

# Resting respiratory sinus arrhythmia in suicide attempters

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## Abstract

Although suicide attempts (SA) occur across a broad range of diagnoses as well as in the absence of a diagnosable disorder, most studies to date have focused on them within a single, specific disorder. Consistent with the NIMH RDoC initiative to identify biobehavioral vulnerabilities that cut across diagnoses, the goal of the present study was to examine potential differences in resting respiratory sinus arrhythmia (RSA) levels in a large, diagnostically heterogeneous sample of women with and without a history of SA who were matched on a broad range of demographic and clinical variables. Participants were 112 women with ( $n = 56$ ) and without ( $n = 56$ ) a history of SA recruited from the community. The two groups were equated on approximate age, race, household income, and lifetime histories of psychiatric diagnoses. Resting electrocardiogram was recorded during a 2-min rest period. RSA was calculated via spectral power analyses with a fast Fourier transform. We found that women with a history of SA exhibited significantly lower resting RSA levels than women with no history of SA, and this difference was maintained even after statistically controlling for the potential influence of women's history of psychiatric diagnoses and their current symptoms of depression and anxiety. These findings suggest the presence of a link between resting RSA and SA history.

## KEYWORDS

heart rate variability, respiratory sinus arrhythmia, suicide, transdiagnostic

## 1 | INTRODUCTION

Between 1999 and 2014, there was a 24% increase in suicide rates in the United States, and suicide is now the second leading cause of death for 10- to 34-year-olds (CDC, 2015). However, the field's ability to predict risk for suicide has not improved in the past 50 years (Franklin et al., 2017). This suggests that existing research does not accurately capture the nature of suicide risk and signals the need for studies that overcome conceptual and methodological limitations of past research. Indeed, the sets of the risk factors examined to date and the methods utilized to examine them by most extant studies have been highly narrow and homogenous (Franklin et al., 2017). Thus, diverse methodology and a novel set of risk factors that would overcome the limitations of the

current literature are needed to advance our understanding of suicide risk and to improve its prevention.

One significant limitation of previous research is its predominant focus on examining correlates and predictors of suicidal thoughts and behaviors (STBs) within a single, specific disorder such as major depressive disorder (MDD). This approach is problematic because it fails to consider risk factors that are common across disorders as well as the subset of individuals who engage in STBs in the absence of a diagnosable disorder. Consistent with the NIMH RDoC initiative, movement away from such a segmented approach and toward a transdiagnostic examination of STBs is necessary. Further, in light of recent evidence that a suicide attempt (SA) is an even greater risk factor for later completed suicide than previously thought (Bostwick, Pabbati, Geske, &

McKean, 2016), a key focus should be on factors that are specifically linked with this dangerous behavior. Indeed, because individuals are often unable or unwilling to report their suicide-related intentions, identifying objective factors that are related to SA across diagnoses is an important step in improving the field's ability to identify those most at risk.

One potentially important factor is emotion (dys)regulation, which is highlighted in leading theories of suicide. For example, according to Baumeister's escape theory of suicide (1990), a desire to die by suicide is a consequence of perceiving the current aversive emotional state as uncontrollable, coupled with a perceived inability to generate adaptive coping strategies. Thus, suicide is viewed as a way of escaping these undesirable negative feelings. Similarly, according to William's (1997) cry of pain model, individuals begin to consider suicide as an option due to the failure to generate more adaptive solutions to their circumstances that are perceived as emotionally intolerable. Linehan's (1993) model of emotion (dys)regulation also posits that emotion regulation difficulties constitute a core precipitant of self-harming thoughts and behaviors. Further, it has been suggested that emotion (dys)regulation is linked with suicidal ideation because of the increased feelings of perceived burdensomeness and thwarted belongingness experienced by emotionally dysregulated individuals (for a review, see Law, Khazem, & Anestis, 2015). According to the prominent interpersonal theory of suicide (Joiner, 2005), perceived burdensomeness and thwarted belongingness increase the likelihood of experiencing suicidal desire. In addition, emotion (dys)regulation may drive individuals to engage in a number of painful and/or provocative experiences, which might in turn increase their acquired capability for suicide (for a review, see Law et al., 2015). Finally, according to the three-step suicidal process model, impaired regulation of emotional responses constitutes one of the three general deficits implicated in suicidal acts (Jollant, Lawrence, Olié, Guillaume, & Courtet, 2011).

Consistent with these theories, there is evidence that self-reported emotion regulation difficulties are associated with a history of SA. For example, studies demonstrate higher levels of nonacceptance of emotions (Rajappa, Gallagher, & Miranda, 2012), higher perceived inability to access (Miranda, Tsypes, Gallagher, & Rajappa, 2013; Rajappa et al., 2012) and utilize (Forkmann et al., 2014) adaptive emotion regulation strategies, and lack of emotional clarity (Pisani et al., 2013) in suicide attempters. There is also evidence that the emotion regulation difficulties observed in individuals with STBs might stem from deficits in executive functioning. Indeed, there is a clear link between broad executive functioning deficits (i.e., inhibition, shifting, updating, and fluency) and suicidality (Bredemeister & Miller, 2015). In addition, meta-analytic findings suggest that vulnerability to STBs stems from the interaction between value-based/

motivational/reward-learning processes and cognitive control processes (Richard-Devantoy, Berlim, & Jollant, 2014). However, despite the strengths of previous research examining emotion (dys)regulation in individuals with STBs, most of these studies have relied on self-report assessments of emotion (dys)regulation, which may be prone to response and recall bias.

Given this, researchers have begun to focus on more objective indices of emotion regulation deficits. Respiratory sinus arrhythmia (RSA), which is often indexed by heart rate variability (HRV), is a noninvasive measure of parasympathetic influences on heart rate during inhalation versus exhalation (Allen, Chambers, & Towers, 2007; Porges, 2007) and has been proposed as a transdiagnostic biomarker of emotion (dys)regulation (for reviews, see Beauchaine, 2015; Beauchaine & Thayer, 2015). Supporting this hypothesis, there is evidence that low resting RSA is associated with the presence of various forms of internalizing and externalizing disorders (Beauchaine, 2015; Beauchaine & Thayer, 2015). RSA levels are also positively correlated with prefrontal cortex activity in neuroimaging paradigms and with performance on executive function tasks (for a review, see Beauchaine & Thayer, 2015), reflecting its influence on cognitive control capacity. Importantly, there is also preliminary evidence for the link between RSA/HRV and STBs. For example, several studies found that adults with suicidal ideation exhibited lower resting RSA (Rottenberg, Wilhelm, Gross, & Gotlib, 2002) and HRV (Chang et al., 2013; Forkmann et al., 2016) than nonsuicidal controls. Another study found that adolescent girls with parasuicidal behaviors (with unknown suicide intent) exhibited lower resting RSA than girls with no history of STBs (Crowell et al., 2005).

Despite the strengths of these studies, however, a number of important questions remain. First, because most individuals who think about suicide do not actually make a SA (e.g., Fergusson, Beautrais, & Horwood, 2003), the identification of factors that are specifically linked with SA has been highlighted as a critical area of inquiry for suicidology research (Klonsky & May, 2013). Consequently, it is important to determine whether these resting RSA findings generalize to individuals' histories of SA. To this end, only one published study of which we are aware has reported resting RSA/HRV in suicide attempters (Wilson et al., 2016). This study focused on women with a lifetime history of major depressive disorder with and without a history of SA. The researchers found that, although the attempters had a marginally lower resting HRV than nonattempters, this difference was not statistically significant ( $p = .09$ ). That said, the sample size in this study was relatively small ( $n = 35$ ), and there was a small to medium effect size difference between groups ( $r_{effect\ size} = .20$ ; Wilson et al., 2016), suggesting that additional research is warranted. A third limitation of previous research is that, although SAs

**TABLE 1** Sample characteristics

Measure	SA history ( <i>n</i> = 56)	No SA history ( <i>n</i> = 56)	<i>r</i> effect size
<b>Demographics</b>			
Age	35.48 (5.44)	34.96 (6.28)	.04
Race (% Caucasian)	41 (73.2%)	43 (76.8%)	-.06
Household income (median)	20,001–25,000	20,001–25,000	.00
<b>Diagnoses</b>			
Lifetime MDD	36 (64.3%)	38 (67.9%)	-.04
Lifetime any anxiety disorder	24 (42.9%)	16 (28.6%)	.14
Lifetime anorexia or bulimia	2 (3.6%)	2 (3.6%)	.00
Lifetime alcohol use disorder	24 (42.9%)	18 (32.1%)	.25
Lifetime substance use disorder	21 (37.5%)	12 (21.4%)	.18
<b>Symptoms</b>			
BDI-II	10.18 (9.13)	8.18 (8.75)	.11
BAI	6.57 (7.52)	4.31 (4.93)	.15

Note. SA = suicide attempt; MDD = major depressive disorder; BDI = Beck Depression Inventory; BAI = Beck Anxiety Inventory.

occur across a broad range of diagnoses as well as in the absence of a diagnosable disorder, most previous studies examining resting RSA/HRV in relation to STBs have focused on individuals with a mood disorder diagnosis (e.g., Chang et al., 2013; Rottenberg et al., 2002; Wilson et al., 2016). This may limit the generalizability of the findings as it is not clear whether similar results would be observed in a more heterogeneous sample of suicide attempters.

Therefore, seeking to both replicate and extend previous research, the goal of the present study was to examine potential differences in resting RSA levels in a large, diagnostically heterogeneous sample of women with and without a history of SA matched on a broad range of demographic and clinical variables. We chose to focus specifically on women for a number of reasons. First, suicide attempts are more common in women. Second, there is evidence that the correlates and characteristics of female versus male suicide attempters may differ (for a review, see Hawton, 2000), so our focus on women reduces the potential heterogeneity of the sample. Third, our focus on women is consistent with the only published study to date to examine resting RSA levels in suicide attempters (Wilson et al., 2016), which also focused on women, and thus allows for an easier comparison between the two studies. We predicted that women with a history of SA would exhibit lower resting RSA levels than nonattempters. We also hypothesized that this difference would be maintained even after statistically controlling for the potential influence of women's history of psychiatric diagnoses and their current depressive or anxious symptoms, thus further strengthening our confidence in the transdiagnostic specificity of the findings to SA history. Finally, given evidence for potentially important differences between those

with a history of one versus multiple suicide attempts (e.g., Esposito, Spirito, Boergers, & Donaldson, 2003; Miranda et al., 2008), we conducted exploratory analyses to determine whether these groups differed in RSA.

## 2 | METHOD

### 2.1 | Participants

Participants in this study were 112 women recruited from the community, 56 with a history of SA and 56 with no such history. The two groups were equated on (a) approximate age, (b) race, (c) household income, (d) lifetime history of MDD, (e) lifetime history of any anxiety disorder, (f) lifetime history of eating disorders (anorexia or bulimia), (g) lifetime history of alcohol use disorder, and (h) lifetime history of substance use disorder. The average age of the participants was 35.22 years ( $SD = 5.86$ ). In terms of race, 75.9% of the women were Caucasian, 20.5% were African American, 1.8% were biracial, and the remainder were from other racial/ethnic groups. The demographic and clinical characteristics of the SA and no SA groups are presented in Table 1.

### 2.2 | Measures

#### 2.2.1 | Suicide attempt history

As part of the assessment, interviewers assessed for the presence of a lifetime SA in women by asking the following question: "A suicide attempt is defined as intentionally hurting yourself with at least some wish to die *at that time*. How many times have you attempted suicide in your life?"

Responses were probed to determine the presence/absence of a lifetime history of SA. The SA group included all women who endorsed a history of at least one prior SA. In our sample, 43 women reported a history of a single SA, and 13 women reported a history of multiple SAs.

## 2.2.2 | Resting electrocardiogram (ECG) RSA data recording and processing

Participants engaged in a 2-min rest period during which they watched a nature video featuring landscape scenes from Olympic National Park. Although not as long as that employed in some research (e.g., 4 or 5 min; Mezulis, Crystal, Ahles, & Crowell, 2015; Wilson et al., 2016), the Task Force of the European Society of Cardiology and the North American Society of Pacing Electrophysiology (Camm et al., 1996) guidelines suggest that only 1 min of recorded data is needed to assess the high frequency components of heart rate variability, which was the focus of this study. During the rest period, ECG data were obtained using a Biopac BioNomadix wireless system and recorded with Acqknowledge v4.2 software. ECG was recorded via a standard three-electrode (Lead II) setup and sampled at 1,000 Hz. Biopac EL503 disposable electrodes that incorporate liquid electrolyte gel and moderately high chloride salt concentration were used in this study. MindWare HRV 3.0.12 was used to inspect, transform, and analyze the ECG signal. ECG data were visually inspected for artifacts (e.g., temporary loss of signal, large movements, or an unusual R-R interval), and artifacts were corrected manually. For example, if one R peak was missing, an R peak was inserted at a time point halfway in between the two neighboring R peaks. Consistent with previous research (Woody, Feurer, Sosoo, Hastings, & Gibb, 2016), epochs with more than 10% artifacts (i.e., 10% of R waves estimated within an epoch) were excluded, and participants with more than 50% of epochs excluded were counted as missing. To calculate RSA, spectral power analyses were performed with a fast Fourier transform. Consistent with Task Force recommendations (Camm et al., 1996), RSA was defined as power density in the .12–.40 Hz frequency band and was calculated by averaging across the 30-s epochs.

## 2.2.3 | Diagnoses and symptoms

The Structured Clinical Interview for DSM-IV Axis I Disorders (SCID-I; First, Spitzer, Gibbon, & Williams, 1995) was used to assess for current and past DSM-IV MDD and anxiety disorders. In our matched sample, 74 women met criteria for MDD history (36 in SA group), 23 met criteria for post-traumatic stress disorder (14 in SA group), 18 met criteria for social anxiety disorder (10 in SA group), 2 met criteria for generalized anxiety disorder (1 in SA group), 2 met

criteria for obsessive compulsive disorder (1 in SA group), 4 met criteria for anorexia or bulimia (2 in SA group), 42 met criteria for alcohol use disorder (24 in SA group), and 33 met criteria for substance use disorder (21 in SA group). To assess interrater reliability, 20 SCID interviews from this project were coded by a second interviewer, and kappa coefficients for diagnoses of MDD and anxiety disorders were good (all  $\kappa \geq .86$ ). In addition, symptoms of depression and anxiety were assessed using the Beck Depression Inventory-II (BDI-II; Beck, Steer, & Brown, 1996) and the Beck Anxiety Inventory (BAI; Beck & Steer, 1993). Both questionnaires exhibited good internal consistency in this sample (BDI-II:  $\alpha = .92$ ; BAI:  $\alpha = .89$ ).

## 2.3 | Data analytic plan

Our primary hypothesis was that women with a history of suicide attempt would exhibit lower resting RSA levels than nonattempters. To test this hypothesis, we first conducted a univariate ANOVA with SA history (yes/no) serving as the independent variable and resting RSA serving as the dependent variable. Second, although, as noted above, the two groups were matched on a number of key demographic and clinical variables, we conducted a series of additional analyses to examine the robustness and specificity of our findings. Specifically, we tested whether resting RSA difference would be maintained even after statistically controlling for the potential influence of women's history of psychiatric diagnoses and their current depressive and anxious symptoms by conducting two separate analyses of covariance (ANCOVAs) with (a) women's history of psychiatric diagnoses (i.e., MDD, any anxiety disorder, anorexia or bulimia, alcohol use disorder, and substance use disorder), and (b) their current depressive and anxious symptoms entered as covariates. Finally, exploratory analyses were conducted to examine potential differences between women with a history of one versus multiple SAs.

## 3 | RESULTS

With regard to our primary hypothesis, we found significant group differences in resting RSA,  $F(1, 110) = 5.12, p = .03, \eta_p^2 = .04$ , with suicide attempters exhibiting significantly lower resting RSA ( $M = 6.28, SD = 1.34$ ) than those without a history of SA ( $M = 6.81, SD = 1.16$ ). This group difference in resting RSA was maintained when we statistically controlled for the influence of women's lifetime history of psychiatric diagnoses,  $F(1, 105) = 4.02, p = .048, \eta_p^2 = .04$ , suggesting that the group difference was not due to their psychiatric diagnosis history. This group difference in resting RSA was also maintained when we statistically controlled for the influence of women's current symptoms of

depression and anxiety,  $F(1, 108) = 4.49, p = .04, \eta_p^2 = .04$ , suggesting that the group difference was not due to current symptom levels. We should also note that our findings were maintained when we statistically controlled for the influence of women's age, income, and race/ethnicity,  $F(1, 107) = 5.09, p = .03, \eta_p^2 = .05$ . Finally, although multiple suicide attempters ( $M = 6.19, SD = 1.75$ ) had slightly lower levels of resting RSA than single attempters ( $M = 6.30, SD = 1.21$ ), this difference was not statistically significant,  $F(1, 54) = 0.07, p = .80, \eta_p^2 = .001$ .

## 4 | DISCUSSION

The goal of this study was to examine potential differences in resting RSA levels between women with and without a history of SA. Importantly, because SAs occur across a broad range of diagnoses as well as in the absence of a diagnosable disorder, we examined this question in a diagnostically heterogeneous sample. We found that women with a history of SA exhibited significantly lower resting RSA levels than women with no such history. These findings are consistent with the only published study to date to report resting RSA levels in suicide attempters, which found lower, although only marginally significant, levels of resting RSA in women with a history of SA and a major depressive disorder, compared to women with a history of major depressive disorder but no history of SA (Wilson et al., 2016). Finally, we sought to examine potential differences in resting RSA levels in women with single versus multiple SA history. In these exploratory analyses, the difference between SA groups was nonsignificant with a very small effect size ( $\eta_p^2 = .001$ ), suggesting that lower levels of resting RSA may be a broad correlate of SA history that does not allow for a differentiation between those with a history of multiple attempts versus only one lifetime SA. Although the current results are consistent with the hypothesis that low resting RSA may be a marker of suicide risk, no causal conclusions can be drawn given the cross-sectional design of the study. Additional research is needed to determine whether RSA prospectively predicts risk for a first SA or risk for reattempting.

The current study had a number of strengths and constitutes an important addition to suicide research and prevention literature. Specifically, consistent with recent recommendations for moving the field of suicide research forward (Franklin et al., 2017), we focused on a relatively novel, theory-based characteristic—resting RSA. In addition, rather than focusing on SA within a single diagnostic group, we focused on a larger, more heterogeneous sample of women with and without SA history, matched on a broad range of demographic and clinical variables. Importantly, the current results also suggest that the link between reduced

RSA levels and SA history is at least partially independent of women's history of psychiatric diagnoses and their current symptoms. In addition, they are in line with the NIMH RDoC initiative to identify biobehavioral vulnerabilities that cut across diagnoses, which also has implications for suicide research and prevention. Further, the current results complement existing research using self-report measures of emotion regulation (e.g., Forkmann et al., 2014; Miranda et al., 2013; Pisani et al., 2013; Rajappa et al., 2012) by showing that individuals with a history of SA also exhibit lower levels of a physiological marker of emotion regulation and cognitive control. This is consistent with the theories highlighting the difficulties in emotion regulation (e.g., Baumeister, 1990; Joiner, 2005; Jollant et al., 2011; Linehan, 1993; Williams, 1997) and cognitive control (e.g., Richard-Devantoy et al., 2014) among individuals with STBs.

Despite these strengths, there were also some limitations that provide directions for future research. First, as noted above, the study was cross-sectional; therefore, longitudinal studies are needed to establish potential validity of resting RSA in the prediction of future suicide risk. Indeed, in the absence of such longitudinal studies, no conclusions can be made about the temporal precedence of resting RSA and SAs. In addition, because our sample focused only on women, it will be important for future studies to examine whether our findings also generalize to men. Further, because suicide attempt history was assessed via a single interview question, future research is needed to examine whether specific SA characteristics, such as its recency, severity, and level of planning, may be associated with resting RSA levels among those with a history of SA. Finally, although statistically significant, the effect size in our study was still relatively small ( $\eta_p^2 = .04$ ) and similar in size to that observed by Wilson et al. (2016). However, whereas replications and longitudinal studies are needed, our findings suggest that lower resting RSA levels may constitute an additional factor to consider in the evaluation of suicide risk. Pending these future studies, in light of the recently discussed limitations of the past 50 years of suicide research (Franklin et al., 2017), which include a predominant focus on homogenous risk factors examined in isolation, RSA levels in combination with other factors might be used in machine learning algorithms that analyze the complex relations between multiple variables to more accurately predict suicide risk (i.e., Franklin et al., 2017).

In sum, the present study is the first to show that women with a history of SA exhibit lower levels of resting RSA than women with no history of SA and that this relation is at least partially independent of current or past depression and anxiety. Although no causal conclusions can be drawn from the current results, they support the utility of future longitudinal research examining whether resting RSA levels can be used

to identify those at increased risk for SA. Ideally, RSA could be used as part of a panel of risk markers that could provide actionable information regarding short-term risk, so that interventions can be targeted to those at greatest risk.

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