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Corresponding author: Weiping Du

82015006@nxnu.edu.cn

Author Affiliation:

Department OF Public Basic Teaching , Xi'an Academy of Fine Arts, China.

Effects of Sleep Deprivation on Heart Rate Variability: A Systematic Review and Meta-Analysis

Zhang, SL; Niu, XD; Ma, JK; Wei, X; Zhang, J; Du, WP.

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 5 June 2025 and was last updated on 5 June 2025.

INTRODUCTION

Review question / Objective Objective: This study systematically reviews and integrates research data from randomized controlled trials through meta-analysis to comprehensively evaluate the impact of sleep deprivation on HRV, further elucidating its mechanisms of action on cardiac autonomic regulation, and providing insights for optimizing sleep interventions and preventing cardiovascular diseases.

Condition being studied Background: Sleep deprivation may lead to autonomic nervous system dysfunction, thereby contributing to cardiovascular diseases, mood disorders, and cognitive decline. Heart rate variability (HRV), as a key indicator for assessing autonomic nervous function, effectively reflects changes in sympathetic and parasympathetic activity and is commonly used to

evaluate the impact of sleep deprivation on autonomic function. However, existing literature exhibits significant heterogeneity, including inconsistencies in HRV measurement methods, variations in intervention durations, and inadequate control of confounding factors.

Objective: This study systematically reviews and conducts a meta-analysis of data from randomized controlled trials (RCTs) to comprehensively assess the effects of sleep deprivation on HRV, further elucidating its mechanisms in cardiac autonomic regulation and providing insights for optimizing sleep interventions and preventing cardiovascular diseases.

Methods: Databases including PubMed, Embase, CNKI, Wanfang, and VIP were searched for RCTs investigating the effects of sleep deprivation on HRV, with the search period spanning from January 2010 to May 2024. The Cochrane Risk of Bias tool was used to assess the quality of included studies, while Review Manager 5.4 and Stata 17.0 were employed for meta-analysis.

Results: A total of 11 eligible studies involving 549 participants were included. The meta-analysis revealed that: (1) Sleep deprivation showed a decreasing trend in the time-domain HRV index SDNN, though without statistical significance (P > 0.05), while the time-domain index RMSSD significantly decreased (P < 0.05); (2) Sleep deprivation significantly increased the frequency-domain HRV indices LF and LF/HF (P 0.05).

Conclusion: This meta-analysis suggests that sleep deprivation may impair cardiac autonomic nervous function, manifesting as reduced RMSSD and elevated LF/HF ratio, indicating sympathetic dominance and diminished vagal activity. However, changes in other HRV indices such as SDNN and HF did not reach statistical significance. These findings imply that sleep deprivation may disrupt the dynamic balance between sympathetic and parasympathetic activity. Future studies should adopt standardized HRV measurement protocols to further validate these trends and explore their physiological mechanisms.

METHODS

Search strategy Randomised Controlled Trial (RCT) on the effect of sleep deprivation on heart 63 rate variability was searched from January 2010 to May 2024 through the databases of 64

PubMed, Embase, China Knowledge, Wanfang and Wipro. A combination of subject 65

terms and free words was used for the search, and the Chinese search library was 66 "China Knowledge", for example, the search formula was: (subject: sleep deprivation) 67

OR (subject: sleep deprivation) AND (subject: autonomic) OR (subject: heart rate 68

variability) OR (subject: HRV). The English search library takes "PubMed"as an 69

(Deprivation, Sleep)) OR (REM Sleep Deprivation)) OR (Deprivation, REM Sleep)) 71

OR (Sleep Deprivation, REM)) OR (Sleep Insufficiency)) OR (Insufficiencies, Sleep)) 72

OR (Insufficiency, Sleep)) OR (Sleep Insufficiencies)) OR (Insufficient Sleep)) OR 73

(Sleep, Insufficient)) OR (Inadequate Sleep)) OR (Sleep, Inadequate)) OR (Sleep 74

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Fragmentation)) OR (Fragmentation, Sleep)) OR (Insufficient Sleep Syndrome)) OR 75

(Insufficient Sleep Syndromes)) OR (Syndrome, Insufficient Sleep)) OR (Sleep Debt)) 76 AND (heart rate variability).

Participant or population Healthy population, Astronauts, Shift worker, Resident doctor, University student.

Intervention Sleep deprivation.

Comparator The control group received no intervention and maintained normal sleep duration.

Study designs to be included Study type: RCT.

Eligibility criteria

Inclusion Criteria

(1) Study type: RCT.

(2) Study subjects without any diseases.

(3) Interventions: The experimental group underwent sleep deprivation intervention; the control group received no intervention and maintained normal sleep duration.

Exclusion Criteria

(1) Excluded conference reports and literature for which full text could not be obtained.

(2) Studies were excluded if they did not report HRV-related outcome indicators clearly (e.g., missing means and standard deviations, absence of control group data, or data presented only in figures without numerical values), which made it impossible to extract valid endpoint data.

(3) Excluded duplicate publications and review articles.

(4) Excluded animal experiments, studies involving diseased populations, or drug interventions.

Information sources PubMed, Embase, China National Knowledge Infrastructure (CNKI), Wanfang, and VIP databases.

Main outcome(s) HRV indicators include timedomain indicators, SDNN, RMSSD, .frequencydomain indicators, LF, HF and LF/HF.

Quality assessment / Risk of bias analysis Since the literature retrieved in this study consists of randomized controlled trials, the Cochrane Risk of Bias Assessment Tool was employed. The Cochrane Risk of Bias Assessment Tool evaluates six key domains: randomization methods, allocation concealment, blinding, completeness of outcome data, selective reporting of results, and other sources of bias.

Strategy of data synthesis Meta-analyses were performed using Review Manager 5.4 and Stata 17.0 software to calculate the effect sizes of the

included studies. All outcome indicators were continuous variables, and the effect sizes were expressed as standardized mean differences (SMD) with 95% confidence intervals. A fixed-effects model was applied when there was no significant heterogeneity (P > 0.05, $l^2 \le 50\%$), whereas a random-effects model was used in the presence of heterogeneity (P < 0.05, $l^2 \ge 50\%$). Subgroup or sensitivity analyses were conducted when heterogeneity was substantial. Publication bias was assessed using Egger's regression test.

Subgroup analysis To explore the reasons for the existence of heterogeneity, this study primarily conducted subgroup analyses on the LF/HF outcome indicators, using factors related to sleep deprivation duration and study subjects as covariates for separate subgroup analyses. Based on sleep deprivation duration, the groups were divided into two subgroups: <24h and \geq 24h. Based on the study subjects, the groups were categorized into five subgroups: healthy general population, shift workers, college students, resident physicians, and miners. As shown in Table 2, the study subjects may be a source of heterogeneity.

Sensitivity analysis When heterogeneity is significant, subgroup analysis or sensitivity analysis should be employed.

Country(ies) involved China.

Keywords Keywords: sleep deprivation; HRV; Meta-analysis.

Contributions of each author

Author 1 - Suling Zhang. Author 2 - Xiaodan Niu. Author 3 - Jinke Ma. Author 4 - Xin Wei. Author 5 - Jun Zhang. Author 6 - Weiping Du.