomized mental health exposure variable at the analytical time point, T. The denominator of each IPTW was the predicted probability of the dichotomized mental health exposure variable at the analytical time point, T. The denominator of each IPTW was the predicted probability of the dichotomized mental health exposure variable at the analytical time point, T. The denominator of each IPTW was the predicted probability of the dichotomized mental health exposure variable at the analytical time point, T.

The weights were multiplied cumulatively across all time points to construct the final IPTW. We constructed separate sets of IPTWs for each of loneliness, anxiety, and worry about COVID-19. An additional set of IPTWs was constructed for each mental health exposure variable, for which the denominator was additionally conditioned on the values of the other two mental health exposure variables at T-1. All weights were trimmed at their 99th percentiles.

The weights were multiplied cumulatively across all time points to construct the final IPTW. We constructed separate sets of IPTWs for each of loneliness, anxiety, and worry about COVID-19. An additional set of IPTWs was constructed for each mental health exposure variable, for which the denominator was additionally conditioned on the values of the other two mental health exposure variables at T-1. All weights were trimmed at their 99th percentiles.

We specified marginal structural models for repeated outcome measures with random person-specific intercepts and slopes to predict the PROMIS® Cognitive Function and Abilities T-scores as the two study outcomes. The BP model coefficients describe the mean change in cognitive T-score in any month associated with having a loneliness, anxiety, or worry score one-unit greater than the sample grand mean in that same month. The WP model coefficients describe the mean change in cognitive T-score in any month associated with having a loneliness, anxiety, or worry score one-unit greater than an individual’s personal grand mean in that same month. For the BP and WP models for each of loneliness, anxiety, and worry about COVID-19 in relation to each cognitive outcome, we applied both sets of IPTWs: those that were and were not conditional on the prior values of the other two mental health exposures. The purpose of this approach was to qualitatively assess the presence of confounding across the mental health exposures under study by comparing estimates from models with each set of IPTWs.

All models adjusted for baseline age, sex, race/ethnicity, highest level of education, relationship status, pre-COVID-19 employment status, use of any mobility aid, pre-COVID-19 social isolation score, and presence of physician-diagnosed hypertension, diabetes, heart disease, asthma, chronic obstructive pulmonary disease, cancer, or other limiting long-standing health condition, and were additionally weighted to represent the US general population aged ≥55 based on age, sex, race, ethnicity, education, marital status, and census region of residence according to the 2018 American Community Survey (Kobayashi et al., 2021). To reduce any potential bias due to study attrition after the cohort baseline (April/May 2020), we also applied attrition weights that were calculated as the inverse probability of retention through the 12-month follow-up. Please see the Supplementary Methods for more details on the
construction of the attrition weights. The IPTWs were applied at level 1 (observation-level) of the models, and the population and attrition weights at level 2 (person-level) of the models (Heeringa et al., 2017).

We conducted a sensitivity analysis to further assess whether study attrition between the cohort baseline (April/May 2020) and analytic baseline (August/September 2020) could have affected our results, which would happen if attrition was differential according to loneliness, anxiety, and COVID-19 worry as well as cognitive status. We compared loneliness, anxiety, COVID-19 worry, and self-rated memory scores at the cohort baseline according to attrition status between the cohort baseline and analytical baseline. Self-rated memory scores were examined in this sensitivity analysis, as the PROMIS® Cognitive Function and Abilities scales were not included at the cohort baseline. All analyses were conducted using Stata 17.0SE (College Station, TX).

2.6. Ethical approval

The University of Michigan Health Sciences and Behavioural Sciences Institutional Review Board approved the COVID-19 Coping Study protocol (HUM00179632) and all participants provided informed consent.

3. Results

Table 1 shows the population and attrition-weighted characteristics of the sample. Mean age of the sample was 68.2 years (95% CI: 67.5, 68.8), 58.2% were female (95% CI: 54.8%, 61.6%), and 84.3% were non-Hispanic white (95% CI: 80.9%, 87.3% Table 1). Across all analytical time points, the sample mean loneliness score was 4.7 out of 9 (95% CI: 4.6, 4.8), the sample mean anxiety score was 1.5 out of 4 (95% CI: 1.5, 1.6), and the sample mean COVID-19 worry score was 2.2 out of 4 (95% CI: 2.2, 2.3), corresponding to “somewhat worried” about the COVID-19 pandemic (Table 1). Across all analytical time points, the sample mean PROMIS® cognitive function T-score was 49.3 (95% CI: 48.7, 49.9) and the sample mean PROMIS® cognitive abilities T-score was 52.7 (95% CI: 52.1, 53.3; Table 1). Supplementary Table 3 shows characteristics of the sample according to inclusion at each analytical time point, indicating that response over the follow-up was similar by sociodemographic group, pre-existing health conditions, mental health scores, and cognitive outcome scores.

Table 2 shows the MSM estimates for the BP and WP relationships between the three mental health exposures and cognitive function and abilities. BP differences in all three of the mental health exposure variables were negatively associated with cognitive function and abilities (Table 2). WP changes in loneliness and anxiety were negatively associated with cognitive function and abilities, while WP changes in worry about COVID-19 were not. For all three mental health exposure variables, the BP associations were stronger in magnitude than the WP associations, and the strongest magnitudes of association were observed for anxiety symptoms and cognitive outcomes (Table 2). When models were additionally conditioned on the time-varying histories of all three mental health exposures, the results were similar (Table 3). In this model set, having an anxiety score that was one unit greater than the sample grand mean at any time point was associated with a 5.45 (95% CI: –6.36, 16.8) increase in cognitive function and a 4.22 (95% CI: –5.29, 13.74) decrease in cognitive abilities.

Note: All estimates applied population weights based on 2018 American Community Survey data and are weighted for attrition. Data are from the cohort baseline in April/May 2020, except for the mean values for depressive symptoms, anxiety symptoms, loneliness, worry about COVID-19, and PROMIS scores, which were calculated as the grand means over the analytical study period from August/September 2020 to April/May 2021.
lower cognitive function T-score and a 5.43 (95% CI: −6.30, −4.56) lower cognitive abilities T-score at that same time point (Table 3).

Similarly, having an anxiety score that was one unit greater than one’s usual level was also associated with worse function and abilities. Elevated worry about COVID-19, relative to other worry, and self-rated memory at the cohort baseline (April/May 2020) were similar among those who remained in the study at the analytical baseline (August/September 2020) compared to those who dropped out, indicating that study attrition between the cohort baseline and analytical baseline does not bias our results (Supplemental Table 4).

4. Discussion

In this longitudinal study of US adults aged ≥55 over a nine-month period during the COVID-19 pandemic, we found that elevated loneliness and anxiety symptoms, both relative to other adults and to one’s usual level, were acutely associated with worse perceived cognitive function and abilities. Elevated worry about COVID-19, relative to other adults but not relative to one’s usual level, was also associated with worse perceived cognitive function and abilities. The associations for anxiety symptoms were of magnitudes considered to be of importance to patients in evaluating their own cognitive changes. For example, a one-unit increase on the anxiety scale relative to one’s usual level was associated with PROMIS® T-score decrements of 4.12 to 4.05 points, just above one-third of a population standard deviation. Given the prevalence of clinically meaningful anxiety symptoms during the COVID-19 pandemic, both the short-term and long-term impacts of anxiety experienced during the COVID-19 pandemic for population cognitive health should be further investigated.

5.06, −3.04) lower cognitive abilities T-score at that same time point (Table 3).

In our sensitivity analysis, we found that loneliness, anxiety, COVID-19 worry, and self-rated memory at the cohort baseline (April/May 2020) were similar among those who remained in the study at the analytical baseline (August/September 2020) compared to those who dropped out, indicating that study attrition between the cohort baseline and analytical baseline does not bias our results (Supplemental Table 4).

4. Discussion

In this longitudinal study of US adults aged ≥55 over a nine-month period during the COVID-19 pandemic, we found that elevated loneliness and anxiety symptoms, both relative to other adults and to one’s usual level, were acutely associated with worse perceived cognitive function and abilities. Elevated worry about COVID-19, relative to other adults but not relative to one’s usual level, was also associated with worse perceived cognitive function and abilities. The associations for anxiety symptoms were of magnitudes considered to be of importance to patients in evaluating their own cognitive changes. For example, a one-unit increase on the anxiety scale relative to one’s usual level was associated with PROMIS® T-score decrements of 4.12 to 4.05 points, just above one-third of a population standard deviation. Given the prevalence of clinically meaningful anxiety symptoms during the COVID-19 pandemic, both the short-term and long-term impacts of anxiety experienced during the COVID-19 pandemic for population cognitive health should be further investigated.

4.1. Comparison to existing literature

Our results are consistent with pre-pandemic evidence from population-based, longitudinal cohort studies indicating that elevated anxiety symptoms and anxiety disorders are associated with increased risks of Alzheimer’s disease and related dementias (Santabárbara et al., 2019; Santabárbara et al., 2020). Anxiety is thought to affect cognitive health directly through neurobiological effects, and indirectly through behavioural coping mechanisms that are dementia risk factors, such as smoking, physical inactivity, and withdrawal from engagement in social relationships (Livingston et al., 2020). We did not identify any studies that have investigated the time-varying, short-term monthly relationships between anxiety symptoms and cognitive outcomes in middle-aged and older adults during or before the COVID-19 pandemic.

Two studies conducted prior to the pandemic found that between-persons differences but not within-person changes in anxiety were associated with measures of cognitive function (Laukka et al., 2018; Marrie et al., 2021). These somewhat conflict with ours, as we observed associations between within-person changes in anxiety and cognitive function and abilities scores. One possible explanation for these inconsistent results is that the anxiety symptoms observed in this study during the COVID-19 pandemic may have been stronger in this sample than in these pre-pandemic samples, such that its relationship with cognitive function was more apparent in the present study. However, comparisons between these previous studies and ours may be difficult, as the previous two studies used different anxiety scales than ours, they had smaller sample sizes and multi-year follow-up times, and one was restricted to multiple sclerosis patients (Laukka et al., 2007; Marrie et al., 2021). A small case-control study identified that older adults with generalized anxiety disorder were more likely to have prevalent cognitive impairment than anxiety-free controls (Mantella et al., 2007), but inference cannot be made about the timing of cognitive impairment onset relative to anxiety onset with that study design. A handful of studies among patients with specific chronic diseases, such as Parkinson’s disease, have identified correlations between anxiety symptoms and cognitive function, but these studies are primarily cross-sectional in design (Laukka et al., 2018; Mantella et al., 2007; Burkauskas et al., 2016; Ehgoetz Martens et al., 2018). Additional large, population-based longitudinal studies are needed to further elucidate the short- and long-term relationships between anxiety symptomatology and cognitive aging outcomes.

Table 3

Results from marginal structural models of the between-persons (BP) and within-person (WP) associations between loneliness, anxiety, worry about COVID-19, and cognitive outcomes, with adjustment for time-varying confounding across the mental health exposures, COVID-19 Coping Study, August/September 2020 to April/May 2021, N = 2258.

| Estimate | Cognitive Function | Cognitive Abilities |
|----------|--------------------|--------------------|
|          | β                  | 95% CI             | β                  | 95% CI             |
| Between-persons |
| Loneliness N = 2203 |
| BP estimate | −0.98 (−1.39, −0.56) | −0.94 (1.16, −0.71) |
| Time        | 0.06 (0.02, 0.13)   | −0.04 (−0.12, 0.04) |
| Anxiety N = 2250 |
| BP estimate | −5.45 (−6.36, −4.54) | −5.43 (−6.30, −4.56) |
| Time        | 0.00 (0.08, 0.08)   | −0.11 (−0.19, −0.03) |
| Worry about COVID-19 N = 2257 |
| BP estimate | −0.56 (−0.96, −0.16) | −0.46 (−0.76, −0.15) |
| Time        | 0.05 (0.04, 0.14)   | −0.02 (0.11, 0.07)  |
| Within-persons |
| Loneliness N = 2203 |
| WP estimate | −0.79 (−1.35, −0.23) | −0.72 (1.06, −0.37) |
| Time        | 0.07 (0.01, 0.14)   | −0.03 (−0.11, 0.05) |
| Anxiety N = 2250 |
| WP estimate | −4.12 (−5.21, −3.03) | −4.05 (5.06, −3.04) |
| Time        | 0.04 (−0.04, 0.12)  | −0.07 (−0.16, 0.01) |
| Worry about COVID-19 N = 2257 |
| WP estimate | −0.24 (−0.70, 0.23) | −0.18 (−0.53, 0.16) |
| Time        | 0.07 (0.02, 0.17)   | 0.01 (0.08, 0.09)   |

Note: Time-varying inverse probability of treatment weights were applied to each model to account for confounding by time-varying history of depressive symptoms, loneliness, anxiety symptoms, and worry about COVID-19, each of which were measured monthly and treated as time-varying confounders. Models additionally adjust for age, sex, race/ethnicity, highest level of education, relationship status, pre-COVID-19 employment status, use of any mobility aid, pre-COVID-19 social isolation score, and presence of physician-diagnosed hypertension, diabetes, heart disease, asthma, chronic obstructive pulmonary disease, cancer, and other limiting long-standing health condition, each of which were measured at the cohort baseline (April/May 2020). BP and WP relationships for each mental health exposure were modelled separately. All estimates applied population weights based on 2018 American Community Survey data and are weighted for attrition.
4.2. Limitations and strengths

The PROMIS® cognitive measures are self-reported. Hence, they may be subject to recall or social desirability bias, and do not objectively capture neuropsychological deficits. However, they are valuable measures that capture the impact of cognition on quality of life, which is highly meaningful to patients. They have been validated against clinical outcomes and are widely used in research studies, thereby improving comparability of our findings to existing literature (HealthMeasures 2019). This study was conducted during a major infectious disease pandemic, and as such does not include those who were too ill to take part, such as those with severe COVID-19. Our data were collected online, and results may not be generalizable to non-Internet users (Kobayashi et al., 2021). However, conducting this study online allowed us to recruit a large sample and rapidly collect relevant data during a period when in-person contact was restricted due to COVID-19 risk (Ilatashwako et al., 2021). Although we applied general population weights developed using American Community Survey data to our models, our results may be subject to residual bias if there are unmeasured drivers of study participation that are correlated with the mental health exposures and cognitive outcomes, but uncorrelated with the sociodemographic variables included in weighting (Hernán et al., 2004). This sample had a higher proportion of non-Hispanic Whites and adults with higher educational attainment than the general US population aged ≥55 years. Population weighting may thus not fully account for any selection bias of this type that could be introduced by differences in race/ethnicity and education across exposure and outcome groups.

Strengths of this study include the timeliness of data collection during the COVID-19 pandemic, large sample size, national scope, commonly used mental health and cognitive function scales, and rich covariate data. We accounted for potential sampling bias and attrition bias through model weighting, and sensitivity analyses further indicated that attrition does not bias our results. We accounted for time-varying confounding by depressive symptoms. Prior to the COVID-19 pandemic, existing research linking mental health symptoms or disorders to cognitive aging outcomes had been largely based on measures of mental health symptoms or diagnoses assessed once at study baseline, despite their time-varying nature. We were able to investigate how within-person fluctuations in anxiety symptoms, loneliness, and COVID-19 worry were related to perceived cognitive function and abilities. However, despite our approach to account for time-varying confounding by depression and other mental health symptoms and our analysis of within-person changes in mental health, our results may still be subject to confounding by unmeasured factors such as personality. We did not identify any other studies that have examined these time-varying relationships on a short-term scale, highlighting the uniqueness of the present study and the contribution it makes to the literature.

4.3. Conclusions

In this large, nation-wide study of US adults aged ≥55 years over a nine-month period during the COVID-19 pandemic, we identified that elevated loneliness and anxiety symptoms were associated with worse perceived cognitive function and abilities. These associations were observed both in comparison to other adults of similar age and to one's own usual levels. Elevated worry about the COVID-19 relative to other adults of similar age was also associated with worse perceived cognitive function and abilities. These findings were independent of a range of sociodemographic, social, and health-related covariates, including depressive symptomatology. Adverse mental health effects are a mechanism through which the COVID-19 pandemic is thought to influence the future burden of dementia among the older population (Chong et al., 2020; Manca et al., 2020). However, it remains unclear whether acute changes in population mental health during the pandemic will have long-term implications. Future research in other populations and settings should evaluate how within-person fluctuations in mental health symptomatology in the wake of the pandemic may affect cognitive outcomes during aging.

CRediT authorship statement

Lindsay C. Kobayashi: Conceptualization, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Writing – original draft, Writing – review & editing; Brendan Q. O'Shea: Conceptualization, Data curation, Formal analysis, Methodology, Writing – review & editing; Carly Joseph: Conceptualization, Methodology, Writing – review & editing; Jessica M. Finlay: Conceptualization, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Writing – review & editing.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Lindsay C. Kobayashi reports financial support was provided by National Institute on Aging. Jessica M. Finlay reports financial support was provided by National Institute on Aging. Jessica M. Finlay reports financial support was provided by National Center for Advancing Translational Sciences.

Acknowledgements

Funding: This work was supported by the National Institute on Aging (P30AG012846, F32AG064815) and the National Center for Advancing Translational Sciences (UL1TR002240), both at the United States National Institutes of Health. The funders had no role in the study design; in the collection, analysis, or interpretation of data; or, in the writing of the report.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ssmmh.2022.100097.

References

Anker JJ, Kushner MG. Alcohol Research: Current Reviews - Co-occurring Alcohol Use Disorder and Anxiety: Bridging Psychiatric, Psychological, and. Amritage, R., & Nellums, L. B. (2020). COVID-19 and the consequences of isolating the elderly. Lancet Public Health, 5(5), e256.
Bekere, S. M., & Abramowitz, J. S. (2017 Dec 1). Psychological predictors of health anxiety in response to the Zika virus. J. Clin. Psychol. Med. Settings, 24(3–4), 270–278.
Bon, L., Kang, D. H., & Brannon, S. (2015). Loneliness and cognitive function in the older adult: a systematic review. Int. Psychogeriatr., 27, 541–553. Cambridge University Press.
Burkaukas, J., Bronzi, J., Benevivis, A., Neusvaskas, J., Zanuinaite, V., & Benevivis, R. (2016). Association of depression, anxiety, and type D personality with cognitive function in patients with coronary artery disease. Cognit. Behav. Neurol., 29(3), 91–99.
Chong, T. W., Carran, E., Amos, D., Latenschlager, N. T., & Castle, D. J. (2020). Mental health of older adults during the COVID-19 pandemic: lessons from history to guide our future. Int. Psychogeriatr., 32(10), 1249–1250.
Czéder, M.E., Lane, R. I., Petrosky, E., Wiley, J. F., Christensen, A., Njaj, R., et al. (2020). Mental health, substance use, and suicidal ideation during the COVID-19 pandemic — United States, June 24–30, 2020. MMWR Morb. Mortal. Wkly. Rep., 69, 1049–1057.
Daly, M., & Robinson, E. (2021). Anxiety reported by US adults in 2019 and during the 2020 COVID-19 pandemic: population-based evidence from two nationally representative samples. J. Affect. Disord., 286, 296–300.
Deimling, G. T., Bowman, K. F., Stern, S., Wagner, L. J., & Kahana, B. (2006 Apr). Cancer-related health worries and psychological distress among older adult, long-term cancer survivors. Psycho Onkol., 15(A), 306–320.
Dijkstra, A., & Brosschot, J. (2003 Sep 1). Worry about health in smoking behaviour change. Behav. Res. Ther., 41(9), 1081–1092.
Ehogetz Martens, K. A., Silveira, C. R. A., Intzandt, B. N., & Almeida, J. Q. (2018). State anxiety predicts cognitive performance in patients with Parkinson’s disease. Neuropsychology, 32(8), 950–957.
Ertman, C. K., Abdalla, S. M., Cohen, G. H., Sampson, L., Vivier, P. M., & Galea, S. (2020). Prevalence of depression symptoms in US adults before and during the COVID-19 pandemic. JAMA Net. Open, 3(9), 100097.
Galea, S., Merchant, R. M., & Lurie, N. (2020). The mental health consequences of COVID-19 and physical distancing: the need for prevention and early intervention. JAMA Intern. Med., 180(6), 817–818.

Hawley, L. C., & Cacioppo, J. T. (2010). Loneliness matters: a theoretical and empirical review of consequences and mechanisms. Ann. Behav. Med., 40(2), 218–227.

HealthMeasures. (2019). Cognitive function: a brief guide to the PROMIS® cognitive function instruments. In Patient-Reported Outcomes Measurement Information System: Dynamic Tools to Measure Health Outcomes from the Patient Perspective (p. 21). Chicago: Northwestern University.

HealthMeasures. (2021). PROMIS®: T-score metric [Internet] [cited 2021 Sep 17]. Available from: https://www.healthmeasures.net/score-and-interpret/interpret-t-scores/promis/.

Heeringa, S. G., West, B. T., & Berglund, P. A. (2017). Analysis of longitudinal complex sample survey data. In S. G. Heeringa, B. T. West, & P. A. Berglund (Eds.), Applied Survey Data Analysis (second ed.). Boca Raton: Taylor & Francis.

Hernán, M. A., & Robins, J. (2020). Causal Inference: what if (first ed., vol. 1). Boca Raton: Chapman & Hall/CRC.

Hernán, M. A., Hernández-Díaz, S., & Robins, J. M. (2004). A structural approach to selection bias. Epidemiology, 15(5), 615–625.

Hlatshwako, T. G., Shah, S. J., Kosana, P., Adebayo, E., Hendriks, J., Larsson, E. C., et al. (2020). COVID-19 mental health impact and responses in low-income and middle-income countries: reimagining global mental health. Lancet Digit. Health, 3(2), e76–e77.

Kessler, E. M., Bowen, C. E., Baer, M., Froelich, L., & Wahl, H. W. (2012 Dec). Dementia worry: a psychological examination of an unexplored phenomenon. Eur. J. Aging, 9(4), 275–284.

Kobayashi, L. C., & Steptoe, A. (2018). Social isolation, loneliness, and health behaviors at older ages: longitudinal cohort study. Ann. Behav. Med., 52(7), 582–593.

Kobayashi, L. C., O'Shea, B. Q., Kler, J. S., Nishimura, R., Palavicino-Maggio, C. B., Eastman, M. R., et al. (2021). Cohort profile: the COVID-19 Coping Study, a longitudinal mixed-methods study of middle-aged and older adults' mental health and well-being during the COVID-19 pandemic in the USA. BMJ Open, Article e044965, 0.

Kola, L., Kohrt, B. A., Hanlon, C., Naslund, J. A., Sikander, S., Balaji, M., et al. (2021). Mental health and the COVID-19 pandemic: a longitudinal probability sample study of the UK population. Lancet Psychiatry, 7(10), 883–892.

Pool, I. R., Burgard, S. A., Needham, B. I., Elliott, M. R., Lang, K. M., & Mendes De Leon, C. F. (2018 Apr 3). Association of a negative wealth shock with all-cause mortality in middle-aged and older adults in the United States. JAMA, 319(13), 1341–1350.

Radloff, L. (1977). The CES-D scale: a self-report depression scale for research in the general population. Appl. Psychol. Meas., 1, 385–401.

Russell, D. W. (1996). UCLA Loneliness Scale (Version 3): reliability, validity, and factor structure. J. Pers. Assess., 66(1), 20–40.

Ryder, K. A., Gontkovsky, S. T., McWan, K. L., Scott, J. G., Bihuracha, K. J., & Beatty, W. W. (2002). Cognitive function in Parkinson’s disease: association with anxiety but not depression. Neuropsychol. Dev. Cogn. B Aging Neuropsychol. Cogn., 9(2), 77–84.

Santabarbara, J., Lipnicki, D. M., Villagraña, B., Lobo, E., & Lopez-Anton, R. (2019). Anxiety and risk of dementia: systematic review and meta-analysis of prospective cohort studies. Maturitas, 119, 14–20.

Santabarbara, J., Lipnicki, D. M., Bueno-Notivol, J., Olaya-Guzmán, B., Villagraña, B., & Lopez-Anton, R. (2020). Updating the evidence for an association between anxiety and risk of Alzheimer’s disease: a meta-analysis of prospective cohort studies. J. Affect. Disord., 262, 397–404.

Santini, Z., L. Niebsch, L., Hinrichsen, C., Meilstrup, C., Madsen, K. R., Koushede, V., et al. (2020) [Internet]. Social Disconnectedness, Perceived Isolation, and Symptoms of Depression and Anxiety Among Older Americans (NSHAP): a Longitudinal Mediation Analysis (vol. 5). Articles Lanceit Public Health. Available from: www.thelancet.com/.

Shankar, A., McMunn, A., Banks, J., & Steptoe, A. (2011). Loneliness, social isolation, and behavioral and biological health indicators in older adults. Health Psychol., 30(4), 377–385.

Shankar, A., Hamer, M., McMunn, A., & Steptoe, A. (2013). Social isolation and loneliness: relationships with cognitive function during 4 years of follow-up in the English Longitudinal Study of Ageing. Psychosom. Med., 75(2), 161–170.

Smith, J., Ryan, L., Fisher, G., Sonnega, A., & Weir, D. (2017). The HRS Psychosocial Working Group. Health and Retirement Study: Psychosocial and Lifestyle Questionnaire, 2006-2016. Ann Arbor.

Sundstrom, A., Adolfsson, A. N., Nordin, M., & Adolfsson, R. (2020). Loneliness increases the risk of all-cause dementia and Alzheimer’s disease. J. Gerontol. A Biol. Med. Sci., 75(5), 919–926.

Sutin, A. R., Stephan, Y., Luchetti, M., & Terracciano, A. (2020). Loneliness and risk of dementia. J. Gerontol. B Psychol. Sci. Soc. Sci., 75(7), 1414–1422.

Terveen, C. B., Peepert, J. D., Chapman, R., Lai, J. S., Terluin, B., Cella, D., et al. (2021 Oct 1). Minimal important change (MIC): a conceptual clarification and systematic review of MIC estimates of PROMIS measures. Qual. Life Res., 30(10), 2729–2754.

Thomas, A. J., & O'Brien, J. T. (2008). Depression and cognition in older adults. Curr. Opin. Psychiatry, 21, 8–13.

Wolf, S., Seiffert, B., Zeibig, J. M., Welkerling, J., Broekmeier, L., Arrott, B., et al. (2021). Is physical activity associated with less depression and anxiety during the COVID-19 pandemic? A rapid systematic review. Sports Med., 51, 1771–1783. Springer Science and Business Media Deutschland GmbH.

Xiong, J., Lipsitz, O., Nasri, F., Lui, L. M. W., Hill, H., Phan, L., et al. (2020). Impact of COVID-19 pandemic on mental health in the general population: a systematic review. J. Affect. Disord., 277, 55–64.