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Research paper

A 50-state survey study of thoughts of suicide and social isolation among older adults in the United States

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ABSTRACT

Background: We aimed to characterize the prevalence of social disconnection and thoughts of suicide among older adults in the United States, and examine the association between them in a large naturalistic study.
Methods: We analyzed data from 6 waves of a fifty-state non-probability survey among US adults conducted between February and December 2021. The internet-based survey collected the PHQ-9, as well as multiple measures of social connectedness. We applied multiple logistic regression to analyze the association between presence of thoughts of suicide and social disconnection. Exploratory analysis, using generalized random forests, examined heterogeneity of effects across sociodemographic groups.
Results: Of 16,164 survey respondents age 65 and older, mean age was 70.9 (SD 5.0); the cohort was 61.4 % female and 29.6 % male; 2.0 % Asian, 6.7 % Black, 2.2 % Hispanic, and 86.8 % White. A total of 1144 (7.1 %) reported thoughts of suicide at least several days in the prior 2 week period. In models adjusted for socio-demographic features, households with 3 or more additional members (adjusted OR 1.73, 95 % CI 1.28–2.33) and lack of social supports, particularly emotional supports (adjusted OR 2.60, 95 % CI 2.09–3.23), were independently associated with greater likelihood of reporting such thoughts, as was greater reported loneliness (adjusted OR 1.75, 95 % CI 1.64–1.87). The effects of emotional support varied significantly across socio-demographic groups.
Conclusions: Thoughts of suicide are common among older adults in the US, and associated with lack of social support, but not with living alone.
Trial registration: NA.

1. Introduction

Older adults represent a particularly high-risk group for suicide in the US and internationally: the 2016 Global Burden of Disease study found that age-standardized mortality rates from suicide were greatest in this group worldwide, regardless of region and gender ("Global, Regional, and National Burden of Suicide Mortality 1990 to 2016," 2019). Rates of suicide among older men in particular approach those of young men, the highest-risk group (FastStats, 2022). Older adults are substantially more likely to die if they make a suicide attempt, consistent with the understanding that such attempts may involve more planning and more lethal means, on average (Cai et al., 2022; Oh et al., 2014). Yet there are few interventions specifically targeting suicidality – i.e., suicidal thoughts and behaviors - and even fewer in this population (Kiosses et al., 2018) (for a review, see Van Orden and Deming, 2018), although psychosocial treatment for late-life depression has shown evidence of

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benefit (Alexopoulos et al., 2021).

Social disconnection is characterized by social isolation and lack of emotional social support (*The Major Health Implications of Social Connection - Julianne Holt-Lunstad, 2021*, n.d.). Disconnection increases with age (Kotwal et al., 2021a). It occurs at its highest levels in mid- and late life (Kotwal et al., 2021a), and predicts increased risk of thoughts of suicide, suicidal behavior, and suicide (Fässberg et al., 2012). Older suicide attempters have fewer closer friends and are less likely to speak with their children or engage in volunteer activities (Szanto et al., 2012).

The COVID-19 pandemic has placed unprecedented stresses on social networks, leading to increased loneliness and social isolation (Kotwal et al., 2021b) (van Tilburg et al., 2021). Older adults, at higher risk of COVID-19 infection and serious illness, were disproportionally impacted by social distancing guidelines (Hwang et al., n.d.). The closure of community and senior centers and the transition of social services to telehealth intensified age-related access disparities for elders who have low technological literacy and have limited social networks. These circumstances provide a unique opportunity to investigate the relationship between social disconnection and thoughts of suicide in late life while accounting for these stressors over time. Clarifying these mechanisms could facilitate development of novel interventions, or better targeting of existing interventions.

While there has been prior investigation of thoughts of suicide and social factors, most has focused on clinical trial populations (Kiosses et al., 2017) or treatment-seeking populations (Barak-Corren et al., 2020, p.; McCoy et al., 2016, 2019), which may not generalize to broader more diverse older adult population. Thus, beyond a lack of understanding of mechanisms, an additional gap is the lack of estimates of the effects of social disconnection in more generalizable cohorts.

To address these gaps, we used data from a large and nationally-representative, 50-state survey conducted over multiple waves, during the COVID-19 pandemic, between February 2021 and December 2021. We aimed to investigate the prevalence of social disconnection among older adults and estimate the extent to which it correlates with thoughts of suicide in a naturalistic setting.

2. Method

2.1. Study design

We examined data from a multi-university consortium, the COVID States Project (covidstates.org), that has surveyed approximately 20,000 United States adults every four to six weeks since April 2020 on a range of topics related to COVID attitudes and behaviors, and more broadly examined aspects of social connectedness, including social interaction, social support, and loneliness. The surveys apply representative quotas and nonprobability sampling (Kennedy and Caumont, n.d.) to approximate the state-level distribution of age, gender, and race and ethnicity for each of the 50 states as well as the District of Columbia, a lower-cost approach to large-scale sampling that has been validated in similar contexts (Coppock and McClellan, 2019; Berinsky et al., 2012). For the present study, we drew on data from the six waves conducted between February and December 2021 that included consistent assessment of social connectedness; for individuals participating in more than one wave, the index survey was included. All sociodemographic variables were collected by self-report; race and ethnicity were drawn from 5 United States Census categories to confirm representativeness of the US population. The study design was determined to be exempt by the Institutional Review Board of Harvard University; survey participants signed consent online prior to survey access. We report results in accordance with AAPOR guidelines (*Survey Disclosure Checklist - AAPOR*, n.d.).

2.2. Outcomes and assessments

Survey participants completed the PHQ-9, a well-validated measure of major depressive symptoms in outpatient settings that reflects the prior 2 weeks (Kroenke and Spitzer, 2002). A value of 10 or greater reflects a minimum of moderate major depression with a sensitivity and specificity of 88 % (Kroenke and Spitzer, 2002), supported by meta-analysis (Levis et al., 2019). Thoughts of suicide was defined on the basis of item 9 of the PHQ-9, which inquires about "Thoughts that you would be better off dead, or thoughts of hurting yourself in some way", with values of not at all (0), several days (1), more than half the days (2), and nearly every day (3). Scores above 0 have been robustly associated with suicide risk, including in older individuals (Louzon et al., 2016; Rossom et al., 2017; Simon et al., 2013).

To characterize aspects of social connectedness, we applied a framework adopted by an NIMH conference report (Lutz et al., 2021) that distinguishes dimensions reflecting social interaction (nature of social network, including household characteristics); social support (instrumental and emotional); and social quality (how the network is perceived, and how much satisfaction or distress it yields, most often reflected in loneliness).

To quantify social interaction, we examined number of household members, as well as number of face-to-face meetings with individuals outside of the household over the past 24 h. To characterize social support, respondents were asked to identify the number of people who could care for them if they became ill (caregiving support), lend them money (financial support), serve as someone to talk to if they felt down or depressed (emotional support), or help them find employment (employment support); these validated questions were drawn from a prior examination of social networks (Lubbers et al., 2019). For example, the emotional support question asks how many people are available "to talk to if you had a problem, felt sad or depressed". Finally, to characterize social quality, individuals in 2 of the 6 survey waves were asked the 3-item loneliness scale (Hughes et al., 2004), specifically developed for application in large-scale surveys and highly correlated with the Revised UCLA Loneliness Scale (Russell et al., 1980).

2.3. Analysis

We used multiple logistic regression to estimate odds ratios for the relationship between individual social characteristics and thoughts of suicide, alone and then with adjustment for sociodemographic features.

Survey results were re-weighted for regression models using interlocking national weights for age, sex, race/ethnicity, education, urbanicity (urban, suburban, or rural), and region, based on the 2019 US Census American Community Survey (Bureau, n.d.) (see Table 1), using the 'survey' package in R 4.0 (R Core Team, 2019), as has been demonstrated to generate reliable estimates for non-probability samples (Valliant, 2020).

In exploratory analysis, we also sought to identify subgroup effects, testing for variables that moderate associations between social disconnection and suicidality using generalized random forests (Athey et al., 2019). The generalized random forest is an extension of the widely-used random forest algorithm (Breiman, 2001), adapted specifically for identifying conditional effects that are robust to out-of-sample prediction. While the standard random forest builds decision trees based on which split, for which variable, generates the biggest difference in outcomes, the generalized random forest identifies which split, for which variable, generates the biggest *differences* in a given association (such as a treatment effect in an experiment). Crucially, each tree in the generalize random forest is split based on one randomly-assigned portion of the sample data. Actual predicted effects are evaluated by then applying those splits to observations from the held-out, "estimating" subsample that was not used to fit the tree. Building held-out estimation into the algorithm allows researchers to test a wide range of potential moderating variables at once in a systematic manner without overfitting to statistical noise, reducing the potential for type 1 error and offering important advantages over traditional approaches to testing for heterogeneity. (Here, trees were estimated in a randomly-selected 70 %,

Table 1
Demographics and clinical characteristics of participants.

	No thoughts of suicide (N = 15,020)	Thoughts of suicide (N = 1144)	Total (N = 16,164)	P value
Age (in years)	70.9 (5.0)	70.4 (4.9)	70.9 (5.0)	<0.001
Gender				0.004
Female	9274 (61.7 %)	657 (57.4 %)	9931 (61.4 %)	
Male	5746 (38.3 %)	487 (42.6 %)	6233 (38.6 %)	
Household income[a]				<0.001
Less than $25k/year	2764 (18.5 %)	320 (28.0 %)	3084 (19.1 %)	
$25k to less than $50k/year	4667 (31.2 %)	343 (30.0 %)	5010 (31.1 %)	
$50k to less than $100k/year	5148 (34.4 %)	325 (28.5 %)	5473 (34.0 %)	
$100k/year or more	2387 (15.9 %)	154 (13.5 %)	2541 (15.8 %)	
Race and ethnicity				<0.001
African American	1041 (6.9 %)	46 (4.0 %)	1087 (6.7 %)	
Asian American	293 (2.0 %)	30 (2.6 %)	323 (2.0 %)	
Hispanic	327 (2.2 %)	34 (3.0 %)	361 (2.2 %)	
Native American	44 (0.3 %)	2 (0.2 %)	46 (0.3 %)	
Other	221 (1.5 %)	21 (1.8 %)	242 (1.5 %)	
Pacific Islander	65 (0.4 %)	9 (0.8 %)	74 (0.5 %)	
White	13,029 (86.7 %)	1002 (87.6 %)	14,031 (86.8 %)	
Setting				0.003
Rural	2718 (18.1 %)	227 (19.8 %)	2945 (18.2 %)	
Suburban	9154 (60.9 %)	639 (55.9 %)	9793 (60.6 %)	
Urban	3148 (21.0 %)	278 (24.3 %)	3426 (21.2 %)	
Education				0.384
Graduate degree	2943 (19.6 %)	219 (19.1 %)	3162 (19.6 %)	
College degree	5533 (36.8 %)	423 (37.0 %)	5956 (36.8 %)	
Some college	3754 (25.0 %)	265 (23.2 %)	4019 (24.9 %)	
High school graduate	2642 (17.6 %)	224 (19.6 %)	2866 (17.7 %)	
Some high school or less	148 (1.0 %)	13 (1.1 %)	161 (1.0 %)	
PHQ-9 Total	2.9 (3.7)	13.0 (6.2)	3.6 (4.7)	<0.001
Moderate or greater depression	951 (6.3 %)	730 (63.8 %)	1681 (10.4 %)	<0.001
PHQ-9 thoughts of suicide score				n/a
0	15,020 (100.0 %)	0 (0.0 %)	15,020 (92.9 %)	
1	0 (0.0 %)	758 (66.3 %)	758 (4.7 %)	
2	0 (0.0 %)	239 (20.9 %)	239 (1.5 %)	
3	0 (0.0 %)	147 (12.8 %)	147 (0.9 %)	

[a] Household income missing for n = 54 without thoughts of suicide, n = 2 with thoughts of suicide.

and then effects estimated in the held-out 30 %.)

As in our prior work (e.g., Green et al. (2020) and Green et al. (in press)) we applied the open-source *grf* package (version 1.2) in R to implement this set of analyses, considering a range of potential moderating variables. These included additional sociodemographic variables (e.g., income, education, urbanicity, US region). We used the default hyperparameters specified in the package's causal_forest() function, with the exception that we generated 5000 trees to minimize overfitting risk.

3. Results

Of 16,164 survey respondents age 65 and older, mean age was 70.9 (SD 5.0); the cohort was 61.4 % female and 29.6 % male; 2.0 % Asian, 6.7 % Black, 2.2 % Hispanic, and 86.8 % White (Table 1). A total of 1144 (7.1 %) reported thoughts of suicide at least several days in the prior 2 week period, including 386 (2.4 %) who reported such symptoms more than half the time.

In the cohort as a whole, *4139 (25.6 %)* reported that they lived alone, while 7868 (48.7 %) lived with 1 other person (Table 2). Respondents reported an average of 5.1 (SD 11.1) face-to-face interactions in the prior 24 h with non-household members; 5022 (31.2 %) reported no such interactions. Additional characteristics of social disconnection are summarized in Table 2.

In logistic regression models, living in a household with 2 or more people was associated with significantly greater likelihood of thoughts of suicide in adjusted models (OR 1.45, 95 % CI 1.11–1.90), as was living with 3 or more people (OR 1.73, 95 % CI 1.28–2.33). (Table 3) Among non-household interactions, lack of any face-to-face meetings in the

Table 2
Social characteristics of adults age 65 years and older who did or did not report thoughts of suicide on PHQ-9 Item 9.

	No thoughts of suicide (N = 15,020)	Thoughts of suicide (N = 1144)	Total (N = 16,164)	P value
Health supports[a]	2.9 (2.4)	2.0 (2.1)	2.8 (2.4)	<0.001
Financial supports[a]	2.0 (2.1)	1.3 (1.6)	1.9 (2.1)	<0.001
Emotional supports[a]	3.6 (2.9)	2.4 (2.3)	3.5 (2.9)	<0.001
Employment supports[a]	1.7 (2.7)	1.0 (2.0)	1.7 (2.6)	<0.001
No health supports[a]	1298 (8.7 %)	235 (20.6 %)	1533 (9.5 %)	<0.001
No financial supports[a]	3511 (23.6 %)	414 (36.4 %)	3925 (24.5 %)	<0.001
No emotional supports[a]	1046 (7.0 %)	229 (20.1 %)	1275 (8.0 %)	<0.001
No employment supports[a]	7446 (50.4 %)	697 (61.8 %)	8143 (51.2 %)	<0.001
Face-to-face meetings[b]	5.2 (11.1)	4.7 (11.1)	5.1 (11.1)	0.179
No face-to-face meetings[b]	4634 (31.0 %)	388 (34.0 %)	5022 (31.2 %)	0.031
Additional household members				<0.001
None	3823 (25.5 %)	316 (27.6 %)	4139 (25.6 %)	
1	7383 (49.2 %)	485 (42.4 %)	7868 (48.7 %)	
2	2513 (16.7 %)	203 (17.7 %)	2716 (16.8 %)	
3+	1301 (8.7 %)	140 (12.2 %)	1441 (8.9 %)	
Loneliness score[c]	4.3 (1.6)	6.5 (2.0)	4.5 (1.8)	<0.001

[a] Instrumental social support data missing for n = 46 (41 without thoughts of suicide, 5 with thoughts of suicide) for health support, n = 137 (129 without, 8 with) for financial support, n = 129 (122 without, 7 with) for emotional support, and 268 (251 without, 17 with) for employment support.

[b] Face-to-face meeting data not available for n = 55 (51 without thoughts of suicide, 4 with thoughts of suicide).

[c] Loneliness data not available for n = 10,045 (9373 without thoughts of suicide, 672 with thoughts of suicide).

Table 3
Association between individual social network features and thoughts of suicide, crude and with adjustment for sociodemographic features.

	Crude OR	Adjusted OR
2 household members (vs 1)	1.02 [0.83–1.25]	1.20 [0.96–1.48]
3 household members (vs 1)	1.22 [0.94–1.57]	1.45** [1.11–1.90]
4+ household members (vs 1)	1.48** [1.11–1.96]	1.73*** [1.28–2.33]
No face-to-face meetings	1.13 [0.96–1.34]	1.09 [0.92–1.30]
No health supports	2.48*** [2.02–3.05]	2.24*** [1.81–2.78]
No financial supports	1.74*** [1.47–2.06]	1.69*** [1.42–2.00]
No emotional supports	2.86*** [2.31–3.54]	2.60*** [2.09–3.23]
No employment supports	1.58*** [1.33–1.88]	1.54*** [1.29–1.83]
Loneliness score	1.72*** [1.62–1.84]	1.75*** [1.64–1.87]

OR, odds ratio.
*** $P < 0.001$.
** $P < 0.01$.

prior 24 h was not associated with significantly greater likelihood of thoughts of suicide (adjusted OR 1.09, 95 % CI 0.92–1.30).

We next examined associations between thoughts of suicide and absence of social support. Individually, lack of each of the 4 categories of social support was significantly associated with suicidality in both crude and adjusted models (Table 3). In models incorporating all categories simultaneously (Fig. 1), the largest independent effect was observed for lack of emotional support (adjusted OR 1.84, 95 % CI 1.38–2.46), followed by health care (caregiving) support (i.e., whether there was someone who could care for them if they became ill) (adjusted OR 1.54, 95 % CI 1.17–2.03).

To characterize effects of loneliness, we then examined the association between thoughts of suicide and the 3-item loneliness scale and suicidality, available for survey participants in 2 of 6 waves (n = 5611). Adjusted models demonstrated significant association (OR 1.75, 95 % CI 1.64–1.87); that is, a 1-point increase on this 6-point scale was associated with a 75 % increase in odds of reporting thoughts of suicide.

Finally, in exploratory analysis, we examined differential associations between emotional support and thoughts of suicide across sociodemographic subgroups using generalized random forests. We focused on emotional support in this analysis as it demonstrated the largest effect on thoughts of suicide in univariate models, in line with previous studies demonstrating it is more predictive of persistent distress (Solomonov

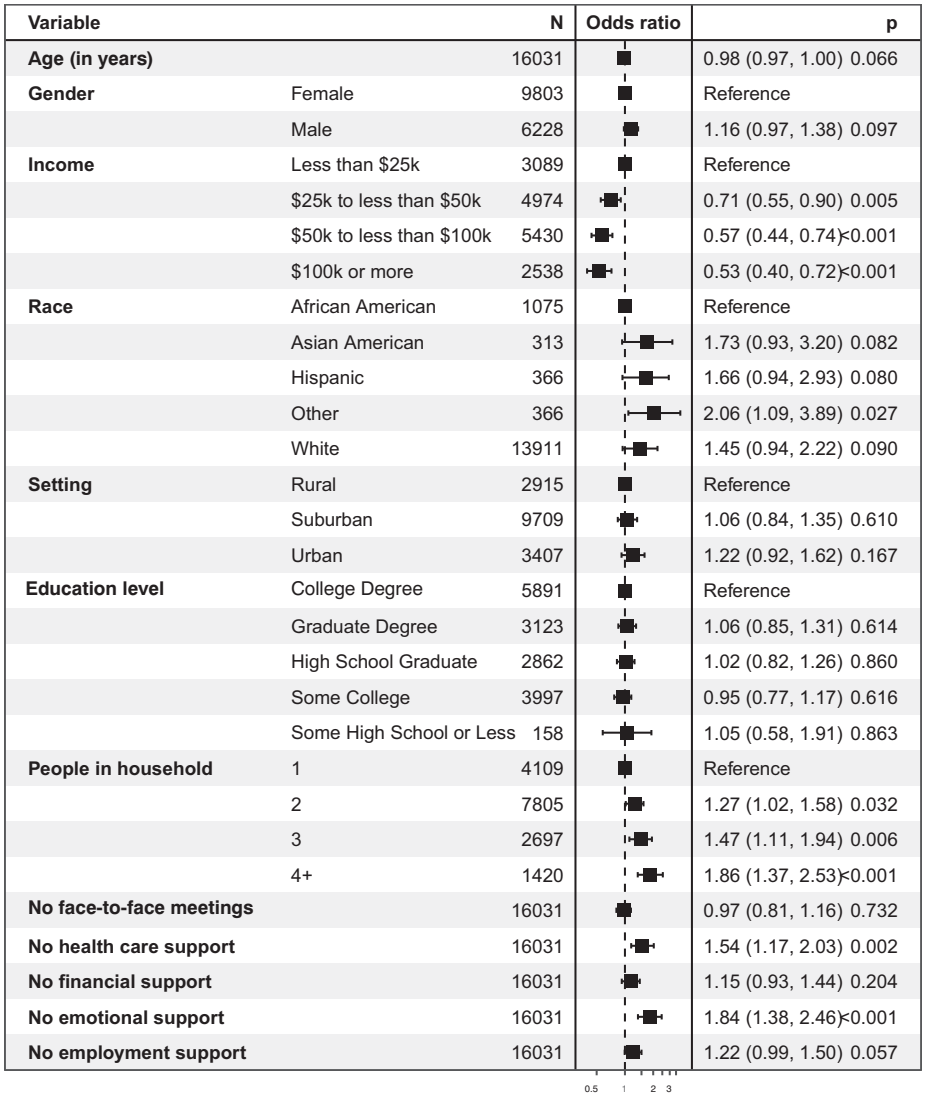

Fig. 1. Logistic regression model for thoughts of suicide incorporating sociodemographic and social connection and support features.

et al., 2021). Analysis of individual variability in predicted effect of emotional support suggests marked heterogeneity (Supplemental Fig. 1). The sociodemographic predictors with greatest importance in identifying differential treatment effects (i.e., most frequently selected as branches in random forests) included age followed by gender, household size, and income, with lesser effects for race and ethnicity and urbanicity (Supplemental Fig. 2). The marginal effects of age, by quantile, are illustrated in Supplemental Fig. 3, indicating that the effect size of association between emotional support and thoughts of suicide among older adults is largest among younger individuals in this group (i.e., the younger-old), and least among older individuals (i.e., the older-old). For household size, emotional support is associated with effect size among the largest households (Supplemental Fig. 4). Conversely, for household income, the effect of lack of social support is greatest among those in the highest-income quartile (Supplemental Fig. 5).

4. Discussion

Using national survey data from 16,164 respondents aged 65 and older, we found that 7.1 % reported thoughts of suicide at least several days in the prior 2-week period, including 2.4 % more than half the days in this period. While 25.6 % of older adults reported living alone, living alone was not associated with greater risk of suicidality; in fact, suicidality was *less* likely among those who lived alone or with a partner compared to larger households. However, thoughts of suicide were more likely among individuals who identified fewer social supports, particularly emotional supports, and greater levels of loneliness.

Social disconnection increases the risk of thoughts of suicide in late life (Joiner, 2007). Our results are broadly consistent with prior studies supporting such an association (Fässberg et al., 2012; Cui et al., 2022). In a case-control design, older adults with thoughts of suicide described lower levels of perceived social support (Harrison et al., 2010); a similar relationship was observed in a small community sample of older adults (Vanderhorst and McLaren, 2005). Poorer social integration – whether with family or community – was also associated with suicide death in older adults (Duberstein et al., 2004). Conversely, a greater sense of belonging, reflecting greater social engagement, correlated with diminished risk for suicidality in this age group in a community sample (McLaren et al., 2007).

Our results underscore the importance of precision in describing social networks: living alone in and of itself is not a risk factor for thoughts of suicide, for example. They are aligned with previous work demonstrating that low perceived social support and lack of social interactions with significant others serve as critical risk factors in late life (Solomonov et al., 2021; Solomonov et al., 2019). These latter factors are modifiable and can be targeted using psychosocial interventions that increase social engagement and alter negative perceptions of social supports (Solomonov et al., 2019; Solomonov and Phan, 2021).

We also demonstrate the application of a machine learning-based methodology for characterizing heterogeneity in the relationship between social connectedness and thoughts of suicide. We show, first, that there is strong evidence of heterogeneity, indicating the potential utility of more targeted interventions, since the risk conferred by a perceived lack of emotional support network varies by population subgroup. Further, we show that, in the case of age, the effect is greatest among younger rather than older individuals in the 65 and older age group. Others reported that the impact of social isolation and loneliness on mental health outcomes during COVID-19 was smaller among the oldest older adults, compared to other age groups, including younger older adults (McDonald et al., 2022). One possible explanation is that the oldest adults show high resilience and often perceive events as less stressful than their younger counterparts, due to increased emotional regulation and life experiences with past public crises (Knepple Carney et al., 2021; Neubauer et al., 2019). Effects also vary by income and household size, although the nature of these effects is more complex and requires further investigation.

Social isolation is not in and of itself simply a proxy for depression. Strategies that reduce depressive symptoms in older adults do diminish suicidality (Alexopoulos et al., 2021), but recent work suggests that the relationship between social connectedness and depression is more complex - and, in particular, highlights the role of positive affect. For example, in a survey of 429 older adults, positive affect was associated with lower levels of loneliness and greater social satisfaction (Davidson et al., 2021). Conversely, loneliness was common in that cohort, despite generally low levels of depressive symptoms. These findings highlight the importance of more nuanced investigation of social connectedness, rather than attributing it solely to depression or negative valence (Solomonov and Phan, 2021). In our sample, depression severity was relatively low, yet approximately a third of older adults reported absence of recent social interactions. Thus, strategies to increase social connectedness could be beneficial to older adults broadly, even those who may not experience depression. For example, psychotherapies based on behavioral activation principles that can increase engagement in rewarding social interactions may be particularly helpful (Solomonov et al., 2019; Solomonov and Phan, 2021).

Though this study employed only a single item to assess thoughts of suicide, that item has been demonstrated to be strongly associated with risk for suicide. Most notably, a prior study found that individuals who endorsed near-daily suicidality were between 5 and 8 times more likely to make a suicide attempt, and between 3 and 11 times more likely to die by suicide within 30 days, than individuals without such frequent ideation (Rossom et al., 2017). Rates of suicide attempt, and death by suicide, remained elevated within 365 days, and elevated risk was also observed in analyses limited to those 65 and older. As such, while we did not assess other suicide risk factors, or employ more detailed measures of suicide, we nonetheless are able to apply a measure with high predictive validity.

We note several additional caveats in interpreting our results. First, while our cohort is likely more generalizable to unselected populations of older adults than clinical/care-seeking samples, it nonetheless remains vulnerable to sources of ascertainment bias. As the survey is delivered via internet, we undersampled groups that are less apt to use such technology, while possibly oversampling those who use the internet for a greater proportion of their social interactions. Depressed older adults often suffer from comorbid medical conditions, disability, and low technological literacy, and may be less likely to participate in an online survey. The use of nonprobability sampling generally allows sampling a much larger cohort, balancing risks to ecological validity inherent in internet sampling (for a discussion of these tradeoffs, see Kennedy and Caumont, n.d.); this approach has been validated in other contexts (Coppock and McClellan, 2019; Berinsky et al., 2012) as well as in our prior work (Perlis et al., in press). On the other hand, as a general opinion survey that is not targeted to individuals with interest in mental health, we avoid other biases that might lead to inflated estimates of risk prevalence.

A second limitation is that we were unable to include more detailed assessments of suicidal behavior or risk – in particular, measures of comorbidity – given the need to keep the survey sufficiently brief. More targeted sub-surveys – for example, to those who endorse thoughts of suicide on initial screening - could help to address this limitation in future work. A final limitation to consider is that the surveys occurred during the COVID-19 pandemic, a source of both acute and chronic stressors that we and others have shown is associated with elevated prevalence of depression and anxiety (Ettman et al., 2020; Rossi et al., 2020). After the pandemic subsides, it will be important to revisit these results to examine the extent to which they will persist absent the high ambient levels of pandemic-associated stress.

5. Conclusion

In aggregate, our results demonstrate that both social disconnection and thoughts of suicide are common among older adults in the United

States. Emotional social support was the strongest predictor of thoughts of suicide, with more pronounced effects in younger older adults. Our findings are correlational in nature, and we cannot assess causality. However, results highlight the need for future longitudinal studies to investigate the bi-directional relationships between social disconnection and thoughts of suicide. Further, our findings may guide development of targeted psychosocial interventions for suicidality, such as streamlined psychotherapies, that modify social risk factors in this vulnerable population.

Ethical standards

The authors assert that all procedures contributing to this work comply with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008.

CRediT authorship contribution statement

All authors participated in conceptualization and design of the study, interpretation of the results and preparation of this manuscript. NS, FMG and RHP conducted the analyses.

Conflict of interest

Dr. Perlis has received consulting fees from Burrage Capital, Genomind, RID Ventures, Belle Artificial Intelligence, Vault Health, and Takeda. He holds equity in Belle Artificial Intelligence, Circular Genomics, Psy Therapeutics, and Vault Health. He receives patent royalties from Massachusetts General Hospital. The other authors report no financial disclosures.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jad.2023.04.038.

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