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Association between suicidal thoughts and behaviours and markers of autonomic functioning and regulation in adults: A systematic review and meta-analysis

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ABSTRACT

Currently, the identification of individuals experiencing suicidal thoughts and behaviours (STBs) rely predominantly on self-report. Previous research on children and young people highlighted an association between difficulties in arousal regulation (reflected, for example, in reduced heart rate variability and altered electrodermal activity patterns) and STBs, but this has not been meta-analytically explored in adults. This systematic review and meta-analysis aimed to quantify the association between STBs and markers of autonomic functioning/regulation in adults. Based on a pre-registered protocol (PROSPERO CRD42024596886), we searched PubMed/MEDLINE, Embase, PsycINFO and Web of Science until 2nd August 2025 for empirical studies assessing the association between measures of autonomic functioning and/or regulation and STBs in adults. Quality of cross-sectional and cohort studies was assessed through the Newcastle-Ottawa Scale. Pooled effect sizes (Hedge's g) were estimated with random-effects meta-analytic models in R. Out of 2726 articles screened, 40 studies were included in the systematic review, and 22 in the meta-analyses (6290 individuals, 28% with STBs). We found reduced heart rate variability in adults with STBs ($g = -0.2469$, $p = 0.0069$) but no significant associations between electrodermal activity patterns and STBs ($g = -0.2563$, $p = 0.3953$). Our results highlight the relationship between reduced cardiac regulation and STBs, providing a rationale for further exploration of cardiac regulation as a potential objective marker for assessing and monitoring STBs in adults. Further research is warranted to understand how these markers can be used in clinical practice to assess and support the management of suicide risk in adults.

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1. Introduction

Suicide represents a major global public health problem, accounting for more than 720,000 deaths worldwide each year (UN News, 2025). Beyond suicide deaths, a substantially larger number of individuals experience suicidal thoughts and behaviours (STBs), an umbrella term that encompasses suicidal ideation (SI), suicide attempt (SA), and death by suicide (Klonsky, 2007). STBs occur across diagnostic categories – including but not limited to mood, anxiety, personality, and neurodevelopmental disorders (Large, 2018) – but can also manifest in individuals without a formal psychiatric diagnosis or with subthreshold symptoms (O'Connor, 2021).

Extensive research has identified a wide range of factors associated with STBs (see Franklin et al. 2017, for a comprehensive review). Consistent with the *stress-diathesis* model of suicide, STBs are thought to emerge from interactions between psychiatric vulnerability and environmental stressors, which are likely to increase vulnerability to STB beyond the presence of psychiatric disorders alone (van Heeringen and Mann, 2014). Indeed, empirical evidence indicates that a substantial proportion of vulnerability to STBs is attributable to genetic factors (DiBlasi et al., 2021) but exposure to adverse childhood experiences (Baldini et al., 2025) and stressful or negative life events (Liu and Miller, 2014) further increases STB risk across the lifespan. Meta-analytic findings also demonstrate that prior STBs are the strongest predictors of subsequent suicidal ideation, suicide attempts, and death, alongside hopelessness, affective and anxiety disorders, histories of abuse, non-suicidal self-injury, and indicators of clinical severity such as personality disorder diagnoses and prior psychiatric hospitalisation (Bostwick et al., 2016; Turecki et al., 2019). At the same time, contextual factors including socio-economic disadvantage and exposure to acute stressors also contribute meaningfully to STBs. Despite this extensive literature, accurately predicting and preventing STBs in clinical practice remains a critical challenge, reflecting the complex interplay between genetic, biological, psychological, clinical, social, and environmental factors that underlie STB vulnerability (Turecki et al., 2019).

One biological system that has received increasing attention in suicide research is the autonomic nervous system (ANS). The ANS plays a central role in regulating physiological arousal and adaptation to environmental demands (Kang et al., 2020; Sarchiapone et al., 2018). It is a key component of the peripheral nervous system and is responsible for regulating involuntary physiological processes such as heart rate, respiration, gastrointestinal activity, thermoregulation, and pupillary responses (Karemaker, 2017). Within the context of suicide research, peripheral markers of ANS functioning can be collected non-invasively and in naturalistic settings, allowing, at least in principle, the monitoring of short-term changes in stress and arousal regulation. These fluctuations may be especially informative during periods of heightened vulnerability to STBs.

The ANS is comprised of three main branches: the sympathetic nervous system (SNS), the parasympathetic nervous system (PNS), and the enteric nervous system (which independently regulates digestion and nutrient absorption but is also influenced by and influences SNS and PNS activity). The SNS, which originates primarily in the thoracolumbar spinal cord and uses norepinephrine as its main postsynaptic neurotransmitter, supports physiological mobilization and arousal (e.g., increased heart rate and energy expenditure). In contrast, the PNS arises from cranial and sacral regions and relies mainly on acetylcholine; through the *vagus* nerve, it exerts inhibitory control over the heart and promotes recovery and energy conservation. These peripheral branches are coordinated by a central autonomic network that includes the hypothalamus, brainstem nuclei, limbic regions, and prefrontal cortical areas such as the anterior cingulate cortex (Quadt et al., 2022). The locus coeruleus–norepinephrine system plays a key role within this network by modulating arousal, attention, and cognitive processing through its widespread connections with cortical and subcortical regions (Aston-Jones and Cohen, 2005).

In humans, ANS functioning is measured indirectly using peripheral physiological markers. Sympathetic activity is commonly indexed using electrodermal activity (EDA) (Wijsman et al., 2011), which reflects changes in the electrical conductance of the skin caused by sweat gland activity, exclusively under sympathetic control. Increases in EDA therefore indicate heightened arousal and are often observed in response to emotionally salient or cognitively demanding stimuli. In contrast, parasympathetic regulation is most frequently assessed through cardiac measures. While heart rate is often considered a relatively non-specific marker of arousal and stress states, heart rate variability (HRV) – the variation in time intervals between successive heartbeats – reflects autonomic regulation of the heart and is continuously modulated by respiration, baroreflex mechanisms, and top-down influences from the central autonomic network, representing an index of vagally mediated parasympathetic control (Gullett et al., 2023). Adaptive regulation of arousal and stress responses relies on the dynamic balance and context-appropriate coordination of the SNS and the PNS, particularly during exposure to stress. Nevertheless, many theoretical frameworks (Beauchaine and Thayer, 2015; Thayer and Lane, 2000, 2009) propose that arousal and emotion regulation are primarily achieved through increased parasympathetic activity, as the sympathetic system predominantly supports activation and reactive mobilization (Ulrich-Lai and Herman, 2009).

A substantial body of research has demonstrated alterations in ANS functioning and regulation (indexed by markers of reduced parasympathetic activation, such as lower HRV, or reduced sympathetic activation, such as reduced electrodermal reactivity in response to stressful or cognitively demanding stimuli) in a wide range of psychiatric conditions, including anxiety disorders, mood disorders, and trauma-related disorders (Alvares et al., 2016), and neurodevelopmental conditions, including Attention-Deficit/Hyperactivity Disorder (ADHD) (Bellato et al., 2020; Bellato, Wiersema, et al., 2023), autism (Arora et al., 2021; Cheng et al., 2020), and conduct problems (Fanti et al., 2019). Previous studies conducted in children and young people have also demonstrated transdiagnostic associations between reduced ANS regulation (particularly, reduced HRV) and clinically assessed emotional dysregulation (Bellato et al., 2024). Reduced parasympathetic regulation has been also linked to heightened emotional reactivity and reduced cognitive flexibility, all of which are transdiagnostic vulnerabilities for psychopathology (Shaffer and Ginsberg, 2017).

In the context of STBs, dysregulation of ANS activity may contribute to increase vulnerability by undermining the individual's capacity to regulate emotional and cognitive responses to stress, either via an excessive sympathetic response or blunted parasympathetic inhibitory regulation. Specifically, chronic *hyper-arousal* may increase susceptibility to intense negative affect, cognitive inflexibility, and maladaptive coping and emotion regulation, especially in response to stress; processes that are central to the transition from suicidal ideation to suicidal behaviour (O'Connor et al., 2021; O'Connor, 2021). Notably, a recent meta-analysis focusing on children and adolescents found evidence for an association between self-injurious thoughts and behaviours, and ANS dysregulation (Bellato et al., 2023). Out of 16 studies included in the meta-analysis, 10 reported data on cardiac measures, and seven reported data on electrodermal activity measures. Overall, the study found evidence of an association between reduced parasympathetically-mediated HRV measures and increased self-injurious thoughts and behaviours (small-to-medium effect). Such association was not detected for sympathetically mediated cardiac measures, such as pre-ejection period, or electrodermal activity measures.

However, the extent to which these findings generalise to adults remains unclear. While individual studies in adult samples suggest that altered ANS functioning – particularly reduced parasympathetic regulation – may be associated with suicidal ideation and behaviour (Chang et al., 2013; Song et al., 2011), no systematic review or meta-analysis has yet synthesised this evidence. This gap is particularly important given that ANS dysregulation may manifest differently across the lifespan and that adult studies more frequently focus on STBs than non-suicidal self-harm. To our knowledge, this is the first systematic review and meta-analysis examining the association between markers of ANS functioning and regulation (including HRV and EDA) and STBs in adults. Based on prior theoretical models and empirical findings, we hypothesised that reduced autonomic regulation (particularly, reduced parasympathetic activity indexed by HRV) would be associated with greater severity of STBs in adults.

2. Materials and methods

We followed the most updated Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (see PRISMA Checklist in Appendix S1) (Page et al., 2021). The study was pre-registered on PROSPERO (CRD42024596886) on 2nd October 2024.

2.1. Search strategy and study selection criteria

The search strategy (Appendix S2) included terms associated with the following semantic domains: (a) markers of ANS regulation and functioning (e.g., HRV, skin conductance), and (b) suicide, self-harm, and self-injurious behaviours. We searched PubMed, Embase, MEDLINE, PsycINFO and Web of Science databases for peer-reviewed journal articles published until 2nd August 2025 and meeting the following inclusion criteria (based on a PECO framework), without any restrictions on language or document type:

- **P**articipants: Adults aged 18 years and above.
- **E**xposure: Presence of STBs determined through clinical interviews or psychometric assessments.
- **C**omparator: Absence of STBs.
- **O**utcomes: Markers of autonomic functioning/regulation (such as HRV, pupillometry, or electrodermal activity).

We therefore included cross-sectional and cohort studies that assessed – in participants aged 18 years or above – at least one measure of ANS functioning/regulation in relation to STBs, measured through clinical interviews or validated psychometric tools. We excluded studies not including adult participants, where the presence of STBs was not determined through clinical interviews or psychometric assessments, and those not reporting on any outcome of interest (i.e., not measuring any markers of autonomic functioning/regulation, or associations between such markers and STBs). We also excluded not-peer-reviewed articles (e.g., conference abstracts, dissertations), non-empirical studies (e.g., editorials, letters to the editors, narrative reviews), those for which the full-text could not be retrieved, and those where STBs were not analysed in relation to any measures of autonomic functioning/regulation. Lastly, we excluded systematic or narrative reviews, but we searched the reference lists of the relevant ones to identify any additional studies that met inclusion criteria but might not have been identified by our search.

2.2. Data selection and extraction

The titles and abstracts of retrieved studies were independently screened by two authors (FC and CS) using Covidence (https://www.covidence.org/). Potentially eligible studies underwent full-text screening by the same authors. The senior author (AB) resolved any disagreements between reviewers. Cohen's kappa (inter-rater reliability) was 0.64 for title-abstract screening and 0.71 for full-text screening, indicating substantial agreement between raters. Data extraction was primarily conducted by FC and cross-checked by CS for accuracy. For each study, we extracted information regarding publication details, study design, sample characteristics (age, sex distribution, source of recruitment, and race/ethnicity distribution), outcome measures (STB measurement or assessment and ANS functioning/regulation measurement and methods, including the condition during which physiological data was collected). We also extracted any statistical results referring to the association between STBs, as applicable. Where data were not reported in the original publication, or when we could not determine final eligibility based on the information provided in the manuscript, we contacted the first and/or corresponding author via email and requested a response within a two-week timeframe. If no reply was received, we sent two further consecutive reminders at two-week intervals.

2.3. Data analysis and synthesis

Data were synthesised and presented narratively, for all studies, and via meta-analyses for studies reporting the following data: (a) mean and standard deviation (SD) or mean and standard error (SE) for ANS-related outcome measures in participants with and without STBs, or *t*-test results for group comparison, (b) correlation or regression coefficients examining the association between STB severity or scores (from validated psychometric tools or measurements) and measures of ANS functioning.

Effect size calculations and meta-analyses were conducted in R version 4.4.2 (R Core Team, 2022). The R package *esc* (Lüdecke, 2019) was used to calculate Hedge's g from retrieved data. Pooled effect sizes were estimated using random-effects meta-analytic models (using the Restricted Maximum Likelihood estimator, REML) via the package *metafor* (Viechtbauer, 2010). Study heterogeneity was assessed using Cochran's Q test (to test whether observed variability in effect sizes exceeded what would be expected by chance) and I^2 (which quantifies the proportion of total variability attributable to true heterogeneity rather than random error). Publication bias was evaluated visually with funnel plots (for meta-analyses including fewer than 10 studies) and – when more than 10 studies were included in a meta-analysis – quantitatively using the rank correlations test for funnel plot asymmetry (Begg and Mazumdar, 1994). To assess the impact of individual studies on the pooled estimates and to address observed heterogeneity, we conducted systematic outlier detection and influence diagnostics. First, studentized residuals were calculated for each effect size; values exceeding 1.96 were flagged as potential outliers. Second, we performed a leave-one-out sensitivity analysis; the multivariate models were re-estimated N times, with one unique effect size excluded in each iteration. This allowed us to evaluate the stability of the pooled effect sizes and identify any single study that disproportionately influenced the overall results or the degree of heterogeneity.

Based on the included articles, we conducted two separate meta-analyses, one focused on cardiac measures and one addressing on electrodermal measures. Subgroup analyses were also planned to examine whether meta-analytic results differed between studies reporting data collected during different experimental conditions (passive resting-state vs. active tasks), between studies reporting on individuals with different STBs (suicidal ideation/thoughts vs. attempts), and between studies using different markers of autonomic functioning. However, we could only conduct such analyses for cardiac measures, since the meta-analysis on electrodermal measures included less than 10 studies. In the first meta-analysis (cardiac measures), we included studies reporting on cardiac markers of autonomic functioning/regulation, including low- and high-frequency HRV (LF-HRV and HF-HRV), Root Mean Square of Successive Differences (RMSSD), and respiratory sinus arrhythmia (RSA). For the meta-analysis of electrodermal measures, skin conductance levels (SCL), skin conductance responses (SCR) and habituation rates (HabR) were included. More information about these measures can be found in Table 1.

Table 1
Summary of ANS functioning/regulation measures included in the meta-analyses.

ANS measure	Description
Cardiac measures	
HRV	HRV is a measure of the variability in heart rate. During resting-state, the parasympathetic branch of the ANS – through the *vagus* nerve – is the main contributor to HRV (Shaffer and Ginsberg, 2017). In this state, HRV increases, reflecting more variability in time between consecutive heartbeats. This indicates a relaxed and adaptable system that can respond to different physiological demands, which additionally correlates with lower stress levels (Beauchaine and Thayer, 2015). On the other hand, when the sympathetic branch is dominant (e.g., during activity and in stressful situations), HRV temporarily decreases, leading to less variability between consecutive heartbeats.
LF- and HF-HRV	LF- and HF-HRV represent different frequency components of HRV. HF-HRV primarily reflects parasympathetic activity and is associated with rapid fluctuations in heart rate, within the frequency range of 0.15–0.40 Hz. On the other hand, LF-HRV reflects both parasympathetic and sympathetic activity, as well as baroreceptor activity, with a typical frequency range of 0.04–0.15 Hz. RMSSD is a time-domain measure that reflects short-term variations between consecutive heartbeats, specifically how much the inter-beat interval changes over a short period and serves as an indicator of parasympathetic activity.
RSA	RSA refers to the variation in heart rate that occurs during breathing, a phenomenon that is primarily governed by the parasympathetic nervous system. During inspiration, the heart rate increases, which enhances the blood flow through the lungs and gas exchange. Conversely, during exhalation, when gas exchange becomes less crucial, the heart rate slows down.
Electrodermal measures	
EDA	Electrodermal activity (EDA) reflect changes in the skin's electrical conductivity in response to stimuli such as excitement and stress, which are linked to sweat gland activity (Posada-Quintero and Chon, 2020). As the sympathetic branch of the ANS controls sweat gland activity during emotional or physiological arousal, EDA can serve as a key indicator of sympathetic functioning. When an individual experiences heightened arousal, the sympathetic nervous system is activated, leading to increased sweat production, which in turn increases skin conductance.
SCL	SCL represents the baseline level of skin conductance over time, indicating the overall activation of the SNS during a resting or baseline state.
SCR	SCR refers to the temporary change in skin conductance that occurs in response to a particular stimulus.
HabR	HabR is the rate at which the skin conductance response reduces after repeated exposure to the same stimulus.

2.4. Study quality assessment

The quality of cross-sectional and cohort studies was assessed by FC (cross-checked by CS for accuracy) using the Newcastle-Ottawa Scale (Wells et al., 2014). The NOS is a tool used for assessing the quality of non-randomised studies, including cross-sectional and cohort-design studies. It evaluates three key components of studies: the assessment of outcomes (for cohort studies) or exposure (for case-control studies), the group selection process, and the comparability of groups. For each study, stars are assigned to each criterion, with greater totals reflecting higher quality.

3. Results

3.1. Characteristics of studies included in the systematic review

The initial search retrieved 4112 records, of which 1386 were duplicates. Following initial screening of 2726 references (based on title/abstract), 2605 references were excluded. After the full-text screening of 113 articles (8 could not be retrieved, because they were not found online or via the University of Southampton library, nor after contacting the first/corresponding author), 41 articles (40 unique studies) met the inclusion criteria and were included in the systematic review, with 23 articles providing relevant data to be included in the meta-analyses (22 unique studies, 6290 individuals, 28% with STBs). The PRISMA flowchart can be found in Fig. 1, specific reasons for exclusion for each article excluded at full-text stage are available in Appendix S3. Detailed information about each study included in the systematic review can be found in Table 2.

Most studies (73%) examined STBs in the context of specific clinical conditions, including mood disorders (n = 24; depression = 19, anxiety = 2, unspecified = 3), unspecified mental disorders (n = 4), and bipolar disorder (n = 1). Nineteen studies were on suicidal ideation, ten on suicide attempts, seven on both suicidal ideation and suicide attempts, two on suicide risk, one on completed suicide, one on self-injurious thoughts and behaviours (also including non-suicidal self-harm). Twenty-four studies (60%) reported on cardiac measures, 15 on electrodermal measures (37%), and one on both. Most studies (73%) only reported data on autonomic measures recorded during baseline/resting-state conditions, with 22% of studies reporting task-related autonomic measures and two (5%) reporting both. Among the studies included in the meta-analysis, 13 (57%) were rated as good quality and ten (43%) as fair quality, with no study being rated as poor quality (Appendix S4; Tables S1 and S2).

3.2. Cardiac measures

Seventeen studies reporting data on cardiac measures were included in the meta-analysis (22 effect sizes, 5102 participants, 27% with STBs). The measures investigated in the meta-analysis included HF-HRV (eight effect sizes), RSA (seven effect sizes), RMSSD (five effect sizes), unspecified HRV (two effect sizes), all cardiac markers of parasympathetic regulation. We found statistically significantly reduced cardiac markers of parasympathetic regulation in those with STBs (Hedge's $g = -0.2488$, $SE = 0.0955$, 95% CI = [-0.4473; -0.0503], $t = -2.6062$, $p = 0.0165$; Fig. 2; Appendix S5, Table S3). We detected statistically significant heterogeneity ($Q = 64.6382$, $p < .0001$; $I^2 = 82.44$) but not publication bias (Kendall's tau = -0.0521, $p = 0.7350$; Fig. S1). The subgroup analyses revealed that the negative association between cardiac markers of arousal regulation and STBs did not significantly differ between studies reporting on baseline/resting-state measures and task-based measures ($F_{1,20} = 0.0281$, $p = 0.8687$). To note, amongst the two studies reporting task-based measures, one measured HF-HRV during a cognitive stressful task (Chesin et al., 2020) and the other measured RMSSD during the Trier Social Stress Test (Moukaddam et al., 2023). We also did not find any differences in pooled effect size between studies reporting on different STBs (ideation/thoughts vs. attempt; $F_{1,18} = 0.0972$, $p = 0.7587$) nor different measures of HRV (frequency vs. temporal; $F_{1,18} = 3.1280$, $p = 0.0939$).

Seven studies were included in the narrative synthesis, since data retrieved were insufficient for calculating effect sizes. Meerwijk and Weiss (2016) and Smith et al. (2020) did not find any statistically significant associations between cardiac measures and STBs; however, these two studies used uncommon measures of HRV, namely low-frequency HRV (and not high-frequency) and the Standard Deviation of RR intervals (SDRR), respectively, and reported some issues with statistical power and small samples (35 and 27 participants, respectively). Similarly, Rechlin et al. (1994) found no significant differences in various HRV metrics between individuals with recent suicide attempts and controls (32 participants in total). Jang et al. (2018) found no significant differences in HRV frequency measures between adults with and without suicidal ideation (however, the sample was quite unique, consisting of bereaved family members after a ferry disaster in South Korea without a formal mental health diagnoses). Czyz et al. (2023) recruited 102 young adults with recent suicidal ideation and/or suicide attempt from emergency departments and found that RMSSD did not predict next-day suicidal ideation. Garland et al. (2017) investigated LF/HF ratio (measured during a dot probe task) in relation to suicidal ideation in 115 adults with chronic pain on long term opioid therapy and found

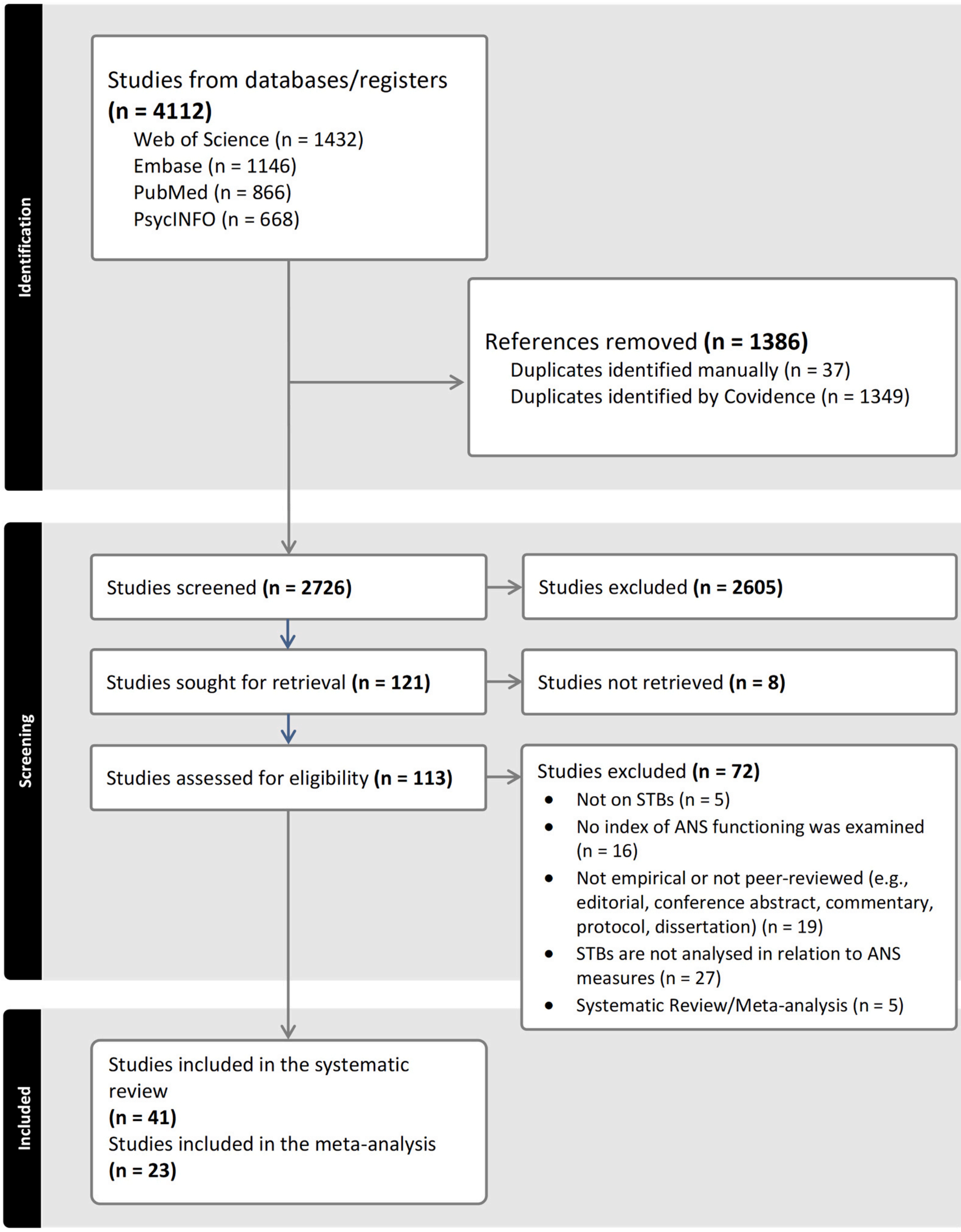

Fig. 1. PRISMA flowchart.

that people with more frequent suicidal thoughts had a stronger stress response (reflected in higher sympathetic activation) to opioid-related cues. Lastly, Rüesch et al. (2023) found lower RMSSD in psychiatric adult inpatients who attempted suicide compared to healthy controls, in line with the main results of our meta-analysis.

3.3. Electrodermal measures

Five studies reporting data on electrodermal measures were included in the meta-analysis (13 effect sizes, 309 participants, 67% with STBs). We found no statistically significant associations between electrodermal activity measures and STBs (Hedge's $g = -0.2563$, $SE = 0.2907$, 95% CI [-0.8897; 0.3771], $t = -0.8816$, $p = 0.3953$; Fig. 3; Appendix S6, Table S4). Statistically significant heterogeneity was detected ($Q = 37.5004$, $p = 0.0002$; $I^2 = 76.55$), but there was not clear evidence of publication bias when analysing funnel plot asymmetry (Fig. S2).

Most studies using EDA measures (11 out of 16) could only be included in the narrative synthesis, since we could not calculate effect sizes for these (quantitative results were not presented in the article and authors were not able to provide such data, or did not reply to our requests). When analysed descriptively, we did observe heterogenous results, in line with our meta-analysis. For example, both Carli et al. (2021) and Thorell et al. (2013) found – in large samples of adults with depression (599 and 783, respectively) – lower EDA in those who were suicidal compared to non-suicidal control groups. Similarly, Smith et al. (2020) found lower electrodermal reactivity (SCRs) associated with more severe suicidal ideation in adults with depression and mild-moderate suicide ideation, while Wolfersdorf et al. found that

Table 2
Summary of studies investigating autonomic functioning in relation to STBs in adults.

First author, year	Study design	Sample characteristics	Race/Ethnicity	STB domain	Autonomic measure	Experimental task/activity	Included in Meta-analysis	Summary of findings
Adolph et al. (2018)	Case-control	85 Psychiatric adult outpatients with mental health disorders. STB group (SI+): n = 44 (Mean age: 38.8 years; 67.1% F); Control group (SI-): n = 41 (Mean age and %F not reported); Source of recruitment: Outpatient University Clinic (Bochum, Germany)	100% White	Suicidal ideation	Cardiac: HF	Baseline/ Resting-state, Sadness-inducing film clip	Cardiac	Reduced HRV reactivity between baseline and a sad film was significantly associated with increased suicidal ideation.
Booij et al. (2006)	Case-control	19 Remitted depressed adults. STB group (History of SI): n = 8 (Mean age: 47.5 years; 62.5% F); Control group (No history of SI): n = 11 (Mean age: 41.2 years; 54.5% F); Source of recruitment: Mood disorder clinic	Not reported	Suicidal ideation	Cardiac: HF	Baseline/ Resting-state	Cardiac	No significant differences were found on HF-HRV between remitted depressed adult with a history of suicidal ideation compared to those without suicidal ideation history.
Carli et al. (2021)	Cohort	599 Psychiatric patients with depression. Clinical Group (Baseline Suicide Attempts): n = 509; (Mean age: 47.32 years; 27.11% M); Clinical group 2 (suicide attempt follow-up): n = 82 (Mean age: 44.93 years; 36.58% M); Clinical group 3 (completed suicide): n = 8 (Mean age: 56.1 years; 62.5% M); Source of recruitment: 5 psychiatric clinics across 9 European countries	Not reported	Suicide attempt	Electrodermal: EDA	Electrodermal Orienting Reactivity (EDOR) Test	No	EDA hypo-reactivity was associated with suicide first attempts and follow-up attempts, but did not predict completed suicide, in adults with depression.
Chang et al. (2012); (Chang et al., 2013)	Case-control	960 Adults with MD and controls. STB group (MD, SI+): n = 261 (Mean age: 42.34 years; 48.7% F); Control group 1 (HC): n = 462 (Mean age: 40.66 years; 48.5% F); Control group 2 (SI-): n = 237 (Mean age: 35.59 years; 51.5% F); Source of recruitment: Outpatient psychiatry, Tri-Service General Hospital, Taipei, Taiwan (STB group); Community, Taipei, Taiwan (control group)	100% (Han Chinese) Asian	Suicidal ideation	Cardiac: HF	Baseline/ Resting-state	Cardiac	HF-HRV was significantly lower in participants with depression and suicidal ideation compared to both healthy controls and adults with depression without suicidal ideation.
Chang et al. (2017)	Case-control	119 Depressed adults. STB group (SI+): n = 58 (Mean age: 32.41 years; 39.70% F); Control group (SI-): n = 61 (Mean age: 31.90 years; 39.30% F); Source of recruitment: Psychiatric Outpatient Clinic at the Tri-Service General Hospital in Taipei, Taiwan	Not reported	Suicidal ideation	Cardiac: HRV	Baseline/ Resting-state	Cardiac	No significant differences in resting HRV parameters between adults with depression with current suicidal ideation and those without.
Chesin et al. (2020)	Case-control	81 Adult college students. STB group (current SI): n = 9 (Mean age: 20 years; 72% F); Control group (no current SI): n = 72 (Mean age: 20 years; 72% F); Source of	38% White; 17% Black; 42% Hispanic; 3% Other	Suicidal ideation	Cardiac: HF	Stressful laboratory task (Stroop Task and Cyberball)	Cardiac	College students with current suicidal ideation showed a smaller decrease in HF-HRV during stress, indicating reduced arousal regulation,

(continued on next page)

Table 2 (*continued*)

First author, year	Study design	Sample characteristics	Race/Ethnicity	STB domain	Autonomic measure	Experimental task/activity	Included in Meta-analysis	Summary of findings
		recruitment: College campus						compared to those without current suicidal ideation.
Czyz et al. (2023)	Cohort	102 Young Adults. Clinical sample (SI): n = 102 (Mean age: 20.9 years; 81.4% F); Source of recruitment: Emergency department with recent suicidal ideation and/or suicide attempt	74.5% White; 5.9% Asian; 4.9% Black; 8.8% More than one race; 2.0% American Indian; 1.0% Unknown; 2.9% Other	Suicidal ideation	Cardiac: RMSSD	Baseline/ Resting-state	No	RMSSD did not predict next-day suicidal ideation in young adults with increased STBs.
Duprey et al. (2019)	Cohort	163 Emerging adults of low-socioeconomic status. Community sample: n = 163 (Mean age: 21.17 years; 55.8% F); Source of recruitment: From the community via online advertisements, word-of-mouth, flyers, and through paid community recruiters selected	57.7% White; 33.1% Black; 5.5% Hispanic; 3.7% Other	Suicidal ideation	Cardiac: HRV	Baseline/ Resting-state	Cardiac	No direct association between suicidal ideation and resting-state HRV.
Edman et al. (1986)	Case-control	67 Adults. Clinical group 1 (Suicidal ideation): n = 11 (Mean age: 40.0 years; 36% F); Clinical group 2 (Nonviolent attempts): n = 16 (Mean age: 41.9 years; 75% F); Clinical group 3 (Violent attempts): n = 8 (Mean age: 41.4 years; 63% F); Control group (healthy controls): n = 32 (Mean age: 40.3 years; 59% F); Source of recruitment: Emergency psychiatric admissions, Karolinska Hospital, Stockholm, Sweden (clinical group); Hospital staff, relatives, friends, and blood donors (control group)	Not reported	Suicidal ideation/ Suicide attempt	Electrodermal: SCR	Auditory habituation task	No	Adults with STBs were more likely to exhibit fast SCR habituation (hypo-arousal) compared to those without STBs.
Forkmann et al. (2016)	Cohort	37 Young Adults. Community sample (SI): n = 37 (Mean age: 24.5 years; 73.0% F); Source of recruitment: Student volunteers	Not reported	Suicidal ideation	Cardiac: RMSSD	Baseline/ Resting-state	Cardiac	Lower RMSSD was not associated with higher suicidal ideation in young adults.
Garland et al. (2017)	Cohort	115 Adults with chronic pain on long term opioid therapy. Clinical sample: n = 115 (Mean age: 48.3 years; 67.8% F); Source of recruitment: Primary care clinics, pain clinics, and neurology clinics in Tallahassee, Florida, through posted flyers and online ads	Not reported	Suicidal ideation	Cardiac: LF/HF ratio	Dot probe task	No	Adults with chronic pain with more frequent suicidal thoughts had stronger stress responses (higher sympathetic activation) to opioid-related cues, shown by their LF/HF ratio.
Jandl et al. (2010)	Case-control	50 Adults with MDD. STB group 1 (Hard Attempted Suicide-HAS): n = 16 (Mean age: 47.3 years; 56.25% F); STB group 2 (Soft Attempted Suicide-SAS): n = 16 (Mean age: 49.8 years; 68.75% F); Control group (Non-Attempted Suicide-NAS): n = 18 (Mean age: 47.9 years; 66.67% F); Source of recruitment:	Not reported	Suicide attempt	Electrodermal: HabR	Habituation Paradigm, Oddball task	Electrodermal	Adults with depression who attempted suicide showed faster electrodermal habituation (hypo-arousal) than non-attempters.

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Table 2 (*continued*)

First author, year	Study design	Sample characteristics	Race/Ethnicity	STB domain	Autonomic measure	Experimental task/activity	Included in Meta-analysis	Summary of findings
		Psychiatric wards of University Hospital of Ulm, Germany						
Jang et al. (2018)	Case-control	83 Bereaved family members after the Sewol ferry disaster. Clinical group (current SI): n = 33 (Mean age: 45.88 years; 60.61% F); Control group (no current SI): n = 50 (Mean age: 44.20 years; 60% F); Source of recruitment: Bereaved family members of victims from the Sewol ferry disaster	Not reported	Suicidal ideation	Cardiac: HRV	Baseline/ Resting-state	No	No significant differences on HRV between bereaved adults with current suicidal ideation and those without
Keller et al. (1991)	Case-control	54 Adults (inpatients) with depressive disorder. Clinical group (Suicidal thoughts and suicide attempts): n = 36 (Mean age and %F not reported); Control group (Nonsuicidal): n = 18 (Mean age and %F not reported); Source of recruitment: Inpatients at Weissenau Psychiatric Hospital	Not reported	Suicidal ideation/ Suicide attempt	Electrodermal: SCL, SCR	Baseline/ Resting-state	No	No significant differences in SCL or and SCRs in adults with depression and STBs, compared to non-suicidal adults.
Khandoker et al. (2017)	Case-control	61 Adults with MDD and controls. STB group (MDD, SI+): n = 16 (Mean age: 37.50 years; 68.75% F); Control group 1 (MDD,SI-): n = 16 (Mean age: 32.31 years; 81.25% F); Control group 2 (HC): n = 29 (Mean age: 28.00 years; 58.63% F); Source of recruitment: Outpatient clinic at the American Center for Psychiatry and Neurology in Abu Dhabi	Not reported	Suicidal ideation	Cardiac: HF	Baseline/ Resting-state	Cardiac	Resting-state HF-HRV was reduced in adults with depression and suicidal ideation, compared to those with depression but with no suicidal ideation
Kleiman et al. (2021)	Case-control	25 Psychiatric inpatients admitted for severe STBs. Clinical group (STBs): n = 25 (Mean age: 33.48 years; 56% F); Source of recruitment: Psychiatric inpatients at psychiatry service, Massachusetts General Hospital	64% White; 20% Asian; 8% Black; 8% Other	Suicidal ideation	Electrodermal: EDA	Baseline/ Resting-state	No	Higher EDA was linked to more severe suicidal thoughts in adults with STBs; however, EDA was more accurate for predicting current rather than future suicidal thoughts.
Kopp (1989)	Case-control	57 Adults with anxiety. Clinical group (Generalised anxiety with SI): n = 28 (Mean age: 36.6 years; 75% F); Control group (healthy controls): n = 29 (Mean age and % F not reported); Source of recruitment: Not reported	Not reported	Suicidal ideation	Electrodermal: EDA	Baseline/ Resting-state	No	Adults with generalised anxiety and suicidal ideation exhibited significantly higher nonspecific EDA on the dominant hand at rest compared to healthy controls.
Lee et al. (2021)	Case-control	1461 Adults who exhibited a range of emotional/psychiatric symptoms. STB group (High suicide risk): n = 229 (Mean age: 42.05 years; 63.2% F); Control group (No suicide risk): n = 1232 (Mean age: 42.05 years; 63.2% F); Source of recruitment:	Not reported	Suicide risk	Cardiac: RMSSD	Baseline/ Resting-state	Cardiac	Lower RMSSD was linked to higher suicide risk in a large cohort of adults with a range of emotional and/or psychiatric symptoms.

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Table 2 (*continued*)

First author, year	Study design	Sample characteristics	Race/Ethnicity	STB domain	Autonomic measure	Experimental task/activity	Included in Meta-analysis	Summary of findings
		Outpatient psychiatric clinic at an academic tertiary hospital						
Lin et al. (2015)	Cohort	49 Psychiatric inpatients with mood disorders. STB group (History of suicide attempt): n = 49 (Mean age: 36.00 years; 100% F); Source of recruitment: Female adults admitted to the psychiatric ward of Mackay Memorial Hospital, Taipei, Taiwan	Not reported	Suicidal ideation	Cardiac: RSA	Baseline/ Resting-state	Cardiac	Higher RSA was associated with greater suicidal ideation in women with mood disorders.
Lin et al. (2019)	Cohort	32 Pregnant women with STBs: n = 32 (Mean age: 29 years; 100% F); Source of recruitment: Obstetric and gynaecology clinics affiliated with the University of Utah and community outreach efforts	54% White; 9% Asian; < 4% Black; 33% Other (including multiracial and other ethnic identities)	STBs	Cardiac: RSA	Baseline/ Resting-state	Cardiac	Lower baseline RSA was associated with higher risk of antenatal STBs in pregnant women.
Meerwijk and Weiss (2016)	Case-control	35 Adults with history of depression. Clinical group (Suicidal desire): n = 11 (Mean age: 34.18 years; 72.73% F); Control group (No suicidal desire): n = 24 (Mean age: 35.42 years; 79.17% F); Source of recruitment: Psychiatric outpatient services and online ads in the San Francisco Bay Area	Clinical group: 36.36% White; 9.09% African American; 18.18% Hispanic; 18.18% Asian; 18.18% Other; Control group: 54.17% White; 8.33% African American; 8.33% Hispanic; 12.50% Asian; 16.67% Other	Suicidal ideation	Cardiac: LF	Baseline/ Resting-state	No	Adults with depression and recent suicidal desire had lower HRV during periods of heightened psychological pain, indicating autonomic nervous system dysregulation, compared with a control group of adults with depression but no STBs.
Moukaddam et al. (2023)	Case-control	31 Adults with mood disorders. STB group 1 (Low suicidality): n = 11 (Mean age: 27.3 years; 56% F); STB group 2 (Moderate-severe suicidality): n = 13 (Mean age: 27.3 years; 56% F); Control group (No suicidality): n = 7 (Mean age: 27.3 years; 56% F); Source of recruitment: Baylor College of Medicine and Harris Health Systems	Not reported	Suicidal ideation/ Suicide attempt	Cardiac: RMSSD	Trier Social Stress Test (TSST)	Cardiac	Higher RMSSD was found in adults with mood disorders and low/severe suicidality, compared to those with mood disorders but no suicidality.
Neacsiu et al. (2018)	Case-control	95 Adults with MDD and controls. Clinical group (MDD + SA): n = 27 (Mean age: 38.93 years; 70.4% F); Control group 1 (MDD-noSA): n = 24 (Mean age: 40.83 years; 50.0% F); Control group 2 (Healthy controls): n = 44 (Mean age: 30.14 years; 65.9% F) Source of recruitment: outpatient/ inpatient clinics and the community in a southeastern urban area using flyers and online ads.	Clinical group: 50% White; 36.2% Black; Control group: 45.8% White; 25% Black	Suicidal ideation	Electrodermal: GSR	Computerized Paced Auditory Serial Addition Task (PASAT-C)	No	Adults with depression and a history of suicide attempts showed increased galvanic skin response during stress, and slower recovery to baseline compared to non-suicidal clinical controls and healthy controls.
Ortiz et al. (2021, 2024)	Case-control	53 Adults with bipolar disorder. STB group (history of suicide attempt): n = 11 (Mean age: 44.7 years; 66% F); Control group (non-SA): n = 42 (Mean age and %F	90% White; 4% Hispanic; 4% Asian; 2% Black	Suicide attempt	Cardiac: RMSSD	Baseline/ Resting-state	Cardiac	Lower RMSSD was found in individuals with bipolar disorder and a history of suicide attempts, indicating reduced

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First author, year	Study design	Sample characteristics	Race/Ethnicity	STB domain	Autonomic measure	Experimental task/activity	Included in Meta-analysis	Summary of findings
		not reported); Source of recruitment: Outpatients from Centre for Addiction and Mental Health (Toronto, Canada) and Royal Ottawa Hospital (Ottawa, Canada)						parasympathetic activity.
Pruneti et al. (2023)	Cohort	53 Adults with mixed anxiety depressive disorder. STB group (Suicidal ideation): n = 53 (Mean age: 27.34 years; 71.7% F); Source of recruitment: Outpatient clinic of the Clinical Psychology, Clinical Psychophysiology, and Clinical Neuropsychology Laboratories of the University of Parma	Not reported	Suicidal ideation	Electrodermal: SCL	Baseline/ Resting-state, Stress Task	Electrodermal	Higher SCL and stress-induced EDA responses were found in adults with anxiety/ depression and more severe STBs.
Rechlin et al. (1994)	Case-control	32 Adults with reactive depression and healthy controls. Clinical group (Suicide Attempters - Reactive Depression): n = 16 (Mean age: 29 years; 62.5% F); Control group: n = 16 (Mean age: 29 years; 62.5% F); Source of recruitment: clinical settings	Not reported	Suicide attempt	Cardiac: HRV	Baseline/ Resting-state	No	No significant differences in HRV were observed between suicide attempters with depression and controls.
Rottenberg et al. (2002)	Cohort	55 Depressed adults. STB group (MDD with SI): n = 55 (Mean age: 33.2 years; 73% F); Source of recruitment: Outpatient psychiatry clinics at a university hospital and self-referred community participants	Not reported	Suicidal ideation/ Suicide attempt	Cardiac: RSA	Baseline/ Resting-state	Cardiac	Higher RSA was significantly associated with lower suicidality symptoms in adults with depression.
Rüesch et al. (2023)	Case-control	92 adults with psychiatric diagnoses. Clinical Group (Suicide Attempters): n = 49 (Mean age: 34.6 years; 50.0% F); Control group (healthy controls): n = 43 (Mean age: 34.1 years; 58.0% F); Source of recruitment: Inpatients and outpatients from Psychiatric University Hospital Zurich, Switzerland (clinical group); Recruited via online advertisements (control group)	Not reported	Suicide attempt	Cardiac: RMSSD	Baseline/ Resting-state	No	RMSSD was significantly lower in psychiatric inpatients who attempted suicide compared to healthy controls.
Smith et al. (2020)	Case-control	27 Adults with MDD and healthy controls. Clinical group (MDD with mild-moderate suicide ideation): n = 11 (Mean age: 43.5 years; 36.4% M); Control group (healthy controls): n = 16 (Mean age: 42.4 years, 31.3% M); Source of recruitment: Wicklow Mental Health Service (clinical group) and graduate students/ hospital staff (control group)	Not reported	Suicidal ideation	Electrodermal/ Cardiac: SCR, SDRR	Baseline/ Resting-state	No	There were no significant associations between HRV and suicidal ideation in adults with MDD. However, lower SCR was associated with higher suicidal ideation.
Thorell (1987)	Case-control	84 Adults with depression and controls. STB group	Not reported	Suicidal ideation/	Electrodermal: SCL	Baseline/ Resting-state	Electrodermal	Suicidal adults with depression showed

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First author, year	Study design	Sample characteristics	Race/Ethnicity	STB domain	Autonomic measure	Experimental task/activity	Included in Meta-analysis	Summary of findings
		(Suicidal): n = 25 (Mean age: 41.0 years; 52% F); Control group 1 (Matched HC): n = 25 (Mean age: 41 years; 50% F); Control group (Non-suicidal): n = 34 (Mean age: 42.8 years; 55.8% F); Source of recruitment: Inpatients and outpatients treated for depressive disorder		Suicide attempt				reduced electrodermal responsiveness compared to those without depression (either healthy controls or non-suicidal adults with depression).
Thorell and d'Elia (1988)	Case-control	14 Depressive adults. STB group (Suicide attempters- depressive): n = 7 (Mean age: 42.5 years; 50% F); Control group (Matched HC): n = 7 (Mean age and %F not reported); Source of recruitment: Psychiatric outpatient department, University Hospital, Linköping, Sweden (STB group); Staff of University Hospital, Linköping, Sweden (control group)	Not reported	Suicide attempt	Electrodermal: SCL	Baseline/ Resting-state	Electrodermal	Suicide attempters with depression had lower SCL than the non-suicide-attemper group.
Thorell et al. (2013)	Case-control	783 Depressed adults. Clinical group (suicides or violent suicide attempts): n = 120; Control group (Non-Suicidal): n = 663 (Mean age: 42.9 years; 59% F). Source of recruitment: Depression Ward, Centre for Psychiatry, Weissenau, Germany.	Not reported	Suicide risk	Electrodermal: HabR	Stimulus-based electrodermal testing	No	Suicidal adults with depression showed lower electrodermal activity (reduced SCR habituation) compared to non-suicidal adults.
Tsypes et al. (2018)	Case-control	112 Women recruited from the community. Community group (SA history): n = 56 (Mean age: 35.48 years; 100% F); Control group (No SA history): n = 56 (Mean age: 34.96 years; 100% F); Community-based recruitment	STB group: 73.2% White. Control group: 76.8% White	Suicide attempt	Cardiac: RSA	Baseline/ Resting-state	Cardiac	Women with a history of suicide attempts had significantly lower RSA than non-attempters.
Wang et al. (2021)	Case-control	55 College students. STB group 1 (SA): n = 13 (Mean age: 18.84 years; 53.85% F); STB group 2 (SI): n = 23 (Mean age: 20.13 years; 30.43% F); Control group (HC): n = 19 (Mean age: 20.84 years; 52.63% F); College students from University in Tianjin, China, as part of questionnaire study	Not reported	Suicidal ideation/ Suicide attempt	Electrodermal: SCR	Iowa Gambling Task	Electrodermal	There were no significant differences in anticipatory SCRs among college students who attempted suicide and those who did not attempt.
Wiebenga et al. (2022)	Case-control	1749 Adults with depressive and/or anxiety disorder. STB group 1(SI-SA+): n = 195 (Mean age: 43.1 years; 69.7% F); STB group 2(SI+SA-): n = 230 (Mean age: 40.8 years; 59.6% F); STB group 3 (SI+SA+): n = 93 (Mean age: 40.2 years; 69.9% F); Control group (SI-SA-): n = 1231 (Mean age: 41.2 years; 68.4% F); Source of recruitment: Community, primary care, and	Not reported	Suicidal ideation/ Suicide attempt	Cardiac: RSA	Baseline/ Resting-state	Cardiac	There were no significant associations between RSA and suicidal ideation/ suicide attempts amongst adults with depressive and/or anxiety disorders.

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First author, year	Study design	Sample characteristics	Race/Ethnicity	STB domain	Autonomic measure	Experimental task/activity	Included in Meta-analysis	Summary of findings
		specialised mental health care across the Netherlands						
Wilson et al. (2016)	Case-control	35 Females with MDD. STB group (SA): n = 13 (Mean age: 34.1 years; 100% F); Control group (non-attempters): n = 22 (Mean age: 31.2 years; 100% F); Source of recruitment: Female participants recruited from studies at the New York State Psychiatric Institute (NYSPI)	STB group: 61% White; 23% Black; 15% Hispanic; 0% Asian; Control group: 59% White; 23% Black; 14% Hispanic; 5% Asian	Suicide attempt	Cardiac: HF	Baseline/ Resting-state	Cardiac	Suicide attempters with MDD had lower baseline HF-HRV than non-attempters.
Wolfersdorf and Straub (1994)	Case-control	60 Depressive adults. Clinical group 1 (Violent suicide attempt males): n = 11 (Mean age: 45 years; 100% M); Control group 1 (Non-suicidal males): n = 11 (Mean age: 45 years; 100% M); Clinical group 2 (Non-violent suicide attempt males): n = 17 (Mean age: 45 Years; 100% M); Control group 2 (Non-suicidal males): n = 17 (Mean age: 45 years; 100% M); Clinical group 3 (Suicide-violent method, male and female): n = 19 (Mean age: 45 Years; 42% F); Control group 3 (Non-suicidal male and female): n = 19 (Mean age: 45 years; 42% F); Source of recruitment: Inpatient psychiatric treatment at the Weissenau State Mental Hospital, Department of Psychiatry at the University of Ulm, Germany	Not reported	Suicide attempt	Electrodermal: HabR	Baseline/ Resting-state	No	Individuals with violent suicidal behaviours showed significantly faster skin conductance habituation (hypo-arousal) compared to non-suicidal controls, suggesting hypo-arousal. However, non-violent suicide attempters showed no significant differences in habituation compared to non-suicidal controls.
Wolfersdorf et al. (1996)	Case-control	57 Psychiatric inpatients (females). Clinical group (SA): n = 35 (Mean age: Not reported; 100% F); Control group (Schizophrenic without SA): n = 22 (Mean age: Not reported; 100% F); Source of recruitment: Weissenau Psychiatric Hospital's Laboratory for Clinical Psychophysiology	Not reported	Suicide attempt	Electrodermal: SCL	Baseline/ Resting-state	No	Adults with schizophrenia who attempted suicide had lower SCL compared to those who did not attempt. On the other side, depressed adults who attempted suicide had higher SCL than non-suicidal adults with depression.
Wolfersdorf et al. (1999)	Case-control	60 Depressed psychiatric inpatients. Clinical group (committed suicide): n = 30 (Mean age: 43.8 years; 57% F); Control group (non-suicidal): n = 30 (Mean age: 44.2 years; 57% F); Source of recruitment: Inpatients at the Depression Ward of the Centre for Psychiatry Weissenau, Germany	Not reported	Suicide	Electrodermal: SCL	Baseline/ Resting-state	No	Lower SCL was found in adult inpatients with depression who committed suicide, compared to the non-suicidal group.

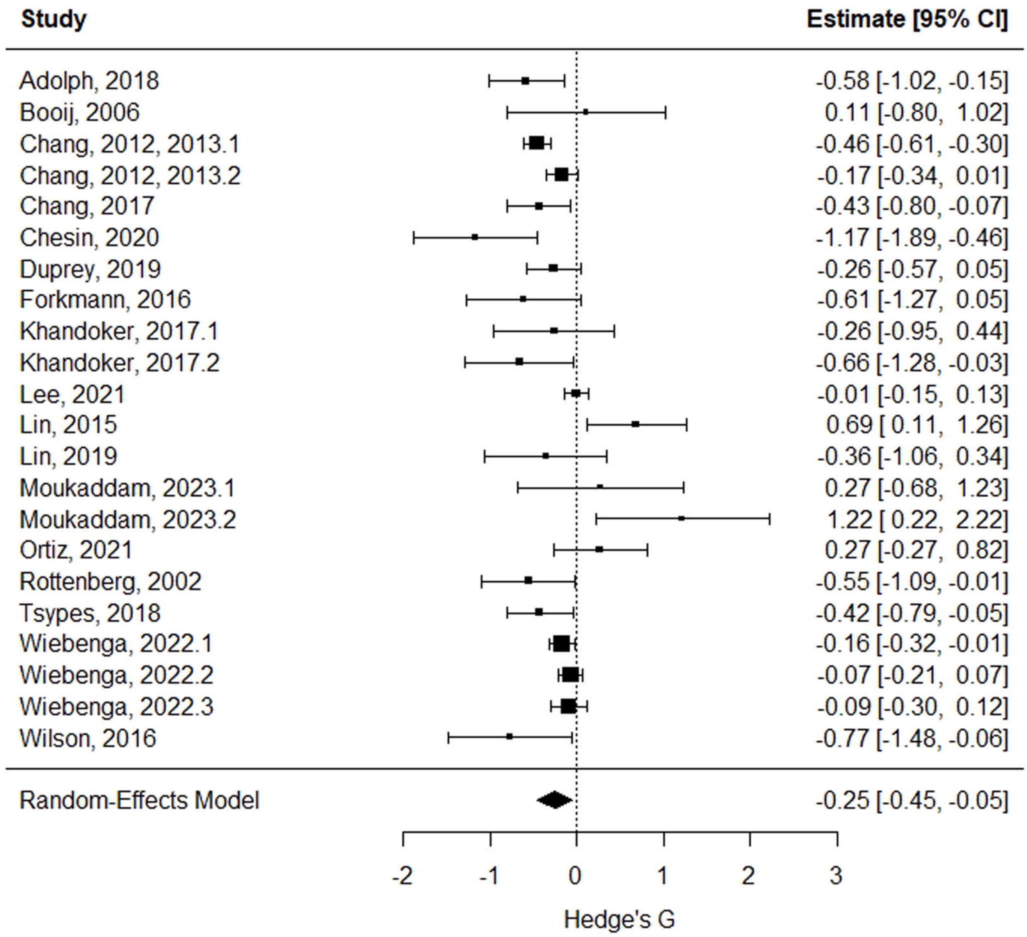

Fig. 2. Forest plot of effect sizes for studies investigating cardiac measures. CI, confidence interval; RE, random effect.

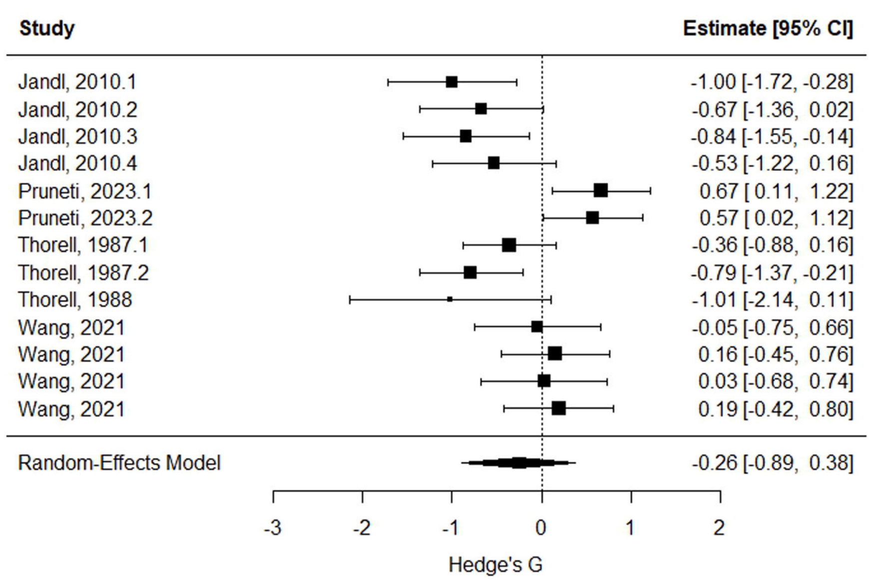

Fig. 3. Forest plot of effect sizes for studies investigating electrodermal activity/reactivity. CI, confidence interval; RE, random effect.

depressed adults who completed suicide (Wolfersdorf et al., 1999), adults with schizophrenia (Wolfersdorf et al., 1996) and with depression (Wolfersdorf and Straub, 1994) who attempted suicide had lower SCL or faster habituation (i.e., reduction in SCR to consecutively presented stimuli) compared to those without STBs. Conversely, other studies found an opposite association between EDA and STBs, namely increased EDA in adults with STBs. For example, Kleiman et al. (2021) reported that increased EDA levels were associated with more severe suicidal thoughts and behaviours in 25 psychiatric inpatients admitted for severe STBs. Kopp (1989) – in adults with generalised anxiety disorder – found higher levels of suicidal ideation being associated with greater EDA at rest. Neacsiu et al. (2018) found increased SCRs during a computerised task, and slower recovery to baseline, in adults with. Lastly, Edman et al. (1986) and Keller et al. (1991) found no significant differences in electrodermal patterns between adults with and without STBs. Taken together, our narrative and meta-analytic findings do not seem to clarify the association (if any) between STBs and EDA patterns.

4. Discussion

4.1. Overview of main findings

This is the first systematic review and meta-analysis investigating the association between autonomic functioning/regulation and STBs in adults. Overall, by analysing data from 22 unique studies (6290 individuals, 28% with STBs), we found a significant association between increased STBs and reduced cardiac autonomic regulation, with a small effect size. Specifically, cardiac markers of parasympathetics regulation (HRV measures and RSA) were reduced in adults with increased STBs. This association was not moderated by the type of experimental condition during which ANS markers were collected, nor by the type of STBs experienced by the participants (suicidal ideation/thoughts vs. suicide attempt). Conversely, our meta-analysis of studies on electrodermal measures did not support a clear association between EDA and STBs, although the narrative synthesis suggested a potentially complex and varying relationship, which may warrant further investigation. These findings build on prior research linking mental distress and psychopathology with altered cardiac markers of ANS functioning and regulation (Beauchaine and Thayer, 2015). Notably, this work also aligns with our previous meta-analysis (Bellato et al., 2023) that found – in children and adolescents – a specific association between self-injurious thoughts and behaviours and reduced parasympathetically-mediated HRV measures (but no significant effect for sympathetically mediated cardiac measures or EDA).

The majority of the studies included in our meta-analyses on cardiac measures (13 out of 18) applied case-control designs, involving either adults with a confirmed psychiatric diagnosis or community samples, with and without a history of suicidal ideation or suicide attempt. The remaining studies used cohort designs, comprising participants with a documented history of suicidal ideation or suicide attempt. This distinction is particularly important because it indicates that the effect sizes we calculated (and the overall pooled effect size) were primarily derived from comparisons within similar populations (e.g., adults with the same diagnosis or community participants), thereby isolating differences in parasympathetic regulation specifically related to STBs. We note that most studies included in this meta-analysis focused on individuals with depression or mood disorders, with only two including a broader range of diagnoses or symptom profiles. Altered cardiac markers of parasympathetic regulation have been reported in physically healthy individuals with mood disorders (Alvares et al., 2016). Building on this, our novel findings suggest that such alterations may be more pronounced in those with mood disorders who also experience STBs, compared to individuals with the same diagnoses but without STBs.

Furthermore, it is worth noting that only a limited number (11 out of 16) of studies on EDA measures – amongst those included in our systematic review – could be meta-analysed. Of the 11 studies included in the narrative synthesis, most (n = 9) detected statistically significant differences in EDA between participants with and without suicidal ideation. Among these, six studies (all conducted in adults with depression) reported reduced EDA responses in those with STBs, while three studies (one each in adults with depression, generalized anxiety disorder, and admitted for severe STBs without a clearly defined clinical diagnosis) found increased EDA activity. For this meta-analysis, we could also not conduct any subgroup analyses, due to the low number of studies included.

4.2. Interpretation & mechanisms

Taken together, our findings suggest that STBs may be linked to a broader pattern of autonomic dysregulation. Overall, the imbalance in ANS functioning observed in individuals with STBs appears more consistently associated with reduced parasympathetic regulation (reflected in diminished HRV and RSA) than with clear alterations in sympathetic activity, which would be reflected in electrodermal patterns. This pattern may indicate – at least in some individuals with STBs – reduced flexibility in responding to stress, thereby increasing vulnerability to emotional dysregulation and contributing to the implementation of maladaptive coping strategies. In other words, disruptions in autonomic balance may help explain why some individuals with STBs often experience heightened emotional reactivity while also struggling to regulate these states effectively.

Although our study cannot establish causal relationships, these findings align with theoretical models conceptualizing STBs as maladaptive coping responses to psychological distress and physiological dysregulation (Alacreu-Crespo et al., 2024; Glenn et al., 2018; Mann and Rizk, 2020; van Heeringen and Mann, 2014). Reduced parasympathetic regulation may be associated with diminished capacity for stress recovery and emotion regulation, which could increase reliance on non-suicidal self-harming or suicidal behaviours as attempts to manage overwhelming affect. Importantly, evidence suggesting that certain self-harming behaviours (e.g., cutting) are associated with self-reported, transient relief from negative affect (Edmondson et al., 2016) – although preliminary and largely theoretical in terms of direct ANS mechanisms – is consistent with the hypothesis that shifts in parasympathetic activity may play a role in short-term affect modulation. Notably, the extent to which these mechanisms similarly apply to suicidal outcomes, beyond non-suicidal self-injury, remains unclear (O'Connor and Kirtley, 2018).

Regarding EDA, our findings were inconsistent, with some studies reporting reduced and others increased responses in individuals with STBS. These divergent findings may reflect the presence of distinct physiological subtypes, consistent with recent evidence suggesting that some individuals exhibit hypo-responsivity, whereas others show hyper-responsivity to stress, as measured via markers of ANS functioning and regulation such as EDA and HRV (Bernanke et al., 2017; Stanley et al., 2019; Weber et al., 2025). Such variability may correspond to different risk pathways, potentially linked to differences in stress reactivity, impulsivity, emotion regulation capacity, or interoceptive processes. Future research should therefore examine whether distinct autonomic profiles characterise subgroups of individuals with STBs, and whether these profiles differentially predict clinical trajectories.

4.3. Implications for future research and clinical practice

While reduced parasympathetic functioning shows promise as a potential biomarker of STBs, our findings underscore that the current evidence remains preliminary and heterogeneous, and further research is clearly warranted. First, it would be important to determine whether ANS dysregulation represents a risk factor for STBs, a consequence, or a non-specific marker of broader emotion dysregulation or related vulnerabilities (e.g., interoceptive alterations). Prospective, large-scale longitudinal studies would allow researchers to disentangle temporal and mechanistic associations, and to establish whether specific autonomic patterns precede STBs or emerge as a sequela of psychological distress. Such designs would also help determine whether autonomic markers have predictive validity for future suicidal behaviours.

Although we did not find significant differences based on experimental condition (resting-state vs. experimental task), this moderation could only be examined for cardiac measures. Examining ANS activity under stress-inducing or ecologically valid task conditions may be particularly informative, as stress-related dysregulation of emotional and cognitive processes likely represents a key pathway linking autonomic functioning to suicidal outcomes. Stress-reactivity paradigms may therefore better capture risk-relevant physiological profiles than resting-state assessments alone.

Future research using EDA measures should aim to clarify the heterogeneous patterns observed for this particular set of measures, for example, by stratifying large samples according to both clinical diagnosis and STB status, and by examining potential subtypes characterized by hypo- vs. hyper-responsivity across autonomic indices. More broadly, integrating multi-modal markers (e.g., combining cardiac, electrodermal, and subjective measures of emotional and physiological functioning) may help identify distinct physiological risk profiles. Future research should also prioritize the collection of longitudinal data, while also building on existing evidence synthesis studies and collaboratively aggregating individual participant data to better elucidate distinct physiological patterns and trajectories, and their relevance for suicide risk.

Importantly, future work should also account for potential confounders and mediators. Factors such as lack of social support, adverse life events, isolation and financial instability are likely to amplify suicide risk and may dynamically interact with physiological imbalances, such as ANS dysregulation. However, most studies to date have examined these factors in isolation, and there is still very limited evidence on how they may work together. Understanding these interactions could provide deeper insights into how physiological, socio-demographic and environmental factors collectively contribute to STBs. At the same time, it is unclear how these combined factors shape the progression of suicidality, for example the transition from suicidal ideation to suicide attempt. This will ultimately improve the accuracy of tools used to identify those at higher risk of suicide and predict future suicide attempts.

Finally, replication across diverse populations and clinical settings is essential to determine the generalizability of ANS markers across psychiatric diagnoses and demographic groups. In the future, autonomic markers, alongside subjective reports and clinical assessment, may provide valuable objective data to support clinical decision-making in the context of STBs. However, current evidence is still preliminary. While autonomic markers could complement, rather than replace, self-report and clinical judgment, establishing their predictive validity and consistency across diverse contexts and considering clinical information, is essential.

4.4. Limitations

Several limitations should be considered when interpreting the findings of this review, particularly given the substantial variability in study designs, participant characteristics, and measurement approaches across the included studies.

A first limitation of the current meta-analysis is the lack of eligible quantitative data specifically addressing self-injurious behaviours in adults, except one study focused on self-injurious thoughts and behaviours (i.e., spanning across self-injury and suicidal ideation) in the meta-analysis of cardiac measures. Second, only a limited number of studies investigating EDA measures could be included in the meta-analysis, as quantitative data necessary for calculating effect sizes were not reported in the manuscripts and could not be obtained from authors. Therefore, the non-significant pooled effect size for the EDA meta-analysis should be regarded as preliminary until more studies clarifying potential associations between STBs and EDA patterns are conducted. Third, in both meta-analyses (cardiac and EDA measures), cross-study heterogeneity was statistically significant. This variability likely reflects differences in sample composition, psychiatric diagnoses, assessment of STBs (e.g., ideation vs. attempts), experimental conditions (resting-state vs. task-based), and analytic strategies. Fourth, the majority of included studies focused on adults with mood disorders, which restricts the generalizability of the findings to other psychiatric populations or to transdiagnostic samples. It remains unclear whether similar autonomic patterns are observed across anxiety disorders, personality disorders, trauma-related conditions, or non-clinical populations at risk, or whether specific risk subgroups exist within these populations. Fifth, many primary studies did not adequately control for psychiatric diagnoses, medication use, or other potential confounds (e.g., substance use, other physical health conditions that are likely to directly affect ANS markers). Consequently, it cannot be fully determined whether observed ANS alterations are specifically associated with STBs or reflect broader psychopathology. Finally, the predominance of cross-sectional designs prevents conclusions regarding directionality or causality. Current evidence does not allow us to determine whether ANS dysregulation precedes the development of STBs, results from psychological distress, or represents a correlate of an underlying third factor. Longitudinal and experimental research is therefore essential to clarify these temporal and mechanistic relationships.

5. Conclusion

In summary, our systematic review with meta-analysis highlights reduced parasympathetic functioning as a promising marker of STBs in adults, while emphasizing the heterogeneity and preliminary nature of the evidence. Findings suggest broader patterns of autonomic dysregulation may underlie maladaptive coping in the context of stress and emotional dysregulation. Nevertheless, future longitudinal, stress-reactivity-focused studies are essential to establish causal pathways, refine biomarker development, and identify potential physiological subtypes of risk.

CRediT authorship contribution statement

Conceptualization: AB; Data curation: CS, FC; Formal analysis: FC; Funding acquisition: n/a; Investigation: CS, FC; Methodology: AB; Project administration: AB; Resources: AB; Software: AB; Supervision: AB, CS; Validation: AB, CS, FC; Visualization: FC; Writing – original draft: CS, FC; Writing – review & editing: AB, CS, FC, SC, VP.

Declaration of Competing Interest

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.neubiorev.2026.106672.

Data availability statement

Data is available on OSF at the following link: https://doi.org/10.17605/OSF.IO/RQA3E.

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