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The Impact of Exercise on Suicide Risk: Examining Pathways through Depression, PTSD, and Sleep in an Inpatient Sample of Veterans

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Suicide has a large public health impact. Although effective interventions exist, the many people at risk for suicide cannot access these interventions. Exercise interventions hold promise in terms of reducing suicide because of their ease of implementation. While exercise reduces depression, and reductions in depressive symptoms are linked to reduced suicidal ideation, no studies have directly linked exercise and suicide risk. The current study examined this association, including potential mediators (i.e., sleep disturbance, posttraumatic stress symptoms, and depression), in a sample of Veterans. SEM analyses revealed that exercise was directly and indirectly associated with suicide risk. Additionally, exercise was associated with fewer depressive symptoms and better sleep patterns, each of which was, in turn, related to lower suicide risk.

Suicide has a large and well-documented impact on public health. Despite efforts to reduce suicide rates by professionals and lay people, these rates have remained relatively unchanged for the last 50 years. Indeed, in the United States, the suicide rate in 2005 was 11.0 per 100,000, nearly identical to the rate of suicide in 1965 (11.1 per 100,000; World Health Organization, 2005). Despite the lack of population-level decline in suicide rates, significant progress has been made in suicide intervention work in recent years.

Interventions developed for people who have attempted suicide have shown associations with reduced risk of future death. For example, using the intervention of sending caring letters to high-risk patients who had lost contact with a hospital was shown to decrease suicides (Motto

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& Bostrom, 2001). A similar intervention also reduced future suicide attempts (Fleischmann et al., 2008). There are a wide number of evidenced-based interventions for populations at particular risk for suicide, including Dialectical Behavior Therapy (DBT; Linehan et al., 2006) and Cognitive Behavioral Therapy for Suicide Prevention (CBT-SP; Brown et al., 2005). Several studies have demonstrated that interventions aimed at decreasing depressive symptoms also reduce suicide ideation (Cukrowicz et al., 2009; Vannoy et al., 2007).

While these interventions are vital and likely save the lives of many people each year, the interventions are not widely available in the community and only focus on those at very high risk for suicide. An approach to suicide prevention that has not been closely examined, but that holds tremendous promise in terms of widespread dissemination, is exercise. Research has consistently demonstrated that exercise is associated with lower levels of clinical and subclinical depression in cross-sectional and experimental studies (Conn, 2010; De Moor, Beem, Stubbe, Boomsma, & De Geus, 2006; Goodwin, 2003; Hoffman et al., 2011; Mead et al., 2009). Indeed, as depression is one of the most robust risk factors for suicide in large population-based studies (Kessler, Borges, & Walters, 1999; Lee et al., 2007; Nock et al., 2008; Petronis, Samuels, Moscicki, & Anthony, 1990), employing exercise for the treatment of depression is a potential avenue to ameliorate or reduce suicide risk.

In addition to these potential benefits, exercise may also impact suicide risk through improvements in posttraumatic stress disorder (PTSD) symptoms and sleep. While there are a substantial number of studies investigating the link between PTSD and suicide, the results of these studies are somewhat mixed. Indeed, although some studies suggest that PTSD is a risk factor for suicide only in the context of co-occurring depression (Campbell et al., 2007; Oquendo et al., 2003; Zivin et al., 2007), the preponderance of evidence seems to point to PTSD as an important independent risk factor for suicide (Guerra & Calhoun, 2011; Jakupcak et al., 2009; Sareen et al., 2007; Surís, Link-Malcolm, & North, 2011; Wilcox, Storr, & Breslau, 2009). Among epidemiological samples, PTSD has been linked to suicide ideation, plans, and attempts (Kessler et al., 1999), and work among clinical populations has demonstrated increased suicide risk among veterans with PTSD (Brenner et al., 2011; Guerra & Calhoun, 2011; Jakupcak et al., 2009; VanCott et al., 2010), as well as civilian PTSD populations (Cougle, Resnick, & Kilpatrick, 2009; Sareen et al., 2007; Wilcox et al., 2009).

With regard to disturbed sleep, several population-based studies have linked sleep problems to higher rates of suicide ideation, attempts, and deaths (Goodwin & Marusic, 2008; Tanskanen et al., 2001; Wojnar et al., 2009). Further, disrupted sleep has been shown to increase suicide risk in people without psychiatric diagnoses and among those with major depressive disorder (MDD), PTSD, and chronic pain. Specifically, sleep disturbances have been linked to suicide ideation, attempts, and deaths (Bernert, Reeve, Perlis, & Joiner, 2009; Carli et al., 2011; Goldstein, Bridge, & Brent, 2008; Krakow, Ribeiro, Ulibarri, Krakow, & Joiner, 2011; Ribeiro et al., 2011; Wong, Brower, & Zucker, 2011).;

Furthermore, there is some evidence that exercise improves both PTSD symptoms and sleep quality. Specifically, research has demonstrated a relation between increased exercise and reduced PTSD symptoms among a nonclinical sample (Rutter, Weatherill, Krill, Orazem, & Taft, 2011), military personnel (LeardMann et al., 2011), and adolescents (Diaz & Motta, 2008; Newman & Motta, 2007).

Two reviews (Driver & Taylor, 2000; Youngstedt, O'Connor, & Dishman, 1997) suggest that both acute and chronic exercise improve total sleep time, REM latency, and delayed REM latency (with moderate effect sizes), but these results are hampered by a strong reliance of the studies on individuals who have relatively mild sleep impairment,

small sample sizes, and differing methodologies. More recent studies employing prospective experimental designs have found support for the impact of exercise on sleep (Buman, Hekler, Bliwise, & King, 2011; Reid, Baron, Lu, Erik, & Zee, 2010).

Based on the literature highlighting potential direct and indirect associations between exercise and suicide, the current study sought to provide the first rigorous examination of direct and indirect pathways linking exercise and suicide risk. We hypothesized a priori that exercise would have a direct association with suicide risk and an indirect association with suicide risk through depressive symptoms, PTSD symptoms, and poor sleep. We chose to examine these relations among a sample of veterans entering residential treatment for PTSD as veterans with PTSD tend to have higher rates of suicide, depression, and sleep disturbance (e.g., Jakupcak et al., 2009; Zivin et al., 2007).

METHOD

Participants included 346 (M_{age} = 45.45 years, SD = 14.27) predominately male (81%) military veterans admitted to a Veterans Administration (VA) 90-day residential rehabilitation program for PTSD. The racial/ethnic composition of the sample was as follows: 54.5% Caucasian, 20.3% Hispanic/Latino, 13.4% African American, 3.2% Native American, 2.2% Asian, 3.5% identified as "other," and 9.2% did not report ethnicity. The mean number of suicide attempts among the sample was 1.52 (SD = 3.15), with the most recent attempt occurring, on average, within the previous 6.5 months (SD = 9.31 months).

Measures

Suicide. Suicide was assessed with eight questions administered at treatment intake (see Table 1). Seven items assessed for history of suicide thoughts, intent, and attempts in a dichotomous (*yes/no*) manner. In addition, information was obtained about family suicide attempts and completions, also assessed dichotomously. The eight items were the suicidality items from the Beck Depression Inventory-II (BDI-II; Beck, Steer, & Brown, 1996). These eight items were submitted to a principle components analysis to identify observed indicators to represent an overall suicide latent variable.

TABLE 1
Suicide Items Administered at Treatment Intake and Factor Loadings on Latent Variable

Question	Factor Loading
Thoughts of suicide	0.76
Number of attempts	0.10
Time since last suicide attempt	0.48
Beck Depression Inventory item 9	0.16
Family member suicide attempt status	−0.01
Family member died by suicide	−0.08
Suicide attempt with a firearm	0.52
Suicide attempt	0.74

Exercise. Exercise within the past month was indexed by a single item at intake: Over the past month, how often have you engaged in regular activities (e.g., brisk walking, jogging, bicycling) long enough to work up a sweat? Respondents provided answers on a 1 *(Not at all)* to 5 *(everyday)* Likert-type scale. While the assessment of a construct with a single item is not ideal, researchers have used single items to index suicide ideation (e.g., Cukrowicz et al., 2009; Vannoy et al., 2007) and exercise (e.g., Li, Carlson, & Holm, 2000; Rose, Elley, Lawton, & Dowell, 2008) in previous studies. The test-retest reliability and concurrent validity of a single-item measure of physical activity with a high degree of similarity to the question used in the current study was investigated (Milton, Bull, & Bauman, 2011). Specifically, the researchers looked at the item: In the past week/month, on how many days have you performed a total of 30 minutes or more of physical activity which was

enough to raise your breathing rate. This may include sport, exercise, and brisk walking or cycling for recreation or to get to and from places, but should not include housework or physical activity that may be a part of your job. They found that the item had good test-retest reliability (past week $r = 0.72$, past month $r = 0.82$) and moderate positive correlations with well-validated measures of physical activity (past week $r = 0.53$, past month $r = 0.48$).

Sleep Quality. Sleep quality was assessed at intake with the Pittsburgh Sleep Quality Index (PSQI; Buysse, Reynolds, Monk, Berman, & Kupfer, 1989). The PSQI is a 19-item questionnaire that provides an index of global sleep quality within the past month. Questions are structured into two different formats: respondents (1) answer open-ended questions in which responses are coded based on established categories on a 4-point Likert-type scale ranging from 0 *(very good)* to 3 *(very bad)* and (2) answer close-ended questions on a 4-point Likert-type scale ranging from 0 *(very good)* to 3 *(very bad).* Scores are based on calculation of scores across types of responses. The PSQI has good psychometric properties (Buysse et al., 1989). The global score was used as an observed variable in the path model, with higher scores indicating poorer sleep quality.

Depressive Symptoms. Symptoms of depression were measured at intake using the *BDI-II* (Beck et al., 1996).The BDI-II is a 21-item self-report measure of depression symptoms. Responses are summed to yield a total score. For the current study, the suicide question was removed from the total score. Total BDI-II score was used as an observed variable within the path model. The BDI has excellent psychometric properties (Beck et al., 1996).

PTSD Symptoms. Symptoms of PTSD at treatment intake were assessed with the PTSD Checklist–Military Version (PCL-M; Blanchard, Jones-Alexander, Buckley, & Forneris, 1996). The PCL-M includes 17 items that correspond to the 17 *DSM-IV-TR* (American Psychiatric Association, 2000) symptoms of PTSD. To account for conceptual overlap with our measure of sleep quality (PSQI), the sleep item was removed prior to calculation of the total score. Total symptom severity was used as an observed variable within the path model. The PCL has demonstrated excellent psychometric properties (Blanchard et al., 1996).

Procedure

Participants were admitted for PTSD treatment at the residential rehabilitation programs of a VA medical center. This program has a national catchment area and admits clinician-referred military veterans with severe PTSD symptoms that typically have not been successfully ameliorated with outpatient treatment. Criteria for enrollment in the program include: (a) military-related PTSD or postdeployment adjustment difficulties, (b) must not currently have psychotic symptoms and be able to ambulate without nurse assistance, and (c) must be able to remain alcohol and substance (c.f., tobacco and caffeine) free during treatment. All data were obtained from questionnaires and interviews administered during the first week of treatment (treatment intake), administered by program staff. Procedures were approved by the Stanford institutional review board.

Analytic Method

We first examined descriptive statistics and correlations between all variables of interest. Second, a principle components analysis (PCA) was conducted to determine the factor structure for a suicide latent variable. Empirically deriving a suicide latent variable was carried out to compensate for the lack of a formal measure of suicide risk. All questions relating to suicide were entered into a PCA. Questions were retained that yielded a factor loading >.50. Retained observed indicators were then used to create a suicide latent variable. Next, using AMOS 20 software, structural

equation modeling (SEM) was used to construct path models to examine the relation between exercise and suicide risk via three meditational pathways. To test for significant mediation, 2,000 bootstrapping resamples were used. Bootstrapping procedures were necessary for accuracy in computing bias-corrected confidence intervals for mediated associations. In addition, this resampling method corrects for non-normal distributions, improving power and Type I error rates (Hu & Wang, 2010). Finally, in order to test the specific associations of each independent mediator, phantom variables were generated and three additional models were tested each isolating a specific mediator while constraining all other paths to those within the primary model (Macho & Ledermann, 2011). The following indices were used to evaluate the overall model fit: The chi-square goodness of fit test (χ^2), the comparative fit index (CFI; Bentler, 1990), the Tucker-Lewis index (TLI; Tucker & Lewis, 1973), the root-mean-square error of approximation (RMSEA; Browne & Cudeck, 1992), and the standardization root-mean-square residual (SRMR; Bentler, 1995). Consistent with recommendations (Hu & Bentler, 1999), CFI and TLI values >.95 and RMSEA and SRMR values <.06 indicated adequate model fit. The maximum-likelihood estimator (MLE) was used to allow for missing data estimation.

RESULTS

Zero-order correlations were conducted among all continuous variables (Table 2). In the case of dichotomous variables, chi-square analyses were conducted. Results indicated that exercise was significantly different between individuals with, versus without suicide ideation (X^2 = 11.00, p = .02). However, there were no differences in exercise between individuals with and without suicide attempts (X^2 = 2.85, p = .58) or attempts by firearm (X^2 = 14.44, p = .27).

Exploratory Factor Analysis

A PCA was conducted to identify the factor structure of suicide among veterans (Widaman, 1993). Based on criterion of .50 as a salient factor loading (Comrey & Lee, 1992), three observed indicators were retained (thoughts of suicide, suicide attempts, and suicide attempt with a firearm; factor loadings of .68, .81, and .69, respectively). Observed indicators with a factor loading <.50 were removed (see Table 1 for details). The retained indicators combined to represent a single-order factor structure with an eigenvalue of 1.61, accounting for 56.58% of variance. This latent variable was used in all subsequent analyses.

Path Analysis: Overall Model

To estimate the associations between exercise, depressive and PTSD symptoms, and sleep quality in terms of suicide, the following model fitting procedures were used. Suicide was represented by the latent variable described earlier. Exercise, sleep quality, PTSD symptoms, and depressive symptoms were all included within the model as observed indicators. Covariances

TABLE 2
Correlations between Continuous Variables

		M	SD	1	2	3	4
1.	Exercise	2.82	1.48	–	−.21**	−.08	−.11
2.	Sleep quality	13.63	3.43	–	–	.31***	.40***
3.	PTSD symptoms	65.11	11.74	–	–	–	.57***
4.	Depression	30.42	11.37	–	–	–	–

*p < .05; **p < .01; ***p < .001.

among the latent variable and residual error terms were freely estimated.

Analysis of fit indices indicated the model fit the data well: χ^2 (8, N = 346) = 8.55 p = .38, CFI = .99, TLI = .99, RMSEA = .01, SRMR = .01. A depiction of the model as well as the direct parameter estimates are provided in Figure 1. Assessment of total and direct associations yielded the following results. First, a direct association of exercise on suicide risk was observed [direct association = −.18; 90% CI (−.27 to −.08) p = .002]. Second, a total association was observed such that exercise, sleep quality, depressive symptoms, and PTSD symptoms all combined to correlate with suicide risk [total association = −.04; 90% CI (−.34 to −.15) p = .001].

Mediation Models

Phantom variables were used to generate three additional models, which were all constrained to the primary model. Each model isolated a specific mediator (depressive symptoms, PTSD symptoms, sleep quality) in order to test the specific indirect association of each mediator on the outcome.

Depressive Symptoms. The first model tested the role of depressive symptoms as a mediator of the relation between exercise and suicide risk. Results indicated a significant indirect association of depressive symptoms on suicide risk [indirect association = .17; 90% CI (.04–.38) p = .03]. A significant total relation was maintained such that exercise correlated with suicide risk when isolating depressive symptoms within the model [total association = −.53; 90% CI (−.86 to −.07) p = .05]. Results combine to indicate that exercise relates to a decrease in suicide risk through a reduction in depressive symptoms.

PTSD Symptoms. The second model examined the role of PTSD symptoms as a mediator of the relation between exercise and suicide risk. Here, an indirect relation of PTSD symptoms on suicide risk was observed [indirect relation = .11; 90% CI (.01–.50) p = .008]. However, the total relation of the model was not maintained when isolating PTSD symptoms [total relation = −.19; 90% CI (−.76–.003) p = .10]. Results suggest that PTSD symptoms do not mediate the association between exercise and suicide risk.

Sleep Quality. The last model tested the role of sleep quality as a mediator of the relation between exercise and suicide risk. Here, an indirect association of sleep quality on suicide risk was observed [indirect association = .03; 90% CI (.01–.07) p = .006]. Further, a significant total relation was maintained such that exercise correlated with suicide risk when isolating sleep quality within the model [total association = −.77; 90% CI (−.96 to −.25) p = .02]. Results indicate that exercise relates to a decrease in suicide risk through improvements in sleep quality.

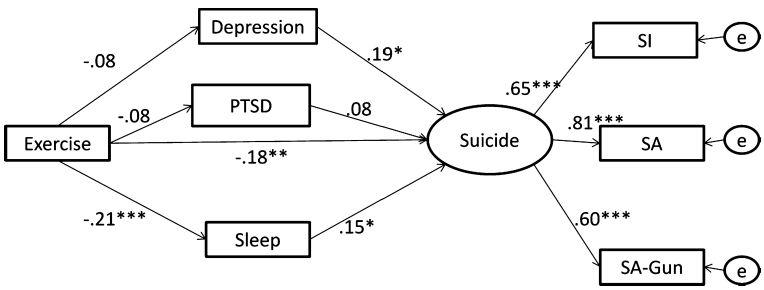

Figure 1. Full structural equation model depicting the path relations (standardized regression weights) between exercise, PTSD, depression, sleep, and suicide. SI, suicide ideation; SA, suicide attempt; SA-Gun, suicide attempt by firearm. *p < .05; **p < .01; ***p < .001.

DISCUSSION

Initial evidence of the potential benefits of exercise in terms of reducing suicide risk. Specifically, exercise had a direct negative association with suicide risk is provided in the current study. Additionally, consistent with hypotheses and previous work, exercise had an indirect relation with suicide risk through its association with depressive symptoms (De Moor et al., 2006; Goodwin, 2003; Mackenzie et al., 2011) and sleep quality (Youngstedt & Kline, 2006). In other words, higher levels of exercise were associated with lower levels of depressive symptoms and higher levels of sleep quality, which were in turn associated with less suicide risk.

Contrary to expectation, however, results indicated that PTSD symptoms did not mediate the relation between exercise and suicide risk. Although there is some support for the relation between exercise and PTSD (Diaz & Motta, 2008; Leard-Mann et al., 2011; Newman & Motta, 2007; Rutter et al., 2011), this research is in a nascent stage. Furthermore, as the literature has suggested that the association between PTSD and suicide may be accounted for by co-occurring depression (Bryan & Corso, 2011; Fordwood, Asarnow, Huizar, & Reise, 2007; Holtzheimer, Russo, Zatzick, Bundy, & Roy-Byrne, 2005; Zlotnick, Mattia, & Zimmerman, 2001), it is possible that accounting for co-occurring mediators in the present analyses may have highlighted a lack of unique association between PTSD and suicide risk. Future work is needed to determine the stability of these associations, particularly given the conflicting evidence regarding the role of depression in the association between PTSD and suicide risk (e.g., Bryan & Corso, 2011; Jakupcak et al., 2009).

This study is the first to our knowledge that establishes a relation (both direct and mediated) between higher levels of exercise and reduced suicide risk. It is important to note that this association was present even in the context of several robust predictors of suicide risk, namely depressive and PTSD symptoms and sleep quality. Although the established associations are an important first step in understanding the impact of exercise on suicide risk, other potential mechanisms warrant investigation. For example, exercise could decrease a sense of perceived burdensomeness (Joiner, 2005) as a person who exercises regularly is likely to see concrete improvements in physical health and mood and gain a sense of self-efficacy in the physical fitness domain. Further, given that many exercise programs include a social component, individuals may experience reductions in thwarted belongingness—another well-supported suicide risk factor (for an excellent review of these constructs, see Van Orden et al., 2010).

While the current study had several important strengths, including a large clinical sample of veterans, relatively high ethnic diversity, strong fit of the hypothesized structural equation model, and novel findings in several areas, it is important to consider the results in light of several limitations. First, the range of PTSD scores was restricted to a fairly severe range. This may have impacted the findings in relation to PTSD and suicide risk and also impacts the ability to generalize the findings of the current study to less severe populations. Second, given that the present sample was composed of a primarily male sample of military veterans, it is unknown if the results would be equally applicable to civilian or predominantly female populations. Third, due to the cross-sectional nature of this study, causal inferences about the relations between variables are not possible, with the testing of mediational relations being less than ideal (Maxwell & Cole, 2007). Future work would benefit from employing a prospective test of the observed associations. Finally, the present study employed self-report as its sole assessment strategy, with a single-item question used to index exercise. Future work would benefit from utilizing multimethod and more rigorous assessment strategies of the

studied variables, such as objective assessments of exercise with verification of behaviors (e.g., Irons, Pope, Vasi, Van Patten, & Jarvis, 2012) and sleep (e.g., polysomnography or actigraphy).

CONCLUSIONS AND FUTURE PROSPECTS

Although the present study has some methodological weaknesses, it also has some important clinical implications. For example, exercise interventions can be deployed in a wide range of settings (e.g., primary care) for those at less acute risk of suicide, thus increasing potential impact on suicide rates. Indeed, Unützer et al. (2002) demonstrated that MDD could successfully be treated in the primary care setting. With regard to suicide, primary care is also an intriguing potential venue for intervention considering a substantial proportion of people who die by suicide have visited their physician in the last month (Luoma, Martin, & Pearson, 2002). Physicians may be more likely to recommend exercise given its many benefits, such as decreasing the risk for coronary heart disease, hypertension, cancer, type II diabetes, obesity, cardiovascular disease, arthritis, osteoporosis, and sexual dysfunction (Penedo & Dahn, 2005). Further, exercise interventions could potentially be used to augment effective interventions for suicide such as CBT-SP and DBT.

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