




## ORIGINAL ARTICLE

# Risk factors of suicidal behaviors in a high-risk longitudinal veteran sample: A network analysis

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## Abstract

**Introduction:** Suicide is a substantial public health burden, particularly among veterans. Risk factors have been delineated for suicide; however, the dynamic interrelations between risk factors have not been fully examined. Such research has the potential to elucidate processes that contribute to suicide risk between individuals with a past suicide attempt (attempters) and those without a past suicide attempt (nonattempters).

**Methods:** In the current study, network analysis was used to compare networks between attempters and nonattempters in a high-risk veteran sample ( $N = 770$ ;  $M_{\text{age}} = 32.3$  years,  $SD = 6.8$ ; 326 with a past suicide attempt) who were followed over 1 year. Networks were estimated to examine (1) concurrent relations of suicide risk factors at baseline and (2) predictability of prospective suicidal behavior (SB).

**Results:** There were no differences in the overall connectivity of attempter and nonattempter networks. Perceived burdensomeness and posttraumatic stress disorder (PTSD) symptoms were most central in the attempters' network, whereas PTSD symptoms and insomnia were most central in the nonattempters' network. The risk factors prospective SB in either network. However, attempters were more likely to engage in SB over the course of the study.

**Conclusion:** These findings highlight the difficulty in predicting who will attempt suicide.

## KEYWORDS

ideation to action, interpersonal theory of suicide, network analysis, suicide, veterans

## INTRODUCTION

Suicide is the tenth leading cause of death in the US, with over 48,000 people dying by suicide each year (Hedegaard et al., 2020). US veterans appear to be at even greater risk for suicide. In 2019, US veterans had a 52.3% higher adjusted suicide rate compared with age- and sex-matched

civilians (U.S. Department of Veterans Affairs, 2021), indicating a need to increase understanding of suicide risk for veterans. To increase the understanding of suicide risk, recent studies are calling for more complex methods, such as network analysis, to investigate the dynamic between risk factors for suicide and suicidality (de Beurs et al., 2019; Rath et al., 2019).

One of the most studied theories of suicidal behavior (SB) is the Interpersonal Theory of Suicide (ITS; Joiner, 2005; van Orden et al., 2010). The central tenet of the ITS is that the desire to die by suicide occurs through heightened feelings that one does not belong (i.e., thwarted belongingness) combined with thoughts that one is a burden to others (i.e., perceived burdensomeness). However, the ITS appears to account for only one plausible path to suicide; a meta-analysis ( $N = 122$  studies) on the ITS found that the interaction between desire (i.e., thwarted belongingness and perceived burdensomeness) and capacity demonstrated only modest effect sizes for suicide attempts (Chu et al., 2017). One potential reason for the modest prediction of SB is that constructs related to suicide arise from a set of interacting symptoms. The fluid vulnerability model of suicide (Rudd, 2006) recognizes SI and SB as a state that emerges from the dynamic interplay of different risk factors (i.e., the suicide mode). Thus, other related risk factors may play an important role in predicting SB.

Several other clinical syndromes and risk factors may contribute to suicide risk above constructs implicated in the ITS. For example, major depressive disorder (MDD) has been associated with SI, attempts, and death (American Psychiatric Association, 2013). Beyond MDD, meta-analyses of suicide antecedents found that substance use is significantly related to suicide death (Arsenault-Lapierre et al., 2004; Knipe et al., 2019). Posttraumatic stress disorder (PTSD) is also associated with SB (Bentley et al., 2016), especially in military populations (Naifeh et al., 2019). Additionally, physical pain severity has been recognized as an important risk factor for suicide in veterans (Ashrafioun et al., 2022; Ilgen et al., 2010). Lastly, several transdiagnostic risk factors related to regulatory systems such as insomnia show a strong association with SI and SB (Allan et al., 2017, 2019; Saulnier et al., 2022; Short et al., 2021). However, each of these does not yield accurate prediction of suicide death, as most people with these disorders and symptoms will not attempt suicide, much less die by suicide.

Although many risk factors for suicide have been delineated, meta-analytic work covering 50 years of risk factor research found that the field's ability to predict suicide is only slightly better than chance (Franklin et al., 2017). Given the poor SB predictive ability demonstrated by Franklin et al. (2017) and others (Fox et al., 2019), it may be that suicide risk cannot be attributed to any single factor or pathway. Thus, it is imperative to account for the complexity of SB and study the interactions between multiple risk factors. Additionally, risk factor research has largely been examined in samples predominately consisting of suicidal ideators (Franklin et al., 2017; Klonsky & May, 2014; May & Klonsky, 2016). As most people who experience suicidal

thoughts never attempt suicide (SAMHSA, 2019) and because suicide attempts confer significant risk for later suicide death (Bostwick et al., 2016), it is crucial to investigate the samples consisting of both individuals who had not attempted suicide and individuals who attempted suicide to better understand what distinguishes these two groups (May & Klonsky, 2016; Nock et al., 2016).

Network analysis offers a novel conceptualization that may improve understanding of suicide risk. In the network approach, there is no unique cause of various syndromes because the symptoms are causing one another, creating a dynamic system which is the disorder itself (Borsboom, 2017; Schmittmann et al., 2013). One of the advantages of the network approach is its ability to model the complex interrelations among constructs, as well as explain how dynamic systems shift from one state to another (i.e., from the non-suicidal to suicidal mode). de Beurs et al. (2019) argued that a network approach could be of great value for understanding SB, especially for understanding how dynamic risk factors lead to SB.

The use of network analysis to investigate SB is in a relatively nascent stage. To date, network analysis has been used to examine cross-sectional predictors of SI in community samples (Bloch-Elkouby et al., 2020; de Beurs et al., 2019; Gijzen et al., 2021; Ordóñez-Carrasco et al., 2021), clinical samples (Bloch-Elkouby et al., 2020; Schönfelder et al., 2021), and in veterans (Armour et al., 2017; Graziano et al., 2021; Simons et al., 2019). Across these cross-sectional studies, perceived burdensomeness, psychological pain, defeat, loneliness, rumination, internal entrapment, and self-destructive behavior were significantly related to the presence and severity of SI. In a prospective study taking place over years, changes in depressive symptoms predicted subsequent changes in SI (Savelieva et al., 2021). In studies using network analysis to examine the momentary predictors of SI in naturalistic settings, perceived burdensomeness and SI at the previous assessment period predicted future SI (Rath et al., 2019).

Comparatively fewer studies have examined cross-sectional predictors of SB in community (Shim et al., 2020) and clinical samples (Schönfelder et al., 2021). Further, only one study to our knowledge has used network analysis to examine prospective risk for SB in veterans. A sample of veterans who endorsed a PTSD Criterion A stressor was used to examine bridge symptoms (i.e., symptoms linking a syndrome to a particular outcome) linking PTSD symptoms to subsequent SB (Spitzer et al., 2020). The avoidance of external reminders, nightmares, sleep disturbance, and psychological distress was the greatest driving force behind SB risk. Although this study provides support for specific symptoms that confer dynamic risk for SB among veterans exposed to a criterion A stressor, the inclusion of more risk factors within the network analysis is needed.

The current study was designed to explore the interplay of well-established suicide risk factors using network analysis. Networks were estimated to examine the interrelations of perceived burdensomeness, thwarted belongingness, depression symptoms, alcohol use, drug use, PTSD symptoms, pain, insomnia, and SI within US veterans who reported previous suicide attempts (attempters) and US veterans who reported current SI but did not report a previous suicide attempt (nonattempters). It was expected that attempters would have more densely connected networks, as the set of risk factors would be more meaningfully connected in those with a prior suicide attempt. No specific hypotheses were advanced regarding differences in local edge strength between attempters and nonattempters due to the relatively little research in this area and exploratory nature of these analyses. Prospective SB over the 12-month study was then included in both groups separately and exploratory predictability analyses were conducted to determine the predictive power of the risk factors for subsequent SB.

## METHODS

Data were collected as a part of a large-scale clinical trial funded by the Department of Defense (W81XWH-13-2-0032). Participants were recruited through social media advertisements and printed fliers inviting them to participate in a telephone-administered study aimed to investigate decisions about seeking mental health treatment. Eligibility criteria included serving in the United States Armed Forces after September 11, 2001, not receiving mental health services at the time of screening, endorsing recent SI (91.0% reported thoughts of being better off dead on the Patient Health Questionnaire-9 [PHQ-9], item 9) or a lifetime suicide attempt.

The initial dataset included 770 current and past military service members ( $M_{\text{age}} = 32.3$  years,  $SD = 6.8$ ; 89.6% male), of which 326 reported a history of SB at baseline (42.3%) and were thus classified as attempters for the purpose of these analyses. Veterans self-identified as 74.8% White, 12.1% Black, 1.8% Native American, 3.0% Asian/Pacific Islander, 7.7% other or mixed race, with 0.6% missing data on race. Additionally, 8.7% identified as Hispanic. Military branch included Army (69.3%), Air Force (8.1%), Marines (16.3%), Navy (9.7%), and Coast Guard (0.1%).

## Procedure

This study was part of a larger clinical trial designed to assess the efficacy of a brief telephone intervention to increase treatment-seeking behavior in military personnel at

risk for suicide. Participants completed the informed consent process and the baseline assessment via telephone. Participants were then randomized into experimental and control conditions after the baseline assessment. Participants were contacted 1, 3, 6, and 12 months after the baseline appointment to complete the respective follow-ups. In the current study, suicide risk factors were measured at baseline and SB was measured at follow-ups. The presence of SB at 12 months was coded “yes” if a participant reported SB at any of the follow-ups. Participants received \$25 for each completed session. The appropriate institutional review boards approved all study procedures.

## Measures

### PTSD Checklist for DSM-IV—Military Version (PCL-M)

The PCL-M is a 17-item measure assessing DSM-IV PTSD symptoms for military personnel (Weathers et al., 1993). Participants reported on PTSD symptoms over the past month. The PCL-M used in the current study demonstrated adequate reliability ( $\alpha = 0.88$ ).

### Insomnia Severity Index (ISI)

The ISI is a 7-item measure assessing insomnia symptoms, satisfaction with sleep patterns, and interference of sleep patterns with daily functioning (Morin et al., 2011). Participants rated insomnia symptoms over the past 2 weeks. In the current study, the baseline ISI demonstrated adequate reliability ( $\alpha = 0.82$ ).

### Columbia-Suicide Severity Rating Scale (C-SSRS)

The C-SSRS is a semi-structured clinical interview designed to assess suicidal thoughts and behaviors over time (Posner et al., 2011) validated for telephone-administration (Arias et al., 2014). The C-SSRS was used to determine past suicide attempts (an eligibility criterion), current SI at baseline, and to gather information about participants' SB throughout the follow-ups. SB across all follow-ups was considered present if a participant reported it at least once.

### Patient Health Questionnaire-9 (PHQ-9)

The PHQ-9 is a 9-item depression questionnaire (Spitzer et al., 1994) that measures DSM-IV depression symptoms.

In this study, item 9 on the PHQ-9 was administered during the screening to assess eligibility. The PHQ-9 was also administered in the baseline appointment to assess depression symptoms over the past 2 weeks. In the current study, the reliability of this scale was adequate ( $\alpha = 0.71$ ).

### Interpersonal Needs Questionnaire-8 (INQ-8)

The INQ-8 is an 8-item scale assessing perceived burdensomeness and thwarted belongingness (Allan et al., 2016). “Recent” symptoms of perceived burdensomeness and thwarted belongingness were reported. Reliability of the INQ-8 subscales was adequate in the current study for perceived burdensomeness ( $\alpha = 0.86$ ) and for thwarted belongingness ( $\alpha = 0.71$ ).

### The Addiction Severity Index (ASI)

The ASI is a structured interview used to assess the severity of alcohol use, drug use, and related problems in adults (McLellan et al., 1992). The interview consists of seven domains: general information, medical status, employment, alcohol/drugs, legal status, family/social history, and psychiatric status. The drug and alcohol use domains were assessed in the current study, each with a composite score ranging from 0 to 1.

### Brief Pain Inventory (BPI)

The BPI is an 11-item scale used to assess the severity of pain (four items) and the interference of pain with daily life (seven items; Cleeland, 2009). In the current study, only the four-item pain severity scale over the past week was used. In the current study, the BPI showed excellent reliability ( $\alpha = 0.92$ ).

### Data analytic plan

A total of two sets of network models were estimated. The first set of models included the nine risk factors for suicide that were assessed at baseline (i.e., perceived burdensomeness, thwarted belongingness, depression, alcohol use, drug use, PTSD, pain, insomnia, and SI) and was estimated separately for attempters and nonattempters. The second set of models included prospective SB over the course of the 12-month study in addition to the baseline risk factors. The second set of models was also tested separately for attempters and nonattempters.

All analyses were carried out using *Rstudio* (version 1.4.1717). Network structures of baseline risk factors were estimated using EBICglasso algorithm (Epskamp & Fried, 2018), implemented in the *qgraph* R package (Epskamp et al., 2012, version 1.6.9.). EBICglasso uses the graphical LASSO (Friedman et al., 2008) in combination with EBIC model selection (EBIC; Chen & Chen, 2008; Foygel & Drton, 2010) for estimating a regularized Gaussian graphical model (GGM; Lauritzen, 1996) in which edges represent partial correlations between pairs of nodes after controlling for all other nodes (Epskamp et al., 2018). The EBIC hyperparameter gamma was used and was set to 0.5 to control for potentially spurious links, as recommended by (Foygel & Drton, 2010). Due to the data being continuous but not satisfying the assumption of normality, nonparametric transformation (Liu et al., 2010) was applied before computing the correlations (i.e., npn was specified as the correlation method).

Network structures including prospective SB were estimated using Mixed Graphical Models (MGMs) implemented in R-package *mgm* version 1.2.12 (Haslbeck & Waldorp, 2016). MGMs were used as these networks consisted of both continuous (baseline risk factors) and categorical variables (SB). The EBIC selection variant of *mgm* was used and the EBIC hyperparameter gamma was set to 0.5. Note that the EBIC selection variant of *mgm* has lower sensitivity but better precision compared with EBICglasso (Isvoranu & Epskamp, 2021). Thus, the network structures including SB are expected to have fewer edges compared with the network structures of risk factors, but the identified edges are more likely to represent true edges.

Accuracy and stability checks were performed to assess the robustness of results. Nonparametric bootstrapping based on 1000 bootstrap samples was used to assess the accuracy of the estimated edge weights. Case-drop bootstrapping was used to examine the stability of the strength index. The bootstrapped difference-test was used to assess whether some edges and nodes were statistically stronger than other edges and nodes within each network. Bootstrapping was accomplished using the R package *bootnet* (Epskamp et al., 2018, version 1.4.3.).

Several indices of local connectivity (i.e., strength, closeness, and betweenness) are usually examined to determine which nodes occupy critical positions in the networks. However, limitations of the closeness and betweenness metrics have been delineated (Bringmann et al., 2019; Epskamp et al., 2018; Hallquist et al., 2019). Strength, the degree to which each node is directly connected to other nodes, shows higher replicability relative to other indices of local connectivity (Isvoranu & Epskamp, 2021) and was thus the only centrality measure computed in this study.



The overall connectivity of the networks (i.e., the weighted sum of absolute connections) was determined for attempters and nonattempters. To statistically compare the overall connectivity of the networks estimated in different subpopulations, the network comparison test (NCT), implemented in R *NetworkComparisonTest* package (van Borkulo, 2017, version 2.2.1), was used with 1000 iterations.

## RESULTS

### Missing data and baseline comparisons

A substantial number of respondents ( $n = 241$ ) had missing data, mostly on insomnia, burdensomeness, and belongingness,<sup>1</sup> as these measures were added by request of the Department of Defense after the study had already begun. Respondents with missing data were omitted from the analyses, for a final sample of 268 attempters and 261 nonattempters. A series of  $t$ -tests<sup>2</sup> were performed to examine differences in baseline risk factors between attempters and nonattempters (Table 1). The two groups significantly differed in terms of depression, PTSD, insomnia, and perceived burdensomeness, with attempters scoring higher on each of the four variables.

### Baseline risk factor networks

The networks of attempters and nonattempters are presented in Figure 1. Network edges represent regularized partial correlations between the risk factors. Edge

weights ranged from  $-0.01$  (belongingness—drug use) to  $0.37$  (burdensomeness—belongingness) in attempters, and from  $0.02$  (belongingness—depression) to  $0.36$  (burdensomeness—belongingness) in nonattempters. The bootstrapped confidence intervals were sizable (Figure S1), especially in the network of nonattempters, suggesting that the order of edge estimates should be interpreted cautiously. The strength centrality estimates showed good stability (above  $0.5$ , as recommended by Epskamp et al., 2018) in both attempters and nonattempters (Figure S2), with centrality coefficients of  $CS_{\text{attempters}} = 0.59$  and  $CS_{\text{nonattempters}} = 0.52$  indicating that approximately 59% of the attempters' and 52% of the nonattempters' data could be dropped to retain a correlation of  $0.7$  with the original dataset (with 95% certainty). Thus, the order of nodes with respect to their strength can be interpreted with confidence.

To examine the difference in connectivity between the two networks, the networks' density (a ratio of detected edges to the overall number of all possible edges in the network was used as a measure of density) was compared. The network of attempters had a density of  $0.47$  (17/36 edges), with the mean weight of  $0.06$ . The network of nonattempters had a density of  $0.53$  (19/36 edges), with the mean weight of  $0.07$ . The global invariance test within the NCT revealed no significant differences between the network of attempters and nonattempters (global connectivity difference =  $0.07$ ,  $p = 0.86$ ), suggesting that the overall connectivity was equivalent across groups. In addition, no significant differences between edge values were found ( $p > 0.05$ ).

Based on the strength index (Table 2), the strongest node in attempters was perceived burdensomeness

	Attempters ( $n = 268$ )		Nonattempters ( $n = 261$ )		$p$
	$M$	$SD$	$M$	$SD$	
Suicidal ideation	1.23	1.35	1.10	1.23	.24 <sup>a</sup>
Depression	18.30	4.69	17.43	4.30	.03 <sup>a</sup>
PTSD	63.51	12.01	58.98	12.09	<.001
Insomnia	18.94	5.99	17.46	6.44	.01
Burdensomeness	14.64	7.04	13.43	6.28	.04 <sup>a</sup>
Belongingness	15.96	5.95	15.68	5.34	.56
Pain	13.63	8.35	13.11	8.23	.47
Alcohol use	0.13	0.18	0.12	0.16	.94 <sup>b</sup>
Drug use	16.55	6.65	16.69	6.51	.22 <sup>b</sup>

TABLE 1 Baseline comparisons of risk factors between attempters and nonattempters

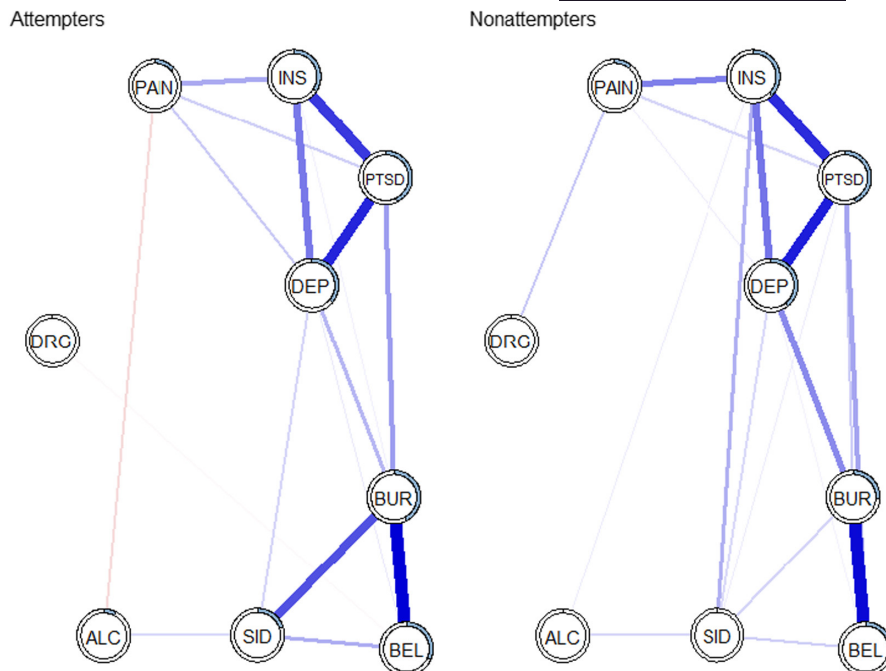
Note:  $T$ -test for independent samples was used to test for differences between groups.

Abbreviations: Belongingness, thwarted belongingness; Burdensomeness, perceived burdensomeness; Depression, depression symptoms; PTSD, posttraumatic stress disorder symptoms.

<sup>a</sup>Equal variances not assumed.

<sup>b</sup>Mann-Whitney's  $U$  test was used.

**FIGURE 1** Networks of suicide risk factors in attempters ( $n = 268$ ) and nonattempters ( $n = 261$ ). ALC, alcohol use; BEL, thwarted belongingness; BUR, perceived burdensomeness; DEP, depression symptoms; DRG, drug use; INS, insomnia; PAIN, Pain; PTSD, PTSD symptoms; SID, suicidal ideation. Blue lines represent positive links between the nodes, and the thicker and more saturated the edge, the stronger the link (Epskamp et al., 2012). Red lines represent negative links between the nodes. The blue part of the ring shows the proportion of explained variance ( $R^2$ ).



**TABLE 2** Standardized strength indices for the risk factor networks in attempters and nonattempters

Risk factor	Attempters	Nonattempters
Suicidal ideation	0.49	0.39
Depression	0.79	0.81
PTSD	0.82	0.94
Insomnia	0.63	0.84
Burdensomeness	0.90	0.67
Belongingness	0.54	0.58
Pain	0.32	0.36
Alcohol use	0.11	0.09
Drug use	0.01	0.08

Abbreviations: Belongingness, thwarted belongingness; Burdensomeness, perceived burdensomeness; Depression, depression symptoms; PTSD, posttraumatic stress disorder symptoms.

(although burdensomeness did not statistically differ from PTSD or depression, see Figure S3), whereas the strongest nodes in nonattempters were PTSD, insomnia, and depression (although depression and insomnia did not statistically differ from burdensomeness, see Figure S3). Drug use and alcohol use were statistically weaker than all other nodes (Figure S3). The nonparametric bootstrapped edge differences were roughly the same in attempters and nonattempters (Figure S4). The network estimated on the sample of attempters had a slightly higher average predictability ( $M_{pred} = 0.25$ , range: 0.00–0.43), when compared with the network estimated on nonattempters ( $M_{pred} = 0.20$ , range: 0.00–0.43). A significant amount

of SI was predicted by the other nodes in the attempter network but not in the nonattempters network (Table 3). Around 25% of the variance of the attempters' network, and around 20% of the nonattempters' network could be explained by the interrelationships between the nodes.

### Risk factor networks including prospective suicidal behavior

Compared with the nonattempters, attempters were more than twice as likely to report SB over the course of the study ( $\chi^2 = 6.47$ ,  $p = 0.01$ , OR = 2.17). Networks were estimated after including both prospective SB and the baseline risk factors (Figure 2). For bootstrapped confidence intervals of the estimated edges, stability coefficients of strength values, and centrality analysis, see Figures S5–S7.

In both the attempter and nonattempters networks, SB was not significantly related to any other nodes. Predictability analysis revealed that the nine nodes did not improve the prediction of SB ( $nCC = 0$  for both networks) above the intercept accuracy ( $CC_{marg} = 0.87$  for both networks; see Table 5). Stated differently, if an estimation was made that no participant would exhibit SB, the estimation would be correct in 86.9% of cases and no additional classification accuracy would be achieved by considering the risk factors. Regarding local connectivity, a similar pattern emerged between the networks estimated without SB and those estimated with SB (for strength indices see Table 4). In addition, the overall connectivity did not differ significantly across the two networks (global connectivity difference = 0.19,  $p = 0.73$ ).

**TABLE 3** Predictability for individual nodes for the risk factor networks

Variable	$R^2$	
	Attempters	Nonattempters
Suicidal ideation	0.20	0.00
Depression	0.36	0.39
PTSD	0.43	0.43
Insomnia	0.34	0.38
Burdensomeness	0.42	0.26
Belongingness	0.32	0.25
Pain	0.13	0.11
Alcohol use	0.08	0.00
Drug use	0.00	0.00

Abbreviations: Belongingness, thwarted belongingness; Burdensomeness, perceived burdensomeness; Depression, depression symptoms; PTSD, posttraumatic stress disorder symptoms.

## DISCUSSION

This study is the second to examine dynamic risk factors for prospective SB among veterans using network analysis. Contrary to hypotheses, there were no differences in the overall connectivity of networks between those who had previously attempted suicide and those who had not. Across networks, insomnia, PTSD, pain, and depression symptoms were grouped together in both networks and were strongly linked to each other. In both networks, PTSD and depression symptoms were linked to perceived burdensomeness. Finally, perceived burdensomeness, thwarted belongingness, and SI formed another group in both networks.

Lack of differences in the overall connectivity was inconsistent with extant research that found more densely connected networks in patients with MDD compared to patients with remitted MDD (van Borkulo et al., 2015) and individuals with social anxiety disorder compared with healthy controls (Heeren & McNally, 2018). Given that both groups in the current study are composed of vulnerable individuals, it is possible that the history of suicide attempts alone (especially when measured without information regarding temporal proximity) was not potent enough to influence overall connectivity in the current sample. Alternatively, the inconsistencies between the current study and prior studies could be due to the inclusion of specific diagnostic groups when estimating networks. For example, in the van Borkulo et al. (2015) study, participants were classified based on diagnostic groups before networks were estimated for symptoms belonging to those diagnostic groups. However, in the current study, participants were divided based on past SB, which is not composed of the symptoms in the network.

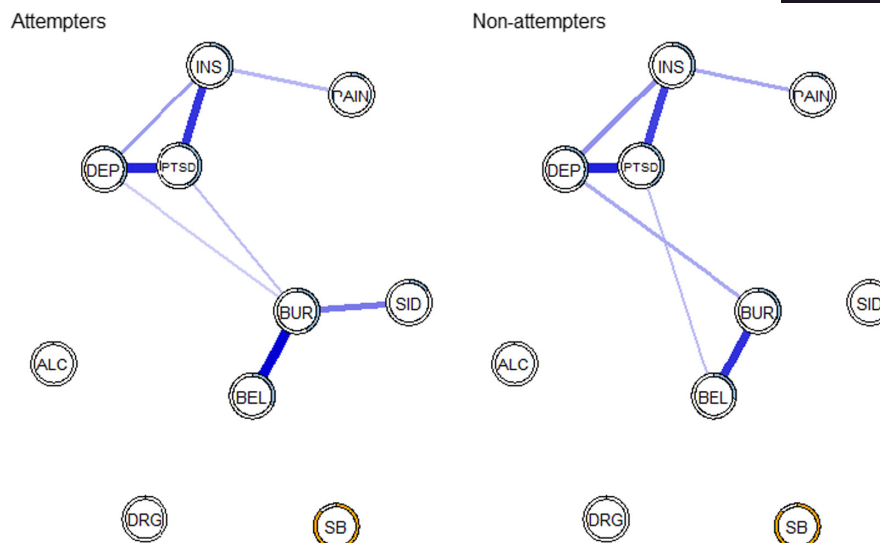
**TABLE 4** Standardized strength indices for the risk factor networks in attempters and nonattempters after including prospective suicidal behavior

Risk factor	Attempters	Nonattempters
Suicidal Ideation	0.20	0.00
Depression	0.54	0.62
PTSD	0.72	0.71
Insomnia	0.55	0.58
Burdensomeness	0.75	0.43
Belongingness	0.38	0.41
Pain	0.11	0.13
Alcohol Use	0.00	0.00
Drug Use	0.00	0.00
Suicidal Behavior	0.00	0.00

Abbreviations: Belongingness, thwarted belongingness; Burdensomeness, perceived burdensomeness; Depression, depression symptoms; PTSD, posttraumatic stress disorder symptoms.

Although there were no differences in overall connectivity between the networks of individuals who had engaged in SB and individuals who experienced SI but had not engaged in SB, there were several differences in local connectivity across networks. In the network of attempters, perceived burdensomeness had the highest strength value, whereas in the nonattempters network, PTSD symptoms had the highest strength value. In addition, the predictability of perceived burdensomeness and its association with SI was greater in the attempter's network. Such findings seem to suggest that perceived burdensomeness might be more important for the risk factor dynamic in attempters. At the same time, PTSD symptoms might be more important for nonattempters. In previous studies, PTSD symptoms have emerged as cross-sectional (Graziano et al., 2021) and longitudinal predictors of SB using network analysis (Spitzer et al., 2020). However, according to the edge difference test, PTSD and depression symptoms were of equal importance as perceived burdensomeness in attempters, whereas depression symptoms and insomnia were of equal importance in nonattempters in the current sample. However, the relatively small sample size across groups may explain the lack of differences in node strength among the most prominent nodes in both networks. Additionally, the local connectivity for insomnia was greater in the nonattempters' network when compared with the attempters' network, and insomnia was positively related to SI in nonattempters but not attempters. Thus, insomnia, above the effects of PTSD symptoms, may be important to consider for suicide risk among individuals without a prior suicide attempt.

The networks including prospective SB used a less sensitive but more precise estimator, causing stronger edges



**FIGURE 2** Networks of suicide risk factors and prospective suicidal behavior in attempters ( $n = 268$ ) and nonattempters ( $n = 261$ ). ALC, alcohol use; BEL, belongingness; BUR, burdensomeness; DEP, depression symptoms; DRG, drug use; INS, insomnia; PTSD, PTSD symptoms; SB, suicidal behavior; SID, suicidal ideation. Blue lines represent positive links between the nodes. The blue part of the ring shows the proportion of explained variance ( $R^2$ ). The orange part of the SB ring (categorical variable) indicates the accuracy of the intercept model.

**TABLE 5** Predictability for individual nodes for the risk factor networks after including prospective suicidal behavior

Variable	$R^2$		CC	nCC	CCmarg
	Attempters	Nonattempters			
Suicidal ideation	0.16	0.00	–	–	–
Depression	0.36	0.38	–	–	–
PTSD	0.43	0.42	–	–	–
Insomnia	0.34	0.32	–	–	–
Burdensomeness	0.42	0.31	–	–	–
Belongingness	0.32	0.27	–	–	–
Pain	0.10	0.11	–	–	–
Alcohol use	0.01	0.00	–	–	–
Drug use	0.00	0.00	–	–	–
Suicidal behavior	–	–	0.87	0.00	0.87

Note: CC, nCC, and CCmarg refer both to attempters and nonattempters.

Abbreviations: Belongingness, thwarted belongingness; Burdensomeness, perceived burdensomeness; Depression, depression symptoms; PTSD, posttraumatic stress disorder symptoms.

to remain in the network (compared with the networks without SB) while weaker edges disappeared (e.g., perceived burdensomeness—SI disappeared from the network of nonattempters). The only variable that remained directly associated with SI was perceived burdensomeness in the attempters' network (across networks with and without prospective SB), whereas no nodes were significantly related to SI in the network of nonattempters.

In the networks that included prospective SB, predictability analysis revealed that SB was not related to any of the risk factors in the networks of individuals who had engaged in SB and individuals who experienced SI but had not engaged in SB. This is consistent

with prior research that suggests our ability to prospectively predict SB remains poor (Franklin et al., 2017). A potential reason for the lack of prospective relations between risk factors and SB is that trait risk factors were assessed in the current study. It may be that momentary fluctuations in risk factors are more important to capture suicide risk. For example, acute alcohol intoxication and related disinhibition is associated with SB (Pompili et al., 2010). However, reports of alcohol use and SB should be captured close temporally to detect this effect. Thus, suicide prediction efforts may be improved by modeling dynamic changes in risk factors over time (Rath et al., 2019).



There are several clinical implications for these findings. First, these results suggest that suicide risk can be modeled by the dynamic interactions of multiple risk factors. Although there were no significant differences in global connectivity between the networks of attempters and nonattempters, SI was only significantly predicted by risk factors within individuals with a SB history. Further, the independent and interactive contributions of multiple risk factors should be considered when assessing suicide risk at the individual level. For example, clinicians should assess whether the presence of one risk factor (e.g., insomnia) makes the presence of another risk factor (e.g., SI) more likely for each individual patient. Certain risk factors (e.g., insomnia) may be may impactful among individuals without a history of suicide attempts, and others (e.g., perceived burdensomeness) may be may impactful among individuals with a past suicide attempt.

Although these findings provide several novel insights into the dynamic processes that contribute to suicide risk, there are a few limitations of the current study. First, all these measures were self-report or clinical interview. Thus, there may have been underreporting on some of the clinical variables, such as alcohol and drug use, given evidence veterans may underreport these concerns (Stecker et al., 2010). Additionally, the current sample consisted of high-risk veterans not receiving care at VA. Thus, these results may not replicate across other samples. Replication attempts should include a more diverse sample to determine if these results are consistent outside of high-risk veterans not receiving treatment through VA.

The current study is the first to our knowledge to provide evidence for prospective contributions of suicide risk factors in dynamic networks between individuals with prior suicide attempt histories and those without a previous suicide attempt. In the current study, the strongest nodes differed across individuals who had previously engaged in SB and individuals who experienced SI but had not engaged in SB. Given this finding, clinical assessments of suicide risk should consider the unique and interactive combination of risk factors on suicide based on an individual's history of engaging in SB. Additionally, this was the third study to model dynamic processes among malleable risk factors for prospective SB. These findings should be applied to assessment practices of SI and SB in clinical settings to monitor changes over time and apply well-validated interventions when appropriate (Jobes, 2012).

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## CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

## DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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## ENDNOTES

<sup>1</sup> Participants with missing values (excluded from the study) reported significantly lower SI and significantly higher PTSD ( $p < 0.05$ ).

<sup>2</sup> Mann-Whitney's  $U$  test was performed in the case of non-normally distributed variables.

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## SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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