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# Heart Rate Variability in Teaching Professionals: A Systematic Review and Evidence Synthesis on Time-Domain Indices and Occupational Stress Relationships

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**ADMINISTRATIVE INFORMATION**

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**Amendments -** This protocol was registered with the International Platform of Registered Systematic Review and Meta-Analysis Protocols (INPLASY) on 19 June 2025 and was last updated on 19 June 2025.

## INTRODUCTION

**Review question / Objective** To systematically evaluate and synthesize existing evidence on time-domain HRV (RMSSD and SDNN) in K-12 teaching professionals, examining typical values, relationships with occupational stress exposure, and methodological approaches used across studies.

**Rationale** Occupational stress among teachers is a critical public health issue, with global estimates indicating that 50–60% of teachers experience chronic work-related stress (OECD, 2021; UNESCO, 2022), linked to cardiovascular dysregulation, emotional exhaustion, and diminished educational quality. Heart rate variability (HRV), particularly time-domain indices such as RMSSD and SDNN, is increasingly used as a non-invasive biomarker to assess autonomic stress reactivity.

Although HRV has been widely applied in healthcare and high-demand occupations, systematic synthesis of HRV evidence specific to teaching professionals is lacking. The distinct occupational demands of educators—emotional labor, workload variability, and administrative burdens—may influence autonomic function in unique ways.

This review is grounded in the Polyvagal Theory and the Allostatic Load Model, which provide neurobiological and systems-level explanations of how chronic and acute stressors disrupt autonomic regulation. Reduced HRV—particularly in time-domain indices like RMSSD and SDNN—is interpreted as a marker of diminished vagal tone, impaired self-regulation, and increased allostatic burden.

SDNN (Standard Deviation of NN Intervals) captures overall variability in heart rate and reflects the influence of both sympathetic and parasympathetic nervous system inputs over longer durations. Chronic stress leads to reduced

SDNN values due to prolonged autonomic imbalance (e.g., sustained sympathetic activation and parasympathetic withdrawal), signifying global autonomic dysfunction and increased cardiovascular risk.

RMSSD (Root Mean Square of Successive Differences) reflects short-term parasympathetic activity and vagal tone. It is sensitive to acute stress reactivity. During stress exposure, RMSSD is typically suppressed due to parasympathetic withdrawal, but in resilient individuals, it rebounds quickly post-stress. Therefore, RMSSD serves as a key marker of immediate autonomic regulation and recovery capacity.

Given that HRV is highly sensitive to multiple confounding factors—including respiration rate, measurement timing (e.g., circadian rhythm), and data processing (e.g., artifact correction, filtering algorithms)—rigorous methodological reporting is essential. This includes specifying the device used, correcting for artifacts prior to selecting the analysis window, and transparently reporting the filter settings applied. These standards ensure data comparability and reproducibility across studies in psychophysiological research in education settings, particularly for school teachers.

**Condition being studied** Occupational stress in teaching professionals refers to the chronic physiological and psychological strain experienced by K-12 educators in response to work-related demands that exceed their coping resources. This condition is characterized by symptoms including emotional exhaustion, anxiety, depression, sleep disturbances, and various physical health complaints.

Teacher occupational stress arises from unique workplace demands such as high emotional labor, administrative burdens, heavy workloads, classroom management challenges, and insufficient organizational support. Chronic exposure to these stressors can lead to autonomic nervous system dysregulation, which is measurable through changes in heart rate variability (HRV). The condition affects approximately 50-60% of teachers globally and significantly impacts both educator wellbeing and educational quality.

## METHODS

**Search strategy** Pubmed:

("teacher stress"[Title/Abstract] OR
"educator stress"[Title/Abstract] OR
"teacher burnout"[Title/Abstract] OR
"workplace stress"[Title/Abstract] OR
"burnout, professional"[MeSH Terms] OR
"stress, psychological"[MeSH Terms] OR
"emotional exhaustion"[Title/Abstract]
)
AND
(
"heart rate variability"[Title/Abstract] OR
HRV[Title/Abstract] OR
RMSSD[Title/Abstract] OR
SDNN[Title/Abstract] OR
"autonomic nervous system"[MeSH Terms] OR
"parasympathetic activity"[Title/Abstract] OR
"autonomic regulation"[Title/Abstract]
)
AND
(
"Teaching"[MeSH Terms] OR
school teacher[Title/Abstract] OR
educator[Title/Abstract] OR
teaching staff[Title/Abstract]
)

Scopus:

( TITLE-ABS-KEY("teacher stress" OR "educator stress" OR "teacher burnout" OR "workplace stress" OR "emotional exhaustion" OR "psychological stress" OR "professional burnout"))AND( TITLE-ABS-KEY("heart rate variability" OR HRV OR RMSSD OR SDNN OR "autonomic nervous system" OR "parasympathetic activity" OR "autonomic regulation"))AND( TITLE-ABS-KEY("teaching" OR "school teacher" OR educator OR "teaching staff")) AND ( LIMIT-TO ( LANGUAGE,"English" ) )

Ebsco Host: Medline Ultimate (7) Academic Search Ultimate (1) CINAHL Ultimate (1)

(TI("teacher stress" OR "educator stress" OR "teacher burnout" OR "workplace stress" OR "emotional exhaustion") OR
AB("teacher stress" OR "educator stress" OR "teacher burnout" OR "workplace stress" OR "emotional exhaustion") OR
MH "Burnout, Professional" OR
MH "Stress, Psychological")
AND
(TI("heart rate variability" OR HRV OR RMSSD OR SDNN OR "parasympathetic activity" OR "autonomic regulation") OR
AB("heart rate variability" OR HRV OR RMSSD OR SDNN OR "parasympathetic activity" OR "autonomic regulation") OR
MH "Autonomic Nervous System")
AND
(MH "Teaching" OR
TI("school teacher" OR educator OR "teaching staff") OR
AB("school teacher" OR educator OR "teaching staff"))

Filter: Past 10 years; Apply equivalent Subjects.

**Participant or population** K-12 teaching professionals (teachers, administrators, counselors, school staff), age (18-65).

**Intervention** Exposure to: Measurement of HRV in occupational or educational work-related contexts Time-domain HRV outcomes: RMSSD and/or SDNN.

**Comparator** Comparator (Comparative Conditions in Observational Contexts): No active intervention is applied. However, included studies involve naturalistic comparisons relevant to occupational stress, such as: High-stress vs. low-stress teacher groups (based on validated instruments)
Workday vs. non-workday HRV recordings
Between-role comparisons (e.g., classroom teachers vs. administrative staff)
These comparative conditions form the basis for examining HRV differences in relation to occupational stress, aligned with the review's first research question.

**Study designs to be included** Observational studies (cohort, cross-sectional).

**Eligibility criteria** Must include at least one of the following:

Between-group comparisons based on stress indicators
Correlation analyses between HRV and stress measures
Within-subject comparisons (work day vs. off day, high-stress vs. low-stress periods)

Minimum sample size: Not prespecified due to design variability; however, studies with extremely small sample sizes (e.g., n < 15) will be evaluated cautiously during quality appraisal and may be excluded from synthesis if data are insufficient for meaningful interpretation.

**Information sources** Electronic data bases PubMed, Scopus, ERIC, MEDLINE Ultimate, Academic Search Ultimate, CINAHL Ultimate. Manual reference screening and forward citation tracking.

**Main outcome(s)** Time-domain heart rate variability (HRV) indices — RMSSD and SDNN — reported in teaching professionals. These will be analyzed in relation to occupational stress exposures or classifications (e.g., high vs. low stress, workday vs. off-day).

**Additional outcome(s)** 1. Correlational data between HRV indices (RMSSD, SDNN) and validated occupational stress indicators (e.g., Perceived Stress Scale [PSS], Maslach Burnout Inventory [MBI], Copenhagen Burnout Inventory [CBI]).
2. HRV measurement protocol characteristics, including:
Device type (e.g., ECG vs. PPG)
Recording duration and measurement position
Artifact correction method and breathing control
Time of day and environmental conditions

3. Subgroup differences where available (e.g., by gender, teaching level, school type, or years of experience).

4. Methodological reporting quality, including transparency and adherence to HRV best-practice guidelines (e.g., filter type, device reproducibility, stationary sequence selection).

**Data management** Records will be managed using a structured system of folders and spreadsheets in cloud-based storage (e.g., Google Drive), with controlled access for the review team.
1. Screening will be conducted in two phases (title/abstract, then full-text) using Excel-based screening logs, with two reviewers working independently. Each decision will be documented in a shared file with inclusion/exclusion reasons.

2. Data extraction will follow a standardized template in Excel, structured around predefined domains aligned with ROBINS-E and JBI checklists. Two reviewers will extract data independently and resolve discrepancies by discussion or third-party adjudication.

3. Version control and audit trail will be maintained through dated filenames and reviewer identifiers to ensure transparency and reproducibility.

4. Reference management will be conducted using free software Endnote 21 for de-duplication and citation tracking.

**Quality assessment / Risk of bias analysis** 1. For cross-sectional studies, we will use the Joanna Briggs Institute (JBI) Critical Appraisal Checklist for Analytical Cross-Sectional Studies, adapted to include HRV-specific quality indicators such as reporting of measurement protocols, artifact correction, and device transparency.

2. For cohort or repeated-measures studies (e.g., workday vs. off-day comparisons), we will apply the ROBINS-E (Risk Of Bias In Non-randomized Studies of Exposures) tool, tailored for HRV research. Key domains assessed will include:

Confounding control (e.g., age, medication, time of day)
Exposure measurement validity (stress classification)
Outcome quality (HRV protocol details: device type, posture, duration, breathing control, artifact filtering)
Completeness of reporting and selective outcome bias

Each domain will be rated as low, moderate, or high risk of bias. Results will be presented in tabular form, and the appraisal will guide sensitivity analyses and interpretation of findings.

**Strategy of data synthesis** The primary analysis will be a structured narrative synthesis aligned with the three research questions. The data will be grouped and summarized according to:

HRV-Stress Relationships (RQ1)
Correlation coefficients (Pearson's r, Spearman's ρ) between RMSSD/SDNN and stress-related measures will be extracted.
If ≥3 studies report compatible effect sizes (e.g., similar HRV indices and stress scales), a random-effects meta-analysis will be considered.
Fisher's Z transformation will be applied to standardize correlation coefficients before pooling.
Descriptive HRV Values (RQ2)
Means and standard deviations of RMSSD and SDNN will be summarized across studies.
Stratification will be performed by measurement context (e.g., workday, resting, teaching vs. non-teaching period).

Heterogeneity will be assessed using $I^2$ and visual inspection of forest plots.

Quantitative analyses will be conducted in Comprehensive Meta-Analysis (CMA 4) and findings will be reported according to PRISMA 2020.

**Subgroup analysis** Methodological Approaches (RQ3)
Study designs, HRV protocols, measurement devices, recording durations, posture, and artifact handling methods will be narratively synthesized.

**Sensitivity analysis** Sensitivity analyses will be conducted to evaluate the robustness of findings by excluding studies at high risk of bias, based on ROBINS-E and JBI assessments. Specifically, studies rated as high risk in two or more key domains (e.g., inadequate HRV protocol, lack of confounder control) will be excluded to observe changes in synthesized results. Additional sensitivity analyses will include:

Exclusion of studies using non-validated HRV devices or stress measures
Stratification by HRV measurement quality (e.g., recording duration, artifact correction, posture control)
Leave-one-out analysis if meta-analysis is conducted.

**Language restriction** English.

**Country(ies) involved** Indonesia, Taiwan, India, the Philippines.

**Other relevant information** A. Adapted ROBINS-E Criteria for HRV Studies
Domain 1: Bias Due to Confounding
• Control for key confounders: age, sex, BMI, medication, caffeine, circadian rhythm, menstrual cycle.
• Ratings:
o Low: All confounders considered
o Moderate: 1–2 omitted but acknowledged
o High: Largely uncontrolled
Domain 2: Bias in Measurement of Exposure (Stress Conditions)
• Exposure/stressor measured via validated scale or well-defined classification.
• Ratings:
o Low: Clear, validated stress measures used
o Moderate: Ambiguity in measurement
o High: Undefined or poorly operationalized stressor
Domain 3: Bias in Participant Selection
• Population appropriateness and sampling clarity
• Ratings:
o Low: Defined inclusion/exclusion for K–12 educators
o Moderate: Partial coverage
o High: Unclear/non-representative sampling
Domain 4: Bias Due to Post-Exposure Interventions
• Consideration of any subsequent interventions post-exposure
• Ratings:
o Low: None or fully controlled
o Moderate: Not clearly reported
o High: Uncontrolled co-interventions
Domain 5: Bias Due to Missing Data
• Handling of dropout or missing physiological/psychological data
• Ratings:
o Low: 20% or unclear method
Domain 6: Bias in Outcome Measurement (HRV Quality)

• Includes device type, posture, breathing, correction for artifacts, timing (circadian), segment selection algorithm, and filter description
• Ratings:
o Low: ≥5 criteria reported
o Moderate: 3–4 reported
o High: ≤2 reported
Domain 7: Bias in Selective Reporting
• Pre-specified HRV metrics and full reporting
• Ratings:
o Low: Complete transparency
o Moderate: Minor omission
o High: Likely selective reporting

B. Adapted JBI Checklist – Cross-sectional Studies
1. Were inclusion criteria clearly defined?
o Specify K–12 relevance and exclusion logic
2. Were study participants and setting described in detail?
o Report demographics, school context, recruitment methods
3. Was HRV exposure measured validly/reliably?
o Include device, duration, posture, filter, artifact correction, and segment choice
4. Were standard criteria used for defining stress/condition?
o Use of validated teacher stress instruments
5. Were confounders identified?
o Identify key autonomic and occupational variables (e.g., medication, work context)
6. Were strategies to deal with confounders stated?
o Report statistical control: matching, regression, stratification
7. Were HRV outcomes measured in a valid and reliable way?
o Describe HRV protocols: posture, breathing, recording environment, analysis transparency
8. Was statistical analysis appropriate?
o Clearly describe models (e.g., correlation, ANOVA, regression), assumptions, and reporting.

**Keywords** Heart Rate Variability; RMSSD; SDNN; Teachers; Occupational Stress; Time-Domain Analysis; Autonomic Regulation; Parasympathetic.

**Dissemination plans** Peer-reviewed journal publication
Academic conferences in occupational health and education.

## Contributions of each author

Author 1 - Yasmine A. Gunawan - Author 1 conceived the study, developed the protocol, designed the search strategy, conducted database searches, led study screening and data extraction, performed risk of bias assessment, conducted data analysis and synthesis, drafted the manuscript.
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Author 5 - Mein-Woei Suen - Author 5 provided methodological guidance on HRV research, expert guidance on social science research, supervised the systematic review process, and critically reviewed the manuscript for important intellectual content.
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