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Systematic Review

Acute and Chronic Effect of Resistance Training on Cardiac Autonomic Function in Patients with Chronic Obstructive Pulmonary Disease: A Systematic Review

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Abstract

This systematic review aimed to evaluate the acute and chronic effects of resistance training (RT) on cardiac autonomic function in patients with chronic obstructive pulmonary disease (COPD). Following Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines, this review was registered in International Prospective Register of Systematic Reviews (CRD4202127541). A systematic search was conducted across PubMed, Web of Science, and Scopus using predefined search criteria. Studies were included if RT was the primary intervention and autonomic markers were assessed in COPD patients. Research involving other exercise types or significant comorbidities was excluded. From 5,159 records, five studies comprising 129 participants met the criteria. Interventions varied from single acute RT sessions to training programs lasting up to eight weeks. All studies measured heart rate variability (HRV), with most reporting significant improvements in time-domain measures and mixed results for frequency-domain parameters. Risk of bias was assessed with the Risk of Bias in Non-randomized Studies of Interventions tool, and evidence quality was appraised using Grading of Recommendations Assessment, Development, and Evaluation approach. Acute RT produced immediate but short-lived changes in autonomic function, while chronic RT consistently improved HRV time-domain indices. RT appears to beneficially influence cardiac autonomic regulation in COPD patients, as reflected by enhanced HRV parameters. These results support RT's role in addressing both muscular and cardiovascular health in this population. However, the limited number of studies, methodological differences, and serious risk of bias highlight the need for larger, well-designed randomized controlled trials to strengthen the evidence base.

KEYWORDS: Cardiac autonomic function, chronic obstructive pulmonary disease, heart rate variability, resistance training

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INTRODUCTION

Chronic obstructive pulmonary disease (COPD) affected 10.6% of the population in 2020 and is still a growing global health concern.[1] The Global Initiative for Chronic Obstructive Lung Disease (GOLD) 2023 report, defines COPD as, "a heterogeneous lung disease that causes persistent, frequently worsening airflow obstruction due to abnormalities of the airways (bronchitis, bronchiolitis) and/or alveoli (emphysema) leading to chronic respiratory symptoms (dyspnea, cough, expectoration, exacerbations)."[2] COPD not only affects the lungs but also causes systemic manifestations, such as musculoskeletal dysfunction, which diminish exercise capacity and quality of life, and autonomic dysregulation, which increases cardiovascular risks. These effects are largely driven by systemic inflammation, oxidative stress, and chronic hypoxia, which impair baroreflex sensitivity (BRS) and promote sympathetic overactivity. Autonomic dysfunction, marked by impaired heart rate variability (HRV), heart rate recovery (HRR), and BRS is a significant predictor of mortality.[3,4]

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Autonomic regulation of the heart is mediated by the sympathetic and parasympathetic branches of the autonomic nervous system, which function involuntarily. Cardiac autonomic control is a key indicator of cardiovascular health.[5] Impaired autonomic control is associated with increased cardiovascular and all-cause mortality, as demonstrated in prospective cohort studies.[6] This can be clinically evaluated by measuring HRV, BRS, and post-exercise HRR using linear and non-linear methods.[7,8] HRV, in particular, provides a non-invasive measure of autonomic function by analyzing the variability between successive R-R intervals on an electrocardiogram.[9] A previous systematic review by Mohammed et al.[10] reported a strong level of evidence for decreased HRV, reduced BRS, and increased muscle sympathetic nerve system (SNS) activity, suggesting potential sympathetic dominance in COPD.

COPD is managed effectively by assessment, reduction of risk factors, achieving stable conditions, and treatment of exacerbations. Among non-pharmacological interventions, pulmonary rehabilitation stands out as one of the most effective treatment options for COPD.[3,11] For those patients with peripheral muscle weakness, the combination of resistance training (RT) and endurance training is recommended.[12] A meta-analysis by Bhati et al.[13] comprising 21 studies across various clinical populations found that RT significantly improves cardiac autonomic control. However, this evidence is not COPD-specific, highlighting the need for a systematic review to evaluate RT's autonomic effects, specifically in COPD patients.[13] Regarding COPD, a systematic review showed aerobic exercise training positively impacted most parameters of autonomic function, but a limited extent on the frequency domain parameters of autonomic function in COPD.[14] RT effects on cardiac autonomic function can be categorized into acute and chronic outcomes. Immediate changes in autonomic regulation following a single session of RT are referred to as an acute effect, while chronic effects are the changes that evolve as a sustained training over weeks or months. Understanding these distinct effects is essential for optimizing exercise prescriptions in COPD rehabilitation programs, as improving autonomic function could decrease cardiovascular risk and improve overall health outcomes.

The available data in the literature suggest that RT may lead to improvement in autonomic functions in COPD patients. However, a deeper understanding awaits a synthesis of the literature. The focus of our review is to assess the effects of one component of pulmonary rehabilitation and physiotherapy, specifically RT, on the autonomic function indices in COPD patients. However, its specific impact on cardiac autonomic function is less well understood. Studies investigating the impact of RT on the autonomic markers and outcomes have not been consistent. This systematic review aims to evaluate the acute and chronic impacts of RT on cardiac autonomic function in COPD patients. By summarizing the findings from existing studies, this review seeks to clarify the role of RT in autonomic modulation and identify gaps in the literature that warrant further investigation.

MATERIAL AND METHODS

This review is conducted to evaluate the acute and chronic impacts of RT on cardiac autonomic function in individuals with COPD in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement.[15] The protocol for this systematic review is registered in the International Prospective Register of Systematic Reviews (PROSPERO) under registration number: CRD42021275418.

1. Inclusion and Exclusion Criteria

Inclusion criteria of the review: Only studies randomized controlled trials (RCTs), non-RCTs, or pre-post experimental studies that examine the impact of RT on autonomic function in COPD patients were considered. Study participants must have COPD as outlined by GOLD criteria (forced expiratory volume in 1 second <0.70). The review focused on studies that include RT as the primary intervention and that assess parameters related to autonomic nervous system function, such as HRV, including linear, non-linear, geometric, and fractal indices, HRR, and BRS. Additionally, studies must be published in English and report on findings that are directly relevant to RT in COPD.

Studies were excluded if they involved exercise interventions other than RT (e.g., yoga, Tai Chi, inspiratory muscle training, aerobic exercise, or multicomponent pulmonary rehabilitation) or if they reported COPD exacerbations during or after the intervention. Studies that were not original research, such as reviews, case reports, theses, conference papers, and pilot studies, and epidemiological study designs like cross-sectional, cohort, and case-control studies were excluded. Additionally, studies including participants with significant comorbid conditions that could confound the assessment of autonomic function, such as uncontrolled hypertension, heart failure, or diabetes, should be excluded unless these conditions were adequately controlled or accounted for in the analysis.

2. Search Strategy and Information Sources

To find clinical trials that assessed the RT impact on cardiac autonomic function in patients with COPD, a methodical literature search was carried out across several electronic databases, including PubMed, Web of Science, and Scopus. We did not include grey literature (such as conference abstracts and theses) or unpublished studies in our search. The search terms were carefully selected to encompass key concepts related to the intervention, outcomes, and population of interest. For the intervention, terms such as "resistance exercise," "resistance training," and "strength training" were used. Outcome variables were described using terms such as "cardiac autonomic control," "heart rate variability (HRV)," "baroreflex sensitivity (BRS)," "arterial baroreflex function," "heart rate recovery (HRR)," and "autonomic function." The population of interest was described using the terms "COPD" and "chronic obstructive pulmonary disease." Boolean operators "AND" and "OR" were employed to connect these terms, ensuring that the search yielded relevant and focused results. In addition to the database search, the reference lists of every primary article were manually examined, to find more relevant research.

This step was included to ensure the review captured all potentially important studies, including those not indexed in the primary databases. The exact search strategy used in PubMed was as follows: ("resistance exercise" OR "resistance training" OR "strength training") AND ("cardiac autonomic function" OR "heart rate variability" OR "heart rate recovery"

OR “baroreflex sensitivity” OR “arterial baroreflex function”) AND (“COPD” OR “chronic obstructive pulmonary disease”). Although this strategy was tailored for each database, it ensured that all relevant studies were captured across PubMed, Web of Science, and Scopus. In order to assess if an article met the inclusion criteria, it was initially screened by evaluating its titles and abstracts. Abstract screening is conducted as an initial step to evaluate compliance with inclusion criteria. Subsequently, articles which did not meet all of the criteria were excluded from the review.

3. Selection of Studies

The search strategy was applicable to each database, and the studies obtained were processed using the Mendeley Desktop reference manager, where results were combined and duplicates were removed. Author A.N. assessed the remaining papers’ titles and abstracts using the predetermined inclusion and exclusion criteria. At this point, studies that failed to meet the inclusion requirements were eliminated.

For articles that passed the title and abstract screening, the full texts were obtained for further evaluation. Full-text screening was conducted by author A.N. to ensure that the studies met all inclusion criteria. Any disagreements that arose during the screening were resolved through discussions with a second author (S.Z.). If consensus could not be reached, a third author (A.M.) was consulted to resolve the disagreement. Additionally, all full-text article references that were included in the review were further reviewed to ensure no relevant studies were missed (Figure 1).

4. Data Extraction

Comprehensive information was gathered for each included study using a standardized data extraction form. Extracted data included study characteristics such as author, year of publication, study location, and study design, participants’ characteristics (e.g., sample size, age, body mass index, and spirometry measures), and detailed descriptions of the intervention (e.g., type of RT, intensity, frequency, volume, progression, number of sessions, and supervision). For studies that included a control group, the control treatment was also described. The key measures related to autonomic function were extracted, including various HRV indices such as linear, non-linear, geometric, and fractal measures. Finally, the main findings of each study regarding the effects of RT on autonomic function were documented (Table 1).

Disagreements arising from the data extraction methods in between reviewers were resolved either through consensus discussions or through the inclusion of a third author (A.M) at certain stages. This process ensured that data extraction was thorough and accurate, providing a solid foundation for the subsequent analysis and synthesis of the included studies. To achieve a reliable synthesis of evidence, this review focused on all relevant research on the impact of RT on cardiac autonomic function in COPD patients, using a thorough search strategy.

Main Points

- Following Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines, five studies (n = 129) were analyzed after screening 5,159 records. Heart rate variability (HRV) parameters (time and frequency domains) were assessed using Risk of Bias in Non-randomized Studies of Interventions and Grading of Recommendations, Assessment, Development, and Evaluations for bias and evidence quality.
- Resistance training (RT) improved time-domain HRV (e.g., standard deviation of normal to normal intervals, root mean square of successive differences) consistently, while the frequency-domain outcomes (low frequency/ high frequency ratio) were mixed. Acute RT induced short-term autonomic changes, whereas chronic RT (up to 8 weeks) showed sustained benefits. Non-linear HRV measures improved (RR triangular index, triangular interpolation of the NN interval histogram, SD1/SD2).
- RT appears beneficial for cardiac autonomic regulation in chronic obstructive pulmonary disease, but larger randomized controlled trials are needed to confirm findings and optimize training protocols.
- Small sample sizes, methodological heterogeneity, and serious bias risk limit conclusions.

5. Quality Assessment

The quality of the included studies was evaluated based on two established frameworks: the Risk of Bias in Non-randomized Studies of Interventions (ROBINS-I) tool for non-randomized studies and the Grading of Recommendations, Assessment, Development, and Evaluations (GRADE) approach for evaluating the overall quality of evidence. These tools provided a comprehensive evaluation of both study-level bias and the strength of evidence for the outcomes of interest.

5.1. Risk of Bias in Included Studies

The quality assessment of the non-randomized studies of interventions was performed using the ROBINS-I tool.[16] This tool, which was developed specifically to assess the risk of bias in non-randomized research, examines studies in seven key areas: confounding bias, participant selection bias, intervention classification bias, deviations from intended interventions, missing data bias, outcome measurement bias, and reported result selection bias. Each domain has signalling questions intended to direct the evaluation of bias for every criterion that assist in forming a conclusion on the risk of bias for the study. Since the majority of studies included in this review were non-randomized or pre–post intervention trials, the use of ROBINS-I was considered appropriate as it provides a structured, domain-based evaluation that aligns with Cochrane standards for non-randomized evidence.

Two authors, A.N. and S.Z., assessed bias risk for each study individually across the seven domains, reconciling disagreements through discussion. A third author, A.M., was consulted to make the final decision in instances where consensus could not be reached. Each domain was given a judgment as low, moderate, serious, critical risk, or no information. Responses to signaling questions within the domains determine the level of risk categorization.[16]

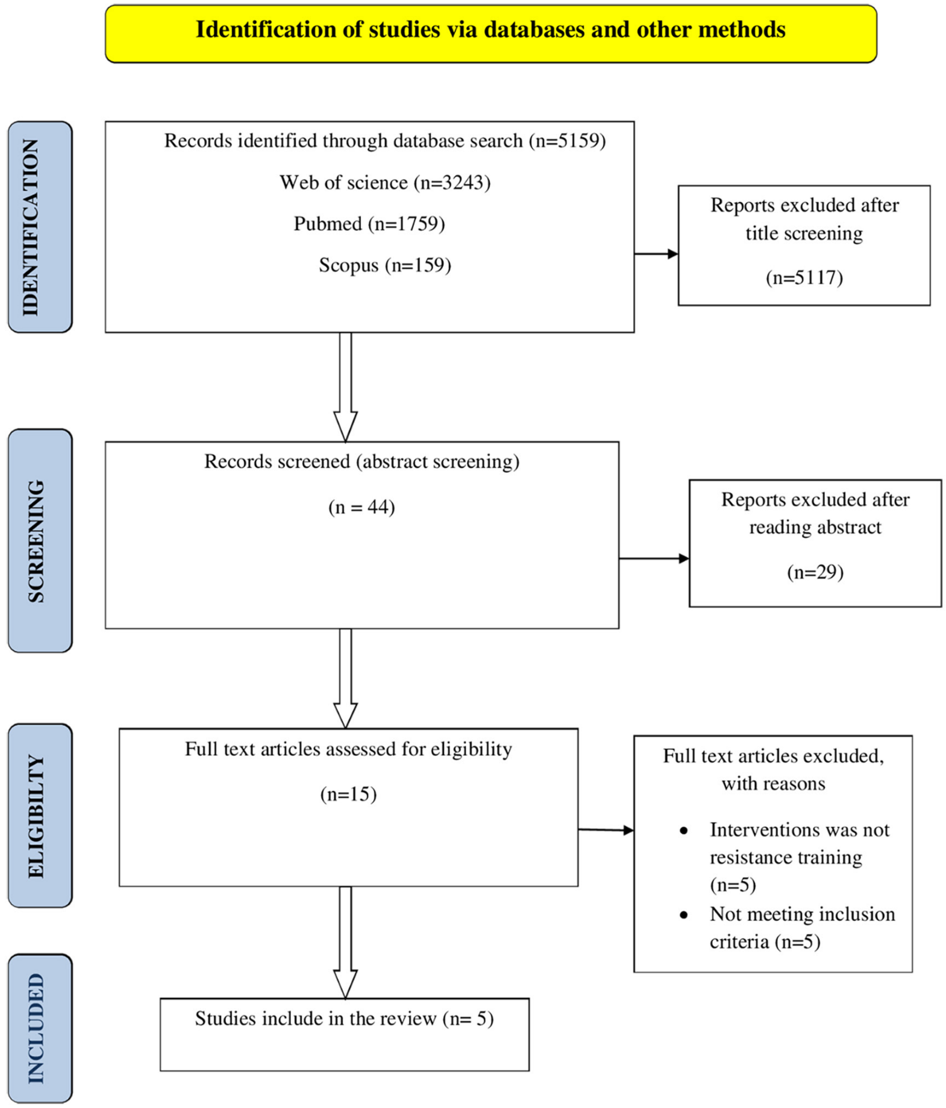

Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow chart

The final risk of bias assessment for each study was based on the cumulative risk judgments across the seven domains. Every domain has to be rated at low risk for the study to be labeled a low risk of bias. Any single domain with a moderate level of concern limits the assessment to moderate concerns. More than one domain with serious concerns, or a single domain with high risk, is labeled as high risk of bias. By summarizing the risk of bias assessment results for each domain across the included research, a clear indication of the methodological limitations and potential biases in the review was then provided. For every domain, a summary of the included studies' risk of bias is provided (Figures 2, 3).

5.2. Quality of Evidence

The overall quality of the evidence supporting each outcome was evaluated using the GRADE approach.[17] GRADE was applied to evaluate the strength of evidence related to the outcome, i.e., HRV. The GRADE framework assesses the quality of evidence in five primary areas: risk of bias, inconsistency, indirectness, imprecision, and publication bias.

The risk of bias in the included studies was initially evaluated using the ROBINS-I tool. Studies with low risk across all domains positively influenced the overall GRADE rating. However, the presence of serious or critical bias in key studies resulted in a downgrade of the evidence quality. Inconsistency was assessed by examining heterogeneity in study outcomes, and any unexplained variations among results also led to a reduction in the quality of evidence. The domain of indirectness was assessed based on how closely the study populations, interventions, and outcomes aligned with the review's objectives. Imprecision was related to sample size and confidence intervals, with smaller studies or wide intervals reducing certainty about the effect estimates, which resulted in lower GRADE ratings. Publication bias was considered in terms of the likelihood that only studies with positive results were published, thus skewing the overall body of evidence.

The GRADE evaluation categorized the overall quality of evidence as high, moderate, low, or very poor. High-quality evidence suggests strong confidence in the findings, while lower levels indicate greater uncertainty and the need for further research. The combined use of ROBINS-I and GRADE ensured

Table 1. Characteristics and results of included studies on resistance exercises

Author/year/ study location	Study design	Sample size	Intervention Methods control and exercise supervised or unsupervised	Outcomes	Findings
Ricci-Vitor et al.,[18] 2013 Brazil	Single arm-pre post experimental trial	n = 20 Age=68 BMI=27.18 FEV1=46.93 FVC=70.12 FEV1/FVC=56	24 morning sessions Frequency – 3/week Intensity – 60% of 1RM and progressed to 80% Volume – 3 sets of 10 repetitions Type – global stretching, lower limb strength training (knee flexion and extension on leg extension); upper limb strength training (shoulder flexion and extension and elbow flexion on simple pulley) Time – 60 min	Time domain, RMSSD SDNN Frequency domain, LF HF	 ↑ ↑ ↑ ↑
Santos et al.,[21] 2017 Brazil	Single arm-pre post experimental trial	n = 21 Age = 68.50 BMI= 26.70 FEV1=47.54% FVC=70.15% FEV1/FVC=55.30%	24 morning session Frequency – 3/week Intensity – 60% of 1RM and progressed to 80% Volume – 3 sets of 10 repetitions Type – global stretching, lower limb strength training (knee flexion and extension on leg extension); upper limb strength training (shoulder flexion and extension and elbow flexion on simple pulley) Time – 60 min	RRtri TINN (ms) SD1 (ms) SD2 (ms) SD1/SD2	↑ ↑ ↑ ↑ →
Ricci-Vitor et al.,[20] 2018 Brazil	Non randomised control trial	n = 55 Elastic tubing (n = 27) BMI=26.47 FEV1=52.34 FVC=70.17 FEV1/FVC=54.60	Frequency – 3 times a week Warm-up before, and cool-down at the end of the session. Resistance elastic tubing training for upper and lower limbs. Two sets and volume of exercise was increased by one set every two sessions upto seven sets. 2 minutes rest interval between each set.	RMSSD (ms) SDNN (ms) LF (ms^2) HF (ms^2) LF/HF VLF (ms) TINN RRtri SD1 (ms) SD2 (ms) SD1/SD2	↑ ↑ ↑ ↑ ↑ ↑ ↑ ↑ ↑ ↑ ↑
		Conventional training (n = 28) BMI=25.13 FEV1=41.45 FVC=69.97 FEV1/FVC=50.2	Conventional training: using weight lifting with pulley equipment. Three sets of 10 repetitions at 60-80% 1 RM were performed.	RMSSD (ms) SDNN (ms) LF (ms^2) HF (ms^2) LF/HF VLF (ms) TINN RRtri SD1 (ms) SD2 (ms) SD1/SD2	↑ ↑ ↑ ↑ ↓ ↑ ↑ ↑ ↓ ↑ ↑

Table 1. Continued

Author/year/ study location	Study design	Sample size	Intervention Methods control and exercise supervised or unsupervised	Outcomes	Findings
Ricci-Vitor et al.,[19] 2014 Brazil	Single arm-Longitudinal clinical trial	n = 21 Age=68.50 BMI (kg/m²)=26.70 FEV1 (%)=47.54 FVC (%)=70.14 FEV1/FVC (%)=55.3	24 morning sessions Frequency – 3/week Intensity – 60% of 1 RM and progressed to 80% Volume – 3 sets of 10 repetions Time – 60 min Type - global stretching (trunk, arm and leg muscles) at the beginning and end of the session, strength training for lower limbs (knee flexion and extension), strength training for the upper limbs (shoulder flexion, shoulder abduction and elbow flexion).	RMSSD (ms) SDNN (ms) LF (ms^2) HF (ms^2) LF (nu) HF (nu)	↑ ↑ ↑ ↑ → →
Nicolino et al.,[22] 2015 Brazil	Cross-over design	n = 12 Age=66 BMI=23 FEV1=42 FEV1/FVC=42	Intensity – 60% and 90% RM Time – 50 min Type – weight training equipment by pulley Volume – 3 series of 10 reps with 1 min rest intervals	Time domain, RMSSD SDNN Frequency domain, LF (ms) LF (nu) HF (ms) HF (nu) LF/HF	I 5 10 15 ↑ ↑ ↑ ↑ ↑ ↑ ↑ ↑ ↑ ↑ ↑ ↑ ↓ ↑ ↓ ↑ ↑ ↑ ↑ ↓ ↑ ↓ ↑ ↑ ↑ ↑ ↓ ↓

N: sample size, BMI: body mass index, FEV1: forced expiratory volume in one second, FVC: forced vital capacity, RM: repetitions maximum, RMSSD: root mean square of successive differences, SDNN: standard deviation of normal to normal intervals, LF: low frequency, HF: high frequency, VLF: very low frequency, TINN: triangular interpolation of the NN interval histogram, RRtri: RR triangular index, SD1: standard deviation of width of Poincaré plot, SD2: standard deviation of length of Poincaré plot, nu: normalized units, ms: milliseconds

(↑ = increase; ↓ = decrease; → = no change)

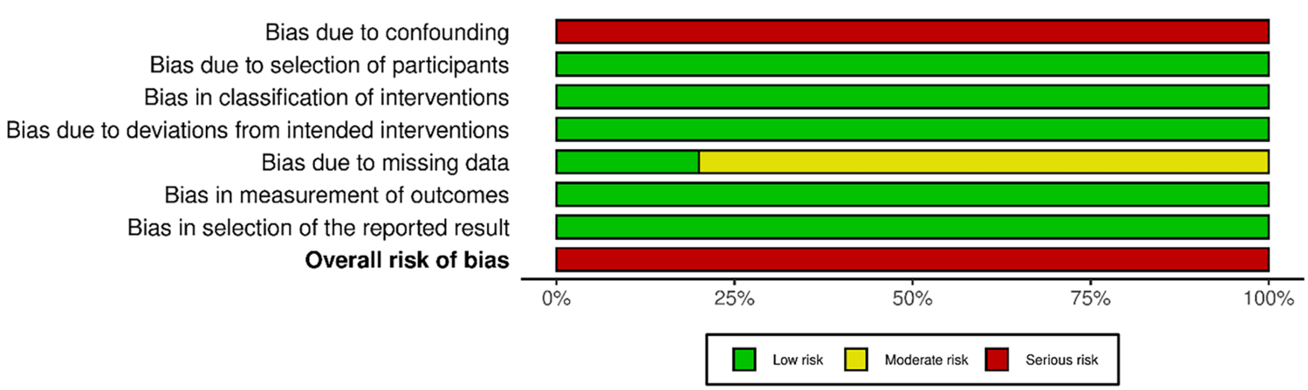

Figure 2. Summary of the included studies by Risk of Bias in Non-randomized Studies of Interventions

a thorough and transparent evaluation of both individual studies and the overall strength of the evidence in this review.

RESULTS

Figure 1 shows that a total of 5,159 studies were initially identified across various databases: 3,243 from Web of Science, 1,759 from PubMed, and 159 from Scopus. After title screening, 5,117 articles were excluded, resulting in 44 studies being selected for abstract screening. Of these, full texts were obtained for 15 articles, which were then assessed based on predefined inclusion and exclusion criteria. During this process, five articles did not meet the inclusion criteria, and an additional five involved interventions that were not related to RT.

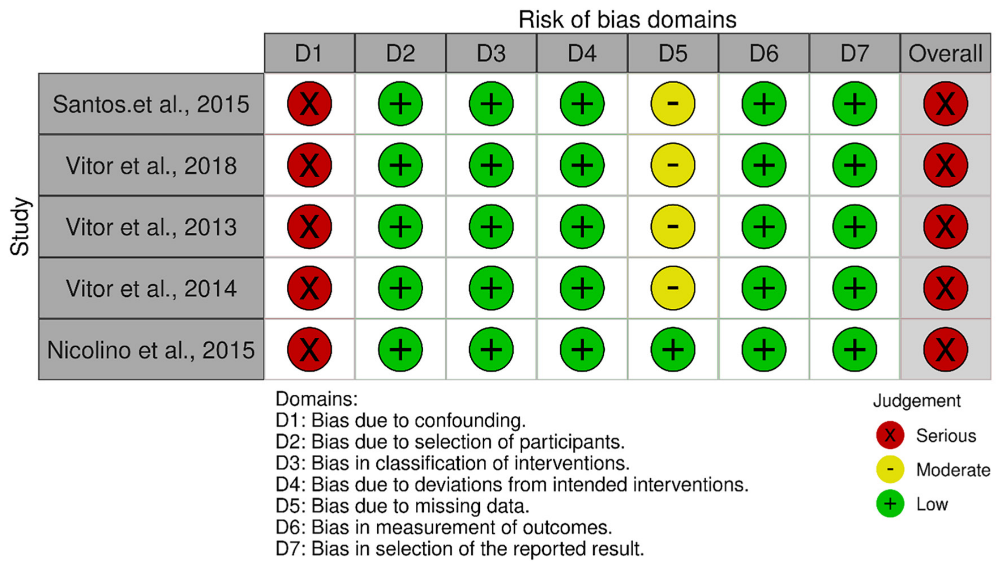

Figure 3. Summary of the included studies by Risk of Bias in Non-randomized Studies of Interventions

1. Participants

Five studies[18-22] consisted of 129 COPD patients with each study's sample size varying between 12 and 55. Variation in sample sizes (12-55 participants) among included studies likely contributed to heterogeneity in the findings. The mean age of the group was 68.50 years, with interventions ranging from one session (acute) to eight weeks of RT (chronic). Among the five included studies, four 18-21 evaluated chronic RT effects, while one[22] assessed acute effects following a single RT session. All studies solely assess cardiac autonomic function by using HRV. HRV was assessed using linear analysis (time and frequency domains) in three studies,[18,19,22] while one study,[21] used only non-linear analysis. Another study[20] employed both linear and non-linear methods for HRV analysis.

2. Exercise Training Interventions

Each study utilized dynamic RT as an intervention. The majority of the studies used a pulley system, while one study used elastic tubing[20] for RT. Exercise intensity was set at moderate to high intensity and was based on repetition maximum (RM) in the majority of the trials,[18,19,21,22] except in one study that was based on maximum voluntary contraction.[20] The duration of the interventions varied, with some studies implementing sessions three times per week lasting 50-60 minutes, ranging from a single bout of RT (acute), to an extended program lasting 8 weeks (chronic).

3. Outcome Measures

All studies included in the analysis evaluated and reported HRV as an indicator of cardiac autonomic regulation. The majority of studies reported linear HRV indices,[18-20,22] while one study also incorporated non-linear measures.[20] Another study specifically focused on non-linear HRV assessment using geometric indices, without including linear measures.[21] Additionally, one study analyzed the fractal characteristics of heartbeat intervals through detrended fluctuation analysis (DFA), reporting Alpha1, Alpha2, Alpha1/Alpha2 ratios, and overall DFA indices.[20] All studies employed short-term HRV recordings for their assessments.[18-22] HRV was measured under resting conditions in all studies,[18-22] with one study also evaluating post-exercise HRV at 5, 10, and 15 minutes after exercise.[22]

4. Heart Rate Variability

Following RT, all studies showed improved adaptation in cardiac autonomic regulation. Linear measures of HRV - standard deviation of N-N intervals (SDNN), low frequency (LF) ms^2, and high frequency (HF) ms^2 were significantly increased after RT in the majority of the study.[18-20] One study reported geometric indices of HRV observed significant increased in triangular index of R-R interval histogram (RRtri), triangular interpolation of N-N interval histogram (TINN), standard deviation 1 (SD1) which measures short-term HRV derived from Poincaré plot & SD2 which measures long-term HRV also from Poincaré plot and SD1/SD2 ratio after training.[21] Following an acute session of RT, SDNN showed a significant increase at all recovery time points, whereas root mean square of successive differences between N-N intervals (RMSSD) remained unchanged from baseline at both 60% and 90% of 1RM. In the frequency domain, there was a significant rise in LF (ms^2) and HF (ms^2), while LF (nu), HF (nu), and the LF/HF ratio showed no significant changes during any recovery time point for both intensity levels.

4.1. Time Domain Parameter

SDNN: The data from two studies revealed significant improvement in SDNN after the exercise program.[18,19] However, one study showed no statistically significant difference between the effect of elastic tubing and conventional training.[20] The acute effect of RT did not show significant differences between the protocols at all time points analyzed ($P > 0.05$). Regardless, SDNN was significantly higher at all timepoints after RT relative to baseline at both 60% and 90% of 1 RM.[22]

RMSSD: One study reported a significant increase in RMSSD following the exercise program when comparing pre- and post-intervention values,[19] while another study observed an increase in RMSSD that did not reach statistical significance.[18]

Additionally, a separate study found no significant differences between elastic tubing and conventional training protocols. However, intra-group analysis revealed a statistically significant increase in RMSSD.[20] Regarding the acute effects of RT, RMSSD showed no significant changes across any of the time points analyzed.

4.2. Frequency Domain Parameters

LF ms²: Only one study shows LF significantly increased after the exercise program.[18] The acute effect of RT shows that the LF (ms²) index is greater during all recovery times compared to rest, for both 60% and 90% of 1RM protocols.[22] Other studies show no significant differences after the exercise program.[19,20]

HF ms²: One study shows HF significantly increases after the exercise program.[18] The acute effect of RT shows that the HF ms² index is higher during all recovery periods compared to rest in both the 60% and 90% of 1RM protocols.[22] However, one study shows no significant differences before and after the exercise program.[19] One study shows no statistically significant differences between the effect of elastic tubing and conventional training; however, intra-group differences showed a significant increase in HF.[20]

LF/HF: The data from two studies revealed no statistically differences when compared before and after exercise and training.[20,22] The acute effect of RT showed LF/HF decrease immediately, 10 and 15 minutes after the exercise session, but improves after 5 minutes.[22] One study revealed LF/HF increases after elastic tubing training and decreases after conventional training.[2]

DISCUSSION

The objective of this systematic review is to explore the most recent evidence on the influence of RT on cardiac autonomic function in patients with COPD as measured by HRV. Although RT shows promise as a non-pharmacological intervention for autonomic regulation in COPD, the current evidence is based on a small number of studies with methodological variability. The inconsistencies in findings, particularly for frequency-domain HRV parameters, suggest the need for cautious interpretation.

An efficient non-invasive way to assess autonomic function is to use HRV. The overall activity of autonomic nerve function is represented by the time domain parameter SDNN. The frequency domain parameter LF, is mainly mediated by sympathetic activity. Parasympathetic activity is represented by the RMSSD and pNN50.[23] Impaired cardiac autonomic control has been shown in prospective longitudinal cohort studies to be a strong predictor of all-cause and cardiovascular disease mortality, and it can be diagnosed clinically by HRV.[13,24] Previous research showed that RT significantly improved cardiac autonomic regulation in clinical populations.[13] Our research revealed that the frequency domain parameter exhibits inconsistent results, while the time domain parameters SDNN and RMSSD are significantly improved. These findings suggest that RT can enhance parasympathetic activity and sympatho-vagal balance in patients with COPD. The findings align with prior systematic review by Bhati et al.[13] which demonstrated a significant improvement in cardiac autonomic control across diverse populations with various health conditions following RT. The meta-analysis concluded that RT enhances vagal tone, reflected in improved HRV indices. Our findings align with a previous review that reported enhanced cardiac autonomic control following RT in various populations, and demonstrate similar improvements in parasympathetic activity among COPD patients.[13] Notably, one study using non-linear HRV analysis (geometric and fractal measures) also observed significant improvements, reinforcing the beneficial effects of RT on autonomic function.[21] Contrary to Camillo et al.[25] suggested that aerobic exercise is superior for autonomic modulation, our results indicate that RT also plays a significant role, especially when considering non-linear HRV indices, which may capture autonomic dysfunction more sensitively in COPD.[25]

Acute Effects of RT: Acute bouts of RT were associated with transient improvements in HRV indices, indicating a short-term parasympathetic rebound post-exercise. For instance, studies reported significant increases in time-domain parameters such as SDNN and RMSSD immediately following RT sessions.[22] These findings suggest that even a single session of RT can elicit favorable autonomic responses, potentially reducing cardiovascular stress in the short term.

Chronic Effects of RT: Chronic RT programs, typically lasting 8 weeks, demonstrated more pronounced and sustained improvements in autonomic regulation. Most studies reported significant improvement in time-domain HRV indices (e.g., SDNN, RMSSD) and some frequency-domain parameters (e.g., LF, HF).[18-20] These long-term adaptations suggest that regular RT can enhance parasympathetic activity and improve sympatho-vagal balance, which is crucial for reducing cardiovascular risk in COPD patients.

The improvement in HRV following RT may be attributed to several physiological mechanisms. RT improves BRS, which is often impaired in COPD due to chronic inflammation and oxidative stress.[21] Increased muscle strength and endurance reduce exertional sympathetic overactivity, allowing for better parasympathetic reactivation.[20] COPD patients often exhibit elevated SNS activity due to chronic hypoxia and systemic inflammation.[26] RT may attenuate SNS hyperactivity by improving cardiovascular efficiency and reducing resting heart rate.[18] RT enhances stroke volume and cardiac output, reducing the heart's workload at rest, which may contribute to better HRV.[22] Increased nitric oxide bioavailability from endothelial adaptations post-RT may also improve autonomic balance.[21] Chronic inflammation in COPD contributes to autonomic dysfunction.[26] RT has been shown to reduce pro-inflammatory cytokines, which may indirectly improve HRV.[20]

Despite the overall positive findings, significant heterogeneity was noted in the assessment methods and exercise protocols across studies. For example, while most studies used linear HRV indices, non-linear measures were less frequently reported but provided additional insights into autonomic modulation complexity. Variability in exercise intensity, volume, and type (e.g., pulley systems vs. elastic tubing) might have influenced outcomes, particularly in frequency-domain parameters like LF/HF ratio. This variability underscores the need for standardized protocols in future research to ensure consistent and comparable results.[21]

However, variability in methods and outcomes among studies necessitates caution in generalization. For instance, one study[20] showed significant within-group improvements, while others reported mixed results for specific HRV indices, particularly in frequency-domain parameters like LF/HF ratio. Furthermore, differences in RT intensity, volume, and type might have influenced outcomes. For instance, frequency-domain parameters such as LF/HF ratios showed mixed results across studies, as seen in Ricci-Vitor et al.[20] and Nicolino et al.[22] This variability might stem from differences in exercise intensity, methodology, or patient heterogeneity. Consistent with earlier reviews Mohammed et al.[14] also noted such inconsistencies in aerobic training studies, suggesting that autonomic responses can vary significantly based on the type and context of exercise.

The majority of the included studies were small-scale, non-randomised or single-arm trials with limited sample sizes (ranging from 12 to 55 participants), which weakens the strength of the evidence. The exclusion of unpublished studies may have introduced potential bias. Across multiple domains, the risk of bias was generally moderate to high, mainly due to confounding variables and inconsistencies in intervention protocols. Although HRV was frequently measured, other indicators of autonomic function such as HRR and BRS were not evaluated. Incorporating these additional markers in future studies could lead to a more comprehensive understanding of RT effects on cardiac autonomic regulation in COPD. The GRADE assessment also reflected moderate to low confidence in the overall evidence quality. While the ROBINS-I tool was used for risk of bias assessment, its applicability is limited for single-arm pre-post studies, which comprised a significant portion of the included research; in such cases, alternative tools like the NIH Quality Assessment Tool may provide more appropriate evaluation. To address these limitations, upcoming research should focus on larger, well-designed RCTs with standardized methods. Furthermore, assessing the impact of RT on a broader range of autonomic outcomes and across more diverse COPD populations would help strengthen its potential clinical relevance.

CONCLUSION

RT appears to positively modulate cardiac autonomic function in COPD patients, with both acute and chronic benefits evident in improved HRV indices. While this review supports the potential of RT to improve cardiac autonomic function in COPD, particularly in time-domain HRV measures, limitations such as small sample sizes, heterogeneity of protocols, and a high risk of bias underscore the need for more rigorous trials. These trials are necessary before widespread clinical adoption. Future investigations should aim to address current gaps, standardize protocols, and validate findings in diverse and larger cohorts to integrate RT as a core component of COPD rehabilitation programs.

Ethics

Footnotes

Authorship Contributions

Concept: A.N., A.M., Design: A.N., A.M., S.Z., Data Collection or Processing: A.N., A.M., Analysis or Interpretation: A.N., A.M., S.Z., Literature Search: A.N., Writing: A.N., S.Z.

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