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Systematic Review

Sedentary Lifestyle, Heart Rate Variability, and the Influence on Spine Posture in Adults: A Systematic Review Study

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Abstract: (1) Background: The rise in sedentary lifestyles has led to more spinal malformations in the population. These malformations are connected to the body's autonomic function, which can negatively impact long-term health. Heart rate variability can be used as a marker to measure how different postures affect autonomic health. This systematic review aims to explore the link between posture and heart rate variability and evaluate potential interventions to address the consequences of sedentary lifestyles. (2) Methods: Data sources: Studies exploring the relationship between posture and heart rate variability were found using PubMed, Embase, Web of Science, and Cochrane on 1 July 24. Eligibility criteria: People aged 18 years or above with a sedentary lifestyle were included. Studies involving children or participants with spinal/musculoskeletal conditions impacting their ability to walk or sit were excluded as they would not accurately reflect posture analysis. PRISMA guidelines were followed throughout, and the quality assessment was achieved using the QualSyst tool. (3) Results: Out of the 753 papers identified, only five met the eligibility criteria. These studies exhibited heterogeneity regarding interventions, aims, and participant populations. All five studies were prospective case series, enabling analysis and comparisons. (4) Conclusions: According to this study, the seated position, especially the forward truncal flexion, had the most significant impact on heart rate variability and sympathetic tone. It may be inferred that sedentary behavior encourages this stress on the body, which can affect one's health, increasing the mortality rate.

Keywords: heart rate variability; posture; sedentary behavior; autonomic function; sitting position

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1. Introduction

1.1. Relevance and Justification of Review

The human body possesses a remarkable ability to adapt and maintain equilibrium in the face of constant internal and external demands. This delicate balance is orchestrated by the autonomic nervous system, which governs involuntary physiological processes, including heart rate [1]. The Autonomous nervous system (ANS) regulates involuntary bodily functions and is divided into two branches: the sympathetic nervous system (SNS) and the parasympathetic nervous system (PNS) [2]. The parasympathetic nervous system (PNS) predominates in quiet 'rest and digest' conditions. It counteracts the effects of the sympathetic nervous system, which is responsible for the 'fight or flight' response [2].

While often overlooked, the subtle fluctuations in the time intervals between consecutive heartbeats, known as heart rate variability, provide a unique window into the dynamic interplay of the sympathetic and parasympathetic branches of the ANS. A healthy heart, rather than beating like a metronome, exhibits a complex variability in rhythm, reflecting its adaptability to physical and psychological stressors [3]. This inherent variability, largely influenced by parasympathetic activity via the vagus nerve, is considered a hallmark of a resilient and responsive cardiovascular system [4,5].

However, this intricate balance can be disrupted by a myriad of factors, leading to alterations in HRV, which are increasingly recognized as indicators of compromised health. While numerous physiological and pathological influences on HRV are well-documented, the impact of lifestyle factors, particularly posture and sedentary behavior, has emerged as a critical area of investigation.

The modern world, characterized by technological advancements and increasingly sedentary occupations, has inadvertently fostered a lifestyle that often prioritizes convenience over movement [6]. This shift toward sedentary behaviors, characterized by prolonged periods of sitting and minimal physical activity, has raised concerns about its potential effects on autonomic health. Sedentary behavior is often intertwined with poor posture, which can lead to musculoskeletal imbalances and potentially impact physiological processes beyond the musculoskeletal system [7].

Emerging research suggests a complex interplay between posture, sedentary behavior, and HRV. Prolonged sitting, especially in positions that compromise spinal alignment, may alter autonomic function, potentially leading to a reduction in HRV [1]. Also, posture affects one's biomechanics, musculoskeletal health, and physiological processes [8]. This potential link between postural habits, sedentary lifestyles, and autonomic dysregulation underscores the need for a comprehensive understanding of these interactions to develop effective strategies for promoting health and well-being.

1.2. Aims

This review aims to explore the existing knowledge on the relationship between posture and heart rate variability and synthesize the findings. It also aims to determine whether changes in posture will benefit heart rate variability and autonomic functions and how this might be utilized in future interventions addressing autonomic health.

2. Materials and Methods

The search strategy and reporting of this review were conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines.

2.1. Eligibility Criteria

Studies were eligible if published in English and compared heart rate variability and posture in a healthy sedentary population. No restriction on study type or methodology was set; however, animal studies and studies involving participants younger than 18 years of age were excluded. Studies involving participants with any disease condition were excluded. Other systematic reviews were not eligible, although the reference lists of reviews identified through the literature search were screened for potentially relevant studies. The inclusion and exclusion criteria are shown in Table 1.

Table 1. Inclusion and exclusion criteria.

Inclusion Criteria	Exclusion Criteria
- Participants over 18 years old - Participants of any race, sex, and demographic - Studies that observe the correlation between change in posture and heart rate variability - Written in English and Peer-reviewed published studies - All study types (case reports, cohort studies, RCT, case series) - Studies published in any year	- Participants below 18 years old - Participants with conditions requiring them to remain sedentary, i.e., wheelchair-bound - Animal studies - Systematic Reviews - Studies not available in English

2.2. Information Sources, Search and Search Strategy

A search was conducted on Google Scholar and PROSPERO to identify any previous systematic reviews conducted in the specific research area. However, no relevant studies were found in these searches.

A comprehensive electronic literature search was performed independently by two researchers, DF and JL, across PubMed, Embase, Web of Science, and Cochrane on 12 April 2023 (revised on 1 July 2024). The search strategy was developed based on the PICOS model and predetermined inclusion/exclusion criteria. A full breakdown of the search strategy is shown in Table 2. The number of studies obtained from each database and the search terms used are given in Appendix A.

Table 2. Full breakdown of words used in literature review.

Posture	Heart Rate Variability	Sedentary Lifestyle
Pose	Cycle length variability	Inactive
Stance	HRV	Sedentary behavior
Position		Desk-bound
Kyphosis		Idle
Lordosis		Seated
		Stationary

The articles obtained from the search engines were exported to Covidence, a systematic review management tool. Duplicate articles found across multiple databases were removed during the importing process, retaining only one copy of each article for the screening stage.

During the screening process, each researcher independently reviewed the titles and abstracts of the articles to determine whether they met the inclusion and exclusion criteria. Any articles that disagreed with the researchers' opinions were categorized as 'conflicts'. Both researchers then discussed their opinions to provide insight into their reasoning, aiming to reach a consensus. Articles considered ambiguous were included for further review in the 'Full-Text Review' to ensure no relevant studies were prematurely excluded.

The remaining articles underwent a full-text review, with each researcher independently assessing them. Like the title and abstract screening, articles were included or excluded based on the predetermined criteria. In cases of conflicting opinions, both researchers collaborated directly to address and resolve any discrepancies, ensuring transparency and understanding of the reasoning behind their decisions.

2.3. Data Collection Process

Two reviewers (DF and JL) worked independently and used a standardized form to extract methodological, demographic, and outcome data. Data extracted included participant characteristics (age range, gender, and number of participants), the location of studies, study aim, and methods. Disagreements were resolved by discussing with each other. Extracted data are shown in Tables 3–5.

2.4. Risk of Bias in Individual Studies

Both researchers of the Systematic Review (JL and DF) independently evaluated the methodological quality of each study using the Assessment Criteria for Evaluating Primary Research Papers from a Variety of Fields (QualSyst) as recommended by The Cochrane Handbook [9,10]. The QualSyst tool employs 14 criteria to assess quantitative studies. For each criterion, if a study fully and adequately addresses the question, it receives 2 marks. If the question is partially addressed, 1 mark is assigned, and if the question is not addressed, 0 marks are given. Any question that does not apply to a particular study is scored as 'N/A' and is excluded from the calculation. The scores for each study are summed up to obtain a 'Total score'. The results for each study are calculated using the predetermined formula

"Total/(28 − (Number of 'N/A' × 2)". Each study is assigned a numerical value between 0 and 1 (rounded to two decimal places), with 0 indicating the highest risk of bias and 1 indicating the lowest risk.

2.5. Risk of Bias across Studies

The relatively low risk of bias for each study, which was previously determined using the QualSyst tool, prevented any estimation of the significant bias across all trials. Each study does, however, outline limitations of design that were taken into account throughout the analysis.

2.6. Additional Analyses

A meta-analysis is a systematic, quantitative study design used to analyze and draw conclusions from previous research. In this systematic review, the five included studies show homogeneity regarding intervention, design, and outcome measures. However, despite these similarities, significant differences between variables hinder a concise analysis. Notably, there is a notable contrast in participant populations among the studies. One study focused on older individuals (aged 60 years and above), while three other studies included younger participants below 35 years old. Additionally, three studies excluded female participants, whereas the other two had both male and female participants. Consequently, no further analyses were conducted.

3. Results

Adheres to PRISMA guidelines.

3.1. Study Selection

Following a comprehensive search across four databases (PubMed, Web of Science, Embase, and Cochrane), a total of 753 articles were imported into Covidence. Among these, 179 duplicates were promptly removed, resulting in 564 unique articles. Both researchers independently screened the titles and abstracts of each article, maintaining a blind review process to ensure unbiased decision-making. Collaboratively, any conflicting choices were resolved through discussion between the researchers, and no third-party involvement was necessary.

Subsequently, 22 studies met the criteria for full-text screening. During this stage, each researcher independently assessed the full texts of the articles to identify potential inclusion or exclusion indicators. To avoid biased opinions, both researchers worked blindly without knowing each other's assessments. Conflicts arising from their independent evaluations were resolved through direct discussion. Finally, five of the initial 22 studies were deemed suitable for data extraction in this systematic review. 17 Studies were excluded as they did not compare HRV and posture or due to the unavailability of the full text. Each of these studies employed a prospective case series design. The results are summarized in the form of a Prisma flow chart (Figure 1).

3.2. Study Characteristic

The characteristics of the included studies are shown in Table 3. A total of five studies were included, which compared heart rate variability and posture. Four of the studies comprised a patient population aged 18–40, and one focused on the older population (age > 60 years).

3.3. Data Extraction

The data extraction tables of the included studies are given in Tables 3–5.

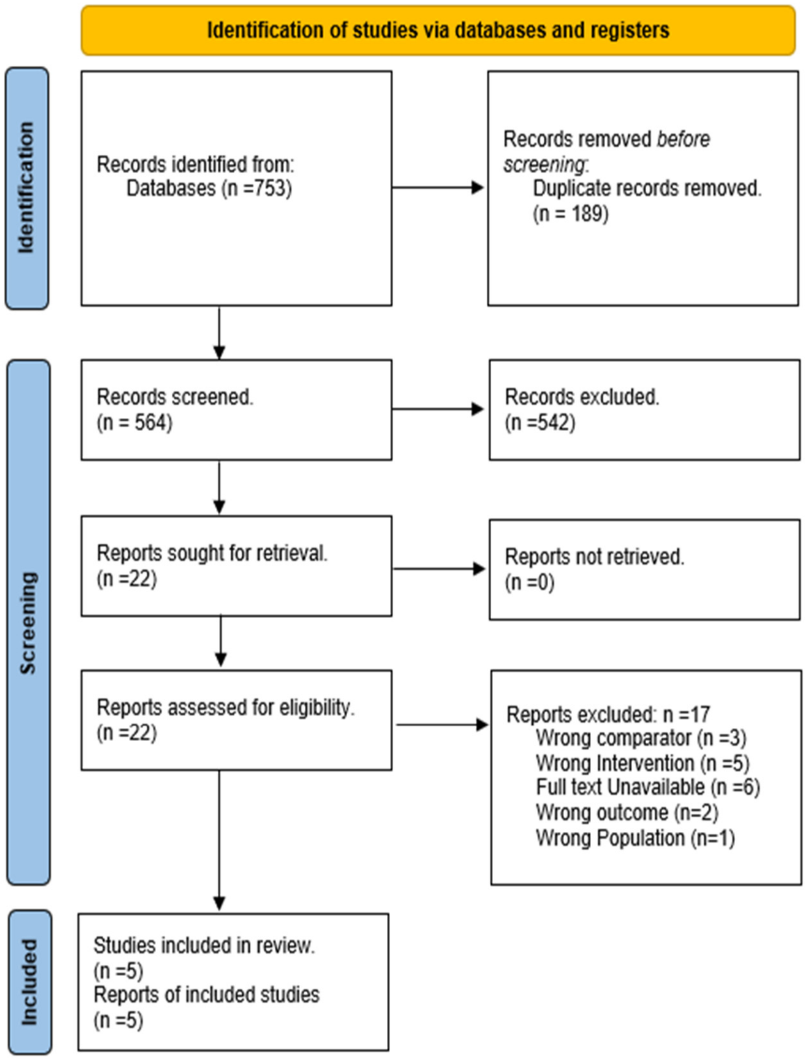

Figure 1. PRISMA flow diagram.

Table 3. Study characteristics of incuded studies.

Study Name	Study Design	Demographics			
		Age Range	Sex	Number of Participants	Country of Study
Chuangchai et al. (2021) [11]	Prospective Case Series	Over 60 years	Male and Female	N = 40 F = 31 M = 9	Thailand
Santos et al. (2019) [12]	Prospective Case Series	18–40 years	Male	N = 35	Brazil
Wang et al. (2022) [13]	Prospective Case Series	23–26 years	Male	N = 12	China
Watanabe et al. (2007) [14]	Prospective Case Series	18–35 years	Male and Female	N = 15 M = 9 F = 6	Australia
Zuttin et al. (2008) [15]	Prospective Case Series	20–25 years	Male	N = 20	Brazil

Table 4. Studies included in systematic review and what intervention was assessed alongside their methodology.

Study Name	Intervention Assessed	Method	
		Length of Intervention	Methodology of Collecting Data
Chuangchai et al. (2021) [11]	Heart rate variability measurements taken in sitting, supine, and standing positions in this order	10 min of both sitting and supine, 5 min of standing. The first 5 min of sitting and supine were disregarded to avoid extraneous factors. Total calculated duration was 15 min.	Three electrodes applied based on a two-lead method. ECG was taken with sampling rate of 1000 Hz using the PowerLab 26 T data acquisition system
Santos et al. (2019) [12]	Heart rate variability recorded in supine and orthostatic positions in this order	Volunteers laid on stretchers for 10 min before heart rate variability was measured for an additional 5 min. Then, they maintained an orthostatic position for 2 min before HRV was measured for an additional 5 min. Total duration was 22 min.	Time series of the R-R intervals (calculated from an ECG) was performed using the POLAR® V800 monitor (Polar Electro 2024, Kempele, Finland).
Wang et al. (2022) [13]	Monitor seven trunk positions in the sitting position simultaneously	Each of the seven postures was held for 3 min, and the interval between each posture was 3 min.	NICOM (Non-Invasive Cardiac Output Monitor) was used to measure cardiac output, stroke volume, stroke volume variation, stroke volume index, cardiac index and heart rate
Watanabe et al. (2007) [14]	Cardiac parameters measured during prone-to-supine and prone-to-sitting positions	Participants would lie prone for 5 min then maneuver to a sitting or supine position for 5 min, which will be the period of data collection. The two interventions were conducted on two consecutive days.	Disposable electrodes were positioned, with the negative electrode over the manubrium and the positive and earth electrodes at the left and right axillary lines.
Zuttin et al. (2008) [15]	Cardiac parameters measured during supine and sitting positions	Data were collected for 15 min for both the sitting and supine positions	Electrodes were positioned, with the negative electrode over the manubrium and the positive and earth electrodes at the left and right axillary lines. Sample frequency of 500 Hz was used.

Table 5. Studies included in systematic review, alongside their participant screening criteria, gathered participant information and methods of controlling confounding variables.

Study Name	Participant Screening Criteria	Control of Participant Confounding Variables	Control of Setting Confounding Variables
Chuangchai et al. (2021) [11]	- No cardiovascular diseases - Able to change body posture without assistance. - Aged 60 years or older	- Age - Diseases - Daily drug treatments - BMI (Height + Weight) - Systolic and Diastolic Blood Pressure - Participants refrained from caffeine for at least 12 h before the test. - Must wear comfortable shirts and shorts that are non-conductive materials	- Light source from low ambient artificial light - Room temperature maintained at 25 °C. - Conducted from 9 a.m. to 11 a.m.

Table 5. *Cont.*

Study Name	Participant Screening Criteria	Control of Participant Confounding Variables	Control of Setting Confounding Variables
Santos et al. (2019) [12]	- BMI between 18.5 and 30 kg/m^2 - Free of apparent diseases or physical disorders - Physical activity levels > 150 min/week in the last 6 months - Absence of drug treatment - Male only - Aged 18–40 years old	- Participants must refrain from stimulants, alcoholic drinks, medication, and physical activity for at least 24 h prior to the study. - Participants took questionnaires about their physical health, sedentary behavior levels, sleep quality, and anamnesis for risk stratification	- Quiet environment - Room temperature set between 22 °C and 25 °C. - Conducted from 2 p.m. to 4 p.m.
Wang et al. (2022) [13]	- No cardiovascular, cerebrovascular, metabolic, motor, respiratory, and nervous system diseases - No recent surgery or history of traumatic pain - Male only	- Participants must fast for 2 h before experimental tests - Participants must not drink alcohol, caffeine, and other foods and drugs that would interfere with the test results 24 h prior to data collection. - Participants must fast for 2 h before data collection	- Conducted from 8 a.m. to 11:30 a.m. - Laboratory maintained at 20–24 °C. - Humidity of laboratory maintained between 50 and 56%
Watanabe et al. (2007) [14]	- Free of apparent diseases or physical disorders - Not taking any medication - Non-smokers - Aged 18–35 years old.	- Participants completed general health, cardiovascular, and pre-experimental questionnaires. - Participants were asked to abstain from food and caffeine 4 h before data collection. - Participants were asked to abstain from alcohol and exercise 12 h before data collection	- Air-conditioned laboratory - Utilized white noise to minimize noise disturbance
Zuttin et al. (2008) [15]	- Not on any medication - Non-smokers - Male only	- Participants underwent evaluations on anamnesis, blood tests, physical therapy inspection, heart and lung auscultation, blood pressure, and cardiovascular evaluation. - Participants were told not to consume caffeine or alcohol on the days before the tests, to eat light meals, and not to perform physical activities 12 h before the tests. - Participants were told to have at least 8 h of sleep the night before data collection	- Room temperature maintained between 22 °C and 24 °C. - Relative air humidity maintained between 40% and 60%. - Conducted between 2 p.m. and 6 p.m.

3.4. Risk of Bias Within Studies

The QualSyst tool was employed to evaluate the potential risk of bias across the included studies, and the findings are presented in Table 6. This tool comprehensively examines various aspects of each study, such as study design, sample size adequacy, control of confounding variables, and the alignment of conclusions with the obtained results. Notably, all the studies demonstrated a similar level of quality. Santos et al. [12] achieved the highest score of 0.95, while both Watanabe et al. [14] and Zuttin et al. [15] received slightly lower scores of 0.91. The average score across all papers was 0.93, indicating a low likelihood of bias in the included studies.

Table 6. Risk of bias of included studies evaluated through QualSyst tool.

Criteria		Chuangchai et al. (2021) [11]	Santos et al. (2019) [12]	Wang et al. (2022) [13]	Watanabe et al. (2007) [14]	Zuttin et al. (2008) [15]
1	Question/objective sufficiently described?	2	2	2	2	1
2	Study design evident and appropriate?	2	2	2	2	2
3	Method of subject/comparison group selection or source of information/input variables described and appropriate?	2	2	2	1	1
4	Subject (and comparison group, if applicable) characteristics sufficiently described?	2	2	2	2	2
5	If interventional and random allocation was possible, was it described?	1	N/A	0	N/A	N/A
6	If interventional and blinding of investigators was possible, was it reported?	N/A	N/A	N/A	N/A	N/A
7	If interventional and blinding of subjects was possible, was it reported?	N/A	N/A	N/A	N/A	N/A
8	Outcome and (if applicable) exposure measure(s) well defined and robust to measurement/ misclassification bias? Means of assessment reported?	2	2	2	2	2
9	Sample size appropriate?	1	2	2	1	2
10	Analytic methods described/justified and appropriate?	2	2	2	2	2
11	Some estimate of variance is reported for the main results?	2	2	2	2	2
12	Controlled for confounding?	2	1	2	2	2
13	Results reported in sufficient detail?	2	2	2	2	2
14	Conclusions supported by the results?	2	2	2	2	2
Total		22	21	22	20	20
Total/(28 − (Number of 'N/A' × 2))		0.92	0.95	0.92	0.91	0.91

3.5. Results of Individual Studies and Synthesis of Results

In each of the five studies assessed, frequency domain, i.e., high frequency (HF), low frequency (LF), and the LF/HF ratio, were the main components of HRV with posture. The HF component of the HRV power spectrum reflects parasympathetic activity, and LF reflects a combination of sympathetic and parasympathetic activity [14]. The ratio LF/HF represents the balance between sympathetic and parasympathetic nerves. An increase in the ratio indicates sympathetic activity predominance, and a decrease indicates parasympathetic predominance [13].

The main goal of Chuangchai et al.'s study [11] was to investigate the possible impact of determining HRV in an orthostatic posture compared to sitting. The study found a high and positive correlation between heart rate variability measurements performed while standing and those taken while sitting for autonomic nervous system responses. The study concluded that heart rate variability recordings while sitting may be impacted by orthostatic hypotension; hence, lying down is advised as being the best position for such recordings. Nevertheless, standing, supine, and sitting positions were used to record heart rate variability.

To analyze the data, the study calculated the means, standard deviations, repeated measures ANOVA results, and paired *t*-test results for each HRV marker in the frequency domain. Statistically significant differences among the three postural positions were observed only for the lower and higher frequency markers, with a *p*-value of 0.004 (considered statistically significant if $p < 0.05$).

According to Santos et al. [12], the study findings indicated that sedentary behavior had the strongest association with autonomic cardiac function at rest compared to other lifestyle factors such as sleep quality, caloric expenditure, and light-intensity physical activities. This was evident through alterations in various cardiac parameters, particularly a reduction in heart rate variability (HRV) when transitioning from a resting position to a supine or orthostatic position. A substantial correlation between sedentary behavior and HRV indices was seen in people lying down. Statistical significance was found in all variables between supine and orthostatic postures, with each *p*-value being <0.001 except LF, which had a *p*-value of 0.005, and confidence intervals were calculated at 95%.

Wang et al. assessed changes in cardiac function in various positions to determine underlying reasons for improving the cardiovascular and autonomic nervous systems. The study assessed HRV in seven positions: neutral trunk posture (supine), posterior extension, forward flexion, left lateral flexion, right lateral flexion, left rotation, and right rotation.

In addition to the HF, LF, and LF/HF ratio, the R-R interval was also assessed as a variable for HRV in this study. The R-R of the posterior extension posture was significantly lower compared to forwarding flexion, left flexion, and right flexion postures ($p = 0.047$, $p = 0.026$, $p = 0.025$), and the RR of the right flexion posture was significantly higher than right rotation posture ($p = 0.020$). The LF/HF in the neural position of the trunk was significantly lower than the posterior extension, forward flexion, and right rotation postures with $p = 0.037$, 0.041, and 0.008, respectively. The frequency domain index LF/HF analysis showed that the sympathetic and parasympathetic tensions were relatively balanced at rest, and other postures showed a sympathetic dominance, suggesting that the neutral posture of the trunk is the best resting posture.

This study also showed that a steady decrease in thoracic volume caused by increased trunk inclination enhanced heart rate variability and autonomic tone. This supports the findings of Santos et al. [12].

Watanabe et al. [14] compared heart rate variability parameters in three positions: sitting, prone, and supine. Between prone and supine, there was no significant difference in HRV parameters, but between prone and sitting postures, there was a significant difference in the balance of autonomic drive to the heart, with a shift toward sympathetic dominance during sitting. The HF, LF, and LF/HF values from prone to sitting posture were $p = 0.001$, 0.61, and 0.001, respectively.

Lastly, the Zuttin et al. [15] study compared HRV in sitting and supine positions. They observed a significant decrease in HRV from supine to sitting posture with $p < 0.05$.

4. Discussion

This systematic review consolidated the existing knowledge regarding the association between posture and heart rate variability in sedentary adults. The objective of the study was to determine how lifestyle modifications and therapeutic approaches can be adapted to improve autonomic function and overall health. Heart rate variability (HRV) is a widely recognized cardiovascular risk marker and provides insights into autonomic tone [16]. All five studies included in this review used frequency-domain analysis methodology to assess heart rate variability, facilitating comparisons despite variations in objectives and interventions.

The overall findings from the analyzed studies indicate that the sitting position has a more pronounced impact on heart rate variability and other cardiac markers than supine and prone positions. Wang et al. [17] examined different sitting positions (e.g., forward flexion, posterior extension) and examined their effects in detail. They found that the forward-leaning posture, which is commonly associated with office jobs and sedentary behavior, had the most detrimental impact on autonomic function. Meanwhile, Santos et al. [12] concluded that reducing sedentary behavior may decrease mortality risk.

Chuangchai et al. [11] focused on assessing the influence of sitting and supine postures on heart rate variability measurements. Their results indicated heightened autonomic responses in the sitting position, which is consistent with the findings of Watanabe et al. [14] and Zuttin et al. [15].

Santos et al. [12] primarily aimed to identify behaviors associated with cardiac autonomic function by examining the impacts of vigorous and moderate exercise, sleep quality, caloric expenditure, and sedentary behavior on heart rate variability. Although components unrelated to posture were not addressed in this review, comparisons of the different effects on heart rate variability provided insight into the process between cardiac function and postural stability.

In addition, even though the changes in heart rate variability were insignificant, the influence of sedentary behavior on heart rate variability was identified as the most significant variable associated with a higher mortality risk. This association underscores the importance of reducing time spent in a sedentary state, as it may contribute to poor long-term outcomes. A meta-analysis based on this study suggested that reducing daily sitting time to less than three hours can increase life expectancy by two years [18].

Wang et al. [13] found that trunk posture changes can affect heart rate, cardiac function, and autonomic nerves. Specifically, posterior extension posture significantly increased heart rate and the LF/HF heart rate variability parameter, whereas trunk flexion posture, resembling a hunched sedentary position, decreased cardiac variables. These findings indicate that maintaining a neutral trunk position is optimal for stable cardiac function and balanced sympathetic tone. The results of Wang et al. [13] provide insights into the relationship between posture and autonomic function and provide more specific findings regarding the impact of different spinal manipulations.

Watanabe et al. [14] found that heart rate variability parameters were less affected by transitions from the prone to supine positions than prone to sitting. Another study comparing cardiovascular parameters between the supine and prone postures showed more significant differences, which could be attributed to the sample size, by which the HRV analysis could not reveal related differences in autonomic regulation of the heart. The difference could also be due to methodological differences, as Watanabe et al. had collected data just five minutes after posture changes [19]. It is essential to consider the time interval between data collection and changes in participant posture because these can affect the variables.

Similar to Wang et al. [13] and Watanabe et al. [14], Zuttin et al. [15] reported that HRV parameters indicated a shift to sympathetic dominance during sitting posture. This aligns with the theory mentioned in the introduction that prolonged sitting, especially in a compromised position, alters autonomic function, leading to a decrease in HRV(1). Studying heart rate variability at rest in supine and sitting postures allows for identifying alterations in sympathetic-vagal balance [20]. The conclusion that the sitting position has the most significant impact on heart rate variability is further supported by the precise findings of Wang et al. [13], which delve into the specific truncal inclinations during sitting that influence autonomic function.

Sedentary postures, especially prolonged sitting, negatively impact cardiovascular autonomic function compared to upright or recumbent postures [21]. Adopting a more active lifestyle and minimizing sedentary time can improve autonomic nervous system regulation and reduce the risk of cardiovascular disease. Maintaining a neutral, upright trunk position also aids in improving autonomic regulation and lowering cardiovascular risk [21–23].

4.1. Clinical Implications

Clinical implications of conducting a study on the relationship between heart rate variability (HRV) and position include the following:

Improved Diagnosis and Risk Assessment: Conducting such a study can enhance our understanding of how different body positions affect HRV and autonomic function. This knowledge can aid healthcare professionals in diagnosing and assessing the risk of cardiovascular disorders more accurately. By incorporating position-specific HRV measurements into clinical evaluations, clinicians can obtain valuable information about an individual's autonomic health and potential cardiovascular risks.

Tailored Interventions: The findings of this study can guide the development of targeted interventions aimed at optimizing HRV and autonomic balance. Healthcare practitioners can use this knowledge to prescribe specific postural modifications or exercises that positively influence HRV.

Rehabilitation and Physical Therapy: Understanding the impact of different positions on HRV can be especially relevant in rehabilitation and physical therapy settings. Therapists can design customized treatment plans that involve specific postures and movements to enhance autonomic function and cardiac health. While using HRV measurements during therapy sessions, we noted that progress can be tracked, and adjustments can be made to optimize the rehabilitation outcomes.

Workplace Ergonomics: Work-related postures play a significant role in sedentary individuals' health, as they spend a considerable amount of time in specific positions. Conducting a study on HRV and position can inform the development of ergonomic guidelines for various occupations, helping employers create healthier work environments. Recommendations for optimal postural positions and regular movement breaks can be implemented to mitigate the negative impact of prolonged sitting and improve autonomic function among employees.

Lifestyle Modifications: Findings from the study can motivate individuals to make lifestyle modifications that promote better HRV and autonomic function. Educating the general population about the relationship between posture and HRV can encourage people to adopt healthier postural habits in daily activities and reduce sedentary behaviors. Public health campaigns and educational initiatives can raise awareness and promote the importance of maintaining proper posture for long-term cardiovascular health.

4.2. Limitations of the Included Studies and Their Synthesis

Each of the analyzed papers had specific limitations that are acknowledged and taken into account in this review.

Chuangchai et al. [11] had an imbalanced sample in terms of sex, with a majority of female participants. The study focused solely on an older population (age 70+ years), which may have influenced the results since autonomic control typically decreases with age (add reference). The researchers attempted to control potential confounding variables using an electronic metronome rhythm to standardize breathing patterns, but participants reported experiencing subjective stress during the interventions, which may have influenced the recorded HRV measurements.

Santos et al. [12] had several methodological limitations. All lifestyle aspects were extracted from self-reported questionnaires, and statistical transformation of the data into Log10 hindered the development of formulas that estimate HRV values from behavioral data. In addition, this study had a limited sample size, making it difficult to generate results. Watanabe et al. [14] also had a limited sample size and thus could not reveal related differences in autonomic regulation of the heart.

The timing of interventions in each study varied throughout the day (Table 5). Although this may be considered insignificant, the influence of circadian rhythms should be considered, particularly in studies assessing autonomic function [24]. Furthermore, in Watanabe et al.'s study [14], the prone-supine and prone-sitting interventions were performed on separate days, not accounting for diurnal variation and the participants' circadian rhythm, affecting baseline measurements. Future research should adopt standardized timing and procedures to address these limitations.

In terms of the systematic review itself, several limitations should be acknowledged. Firstly, none of the studies included were RCTs, which could provide a better distribution of characteristics among groups. While random allocation and blinding would be challenging due to the nature of the interventions involving posture changes, it is important to consider this limitation. Additionally, the included studies had relatively small sample sizes, which limited the statistical power and generalizability of the findings.

Secondly, the review included only five studies, which limited the reliability of the synthesized results. The studies exhibited both heterogeneity and homogeneity in various aspects, making it challenging to draw definitive conclusions.

Lastly, some of the analyzed papers did not primarily focus on measuring HRV in terms of posture changes but used HRV as a measurement tool to compare differences among study populations. This made direct comparisons between the results of the papers difficult.

These limitations should be considered when interpreting this review's findings. However, they should not significantly impact the primary results of the review. Despite these limitations, the overall synthesis of the findings provides valuable insights into the relationship between posture and heart rate variability and contributes to our understanding of the impact of body position on autonomic function.

5. Conclusions

Our study enhances our understanding of the relationship between heart rate variability and posture in a sedentary population. This study showed that postural changes led to autonomic adjustments in the parasympathetic and sympathetic nervous systems, as indicated by a difference in HRV parameters. Our findings directly demonstrate the impact of posture on autonomic nervous system activity in sedentary individuals. The consistent findings of sympathetic predominance during sitting, as opposed to supine or prone positions, suggest that prolonged sitting may have negative consequences for cardiovascular health. In the seated position, trunk forward flexion, posterior extension, lateral flexion, and trunk rotation lead to changes in autonomic nerves and cardiac function. This shows that sedentary behavior or long sitting hours, as in the case of office workers, affect posture and cause a change in the neurocardiac system.

Reducing sedentary behavior to less than 3 h and promoting correct sitting posture (reduce forward flexion and sitting with a straight back) during periods of inactivity or use of adjustable/semi-standing desks and comfortable chairs can improve autonomic function and should be a key focus in future ergonomic interventions. Future research should investigate whether intermittent physical activity can mitigate these negative effects. This has direct implications for developing effective workplace interventions. This approach would be particularly relevant considering that many office workers engage in prolonged periods of sedentary behavior followed by short bouts of exercise as part of their daily routines.

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Protocol and Registration: This systematic review has been registered under point 24 a/b/c of PRISMA guidelines in the INPLASY database with the registration number INPLASY202460055.

Appendix A. Search Terms from Each Database

Database	Search Terms	Document Search Result
PubMed	((Posture OR Pose OR Stance OR Position OR Kyphosis OR Lordosis) AND (Sedentary lifestyle OR Inactive OR Sedentary behaviour OR Desk-bound OR Idle OR Seated OR Stationary)) AND (Heart rate variability OR Cycle length variability OR HRV)	416
Embase	'posture'/exp OR posture OR pose OR 'stance'/exp OR stance OR 'position'/exp OR position OR 'kyphosis'/exp OR kyphosis OR 'lordosis'/exp OR lordosis AND (heart AND rate AND variability OR cycle) AND length AND variability OR hrv AND (sedentary AND lifestyle OR inactive OR sedentary) AND behaviour OR 'desk bound' OR idle OR seated OR stationary	97
Web of Science	(((((ALL = (Posture)) OR ALL = (Pose)) AND ALL = (Stance)) OR ALL = (Position)) OR ALL = (Kyphosis)) OR ALL = (Lordosis) AND ((ALL = (Heart Rate Variability)) OR ALL = (Cycle length variability)) OR ALL = (HRV) AND ((((((ALL = (Sedentary Lifestyle)) OR ALL = (Inactive)) OR ALL = (Sedentary behaviour)) OR ALL = (Desk-bound)) OR ALL = (Idle)) OR ALL = (Seated)) OR ALL = (Stationary)	151
Cochrane	(heart NEXT (rate*) NEXT (variability*)) OR (cycle NEXT (length*) NEXT (variability*)) AND (posture) OR (pose) AND (stance) AND (position) AND (kyphosis) (Word variations have been searched) AND (sedentary NEXT (lifestyle* OR behaviour*)) OR (sedentary): OR (stationary):ti,ab,kw OR (seated):ti,ab,kw OR (desk NEXT (bound*)):ti,ab,kw	0

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