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REVIEW

Exercise Interventions in the Management of Postural Orthostatic Tachycardia Syndrome: A Scoping Review

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Objective: This review aims to identify the exercise rehabilitation approaches used for patients with POTS (Postural Orthostatic Tachycardia Syndrome).

Methods: An electronic literature search was conducted using the PubMed database, covering January 2005 to October 2023. Studies were included if they reported an exercise rehabilitation intervention for POTS patients and resulting clinical outcomes. Eligible study designs included randomized and non-randomized clinical trials and case reports.

Results: Initially, 34 publications were identified, but only 14 met the criteria for inclusion. After a thorough analysis, 7 studies were included in this scoping review. The majority of the studies stated aerobic exercise training significantly improves symptoms in most of the patients with orthostatic intolerance, reduces the frequency of syncope, enhances patient quality of life, and improves autonomic balance as assessed by heart rate variability analysis and cardiorespiratory endurance. Short-term exercise training was found to boost physical fitness and cardiorespiratory responses in patients with POTS. Therefore, exercise training can serve as an effective non-pharmacological therapy for managing POTS.

Conclusion: This scoping review identified different approaches used for exercise rehabilitation in POTS patients. However, more research is needed to identify the optimal exercise rehabilitation program for this patient population.

Keywords: POTS, exercise, rehabilitation, COVID-19

Introduction

Postural orthostatic tachycardia syndrome (POTS) is characterized by a significant rise in heart rate (HR) upon standing, along with an inability to maintain an upright position for extended periods due to severe light-headedness, weakness, and near-fainting episodes.[1] Patients with POTS typically exhibit a lower peak oxygen uptake (VO2peak) compared to healthy sedentary individuals, indicating reduced physical fitness levels.[2] The symptoms of POTS are diverse and may include rapid heartbeat, light-headedness, fainting, fatigue, fluctuating blood pressure, exercise intolerance, nausea, anxiety, blurred vision, and headaches.[3] Treatment mostly includes self-care practices to help deal with the symptoms, although medications may be used less frequently.[4]

Two primary forms of idiopathic POTS are widely recognized: partial dysautonomia (neuropathic) and hyperadrenergic.[5] Partial dysautonomia arises from insufficient peripheral and splanchnic vasoconstriction under orthostatic stress. Hyperadrenergic POTS, characterized by excessive norepinephrine release, may result from increased norepinephrine production and release at synapses or reduced norepinephrine re-uptake. Key features of hyperadrenergic POTS include orthostatic hypertension and migraines.[6]

The exact cause of POTS remains unknown. However, potential triggers include hereditary factors, underlying conditions such as diabetes, amyloidosis, sarcoidosis, cancer, or after a viral illness, traumatic event, pregnancy, or may be associated

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with autoimmune disorders such as lupus, Sjogren syndrome, and celiac disease. Additionally, alcohol or metal poisoning, and chronic fatigue syndrome may lead to POTS.[7]

According to Mallick et al,[8] some individuals who have recovered from COVID-19 may present symptoms for several months. Medical professionals are still working to identify the root causes of these prolonged symptoms. Some individuals experiencing post-COVID symptoms, often referred to as "long-haulers", may actually be suffering from POTS. Researchers suggest that COVID-19 can trigger POTS, as a significant amount of patients who recover from COVID-19 are now showing POTS-like symptoms such as brain fog, tachycardia (elevated HR), and severe chronic fatigue.[9]

A recent review estimates that between 2% and 14% of people who had COVID-19 might develop POTS in the months following their illness.[10] An even larger number of people, ranging from 9% to 61%, might exhibit POTS-like symptoms that typically occur upon standing. Another study reported that among over 12,000 adults who had COVID-19, 260 (2086 per 100,000) developed POTS post-infection, while approximately 123 adults (987 per 100,000) had POTS prior to contracting COVID-19.[11]

Increasing evidence supports the recommendation that exercise training should be included as an important part of a treatment plan for POTS. A progressive aerobic exercise routine starting with recumbent aerobic exercises and leg resistance training, and eventually transitioning to upright exercises, has been shown to improve quality of life and reduce orthostatic HR in many patients. Multiple studies have supported the effectiveness of these exercise programs in improving POTS symptoms.[12–15] Consensus for long-term management of POTS patients after COVID-19 has not been reached.[16,17]

Early incorporation of exercise and non-pharmacological interventions is recommended when treating POTS. Initiating with horizontal exercises is essential, and supervised training is preferred to optimize the functional capacity of POTS patients. Other non-pharmacological interventions, such as volume expansion, can also help prevent orthostatic intolerance and manage acute symptoms. While exercise has been clinically proven to have therapeutic effects on POTS, more research is needed to investigate the effectiveness of other non-pharmacological treatments for this condition.[12]

The exploration of exercise as a treatment for patients with POTS has been expanding in the literature, but there are still gaps in knowledge regarding the best exercises and protocols for this population. Additionally, the tolerance for exercise and potential side effects are being currently assessed. Therefore, further exploration in this area is necessary to ensure safety and improvements in the clinical field. The aim of this article is to provide a scoping review of the existing applications of exercise therapy in POTS patients.

Methods

A scoping review is a type of research synthesis designed to systematically provide an overview of the literature on a specific topic or research area, allowing for the identification of key concepts; research gaps; and types and sources of evidence that can guide practice, policy, and future research.[18] The present study was executed following the methodological framework established by Arksey and O'Malley,[19] which involves five primary steps:

1 – Formulating a research question
2 – Identifying relevant studies
3 – Assessing and selecting studies for inclusion
4 – Charting the data
5 – Collecting, summarizing, and reporting the findings

Research Question

This scoping review aimed to identify rehabilitation exercises suitable for patients with POTS and their effect on clinical outcomes. To achieve this goal, the review focused on two key research questions: (1) How are rehabilitation exercise approaches employed for patients with POTS? (2) What is the clinical impact of exercise programs that have been tested in patients with POTS?

Search Strategy

For this review, we conducted an electronic literature search on the PubMed database. The search was carried out to find potential studies that could be included in the review. We looked for studies that were published between January 2005 and October 2023. To refine our search, we used the Boolean search term: ((postural orthostatic tachycardia syndrome) OR (POTS) OR (Orthostatic Intolerance)) AND ((rehabilitation) OR (exercise)). This search yielded 34 potential papers that could be considered for inclusion in the study.

Two authors evaluated 34 abstracts that included clinical trials, randomized controlled trials, and case reports. The clinical trials were selected based on the National Institutes of Health (NIH) definition, which requires a research study to assign one or more human subjects to one or more interventions (including placebos or other controls) to evaluate the effects of those interventions on health-related biomedical or behavioral outcomes.

Randomized controlled trials (RCTs) are prospective studies that aim to evaluate the efficacy of a new intervention. While no single study can establish causality, randomization minimizes bias and provides a robust method to explore cause–effect relationships between an intervention and its outcomes. Randomization ensures that participant characteristics, both observed and unobserved, are equally distributed between the groups, allowing any differences in outcome be attributed to the intervention. To design an RCT, researchers must meticulously define the target population, the interventions to be compared, and the desired outcomes. Following this, the number of participants required to detect a significant relationship is calculated (power calculation). Participants are then recruited and randomly allocated to either the intervention or control group.[20,21]

Case reports are an essential part of medical progress and often lead to new ideas in medicine. They provide a prompt and concise way for busy clinicians to communicate their findings without having to conduct large-scale research. Some case reports may also include a comprehensive review of relevant literature on the topic.[22]

Excluded studies were systematic reviews, protocols, feasibility studies, studies without an exercise program or clinical outcomes, or not specific for POTS diagnosis.

Study Selection

After the initial selection process, a total of 14 papers were found to be relevant to the research question. These papers were then thoroughly reviewed and analyzed, resulting in 7 papers being selected for the final study. The entire process is illustrated in Figure 1.

Data Extraction

The data extraction documented the first author and year of each publication, along with the country, number of participants, and patient demographics such as sex and age. The study type is also mentioned in Table 1. The specific exercise protocol, characteristics, and side effects of each study are described in Table 2. The main outcomes, results and important conclusions are included in Table 3.

Results

The most recent study on POTS was published in 2023, while the earliest study was published in 2005. Out of the studies reviewed, 71.4% were clinical trials (non-randomized), 14.3% were randomized controlled trials, and 14.3% were case reports. The patients who participated in the studies had been diagnosed with POTS, and in the studies with a control group, healthy subjects were matched to the POTS sample. The studies showed that POTS was more prevalent in females.

For instance, Gibbons et al[24] reported that 90% of their sample were females and 10% were males (43 females and 5 males). Richardson et al[25] conducted a case report with one female participant. George et al[13] reported that 86% of their sample were females and 14% were males (216 females and 35 males). Fu et al[26] found that 95% of their sample were females and 5% were males (18 women and 1 man). Similarly, Shibata et al[15] found that 95% of their sample were females and 5% were males (18 women and 1 man). Finally, Fu et al[27] reported that 96% of their sample were females and 4% were males (26 women and 1 man). Most of the studies were administered in the United States, with six studies from the US and only one study from the United Kingdom (refer to Table 1).

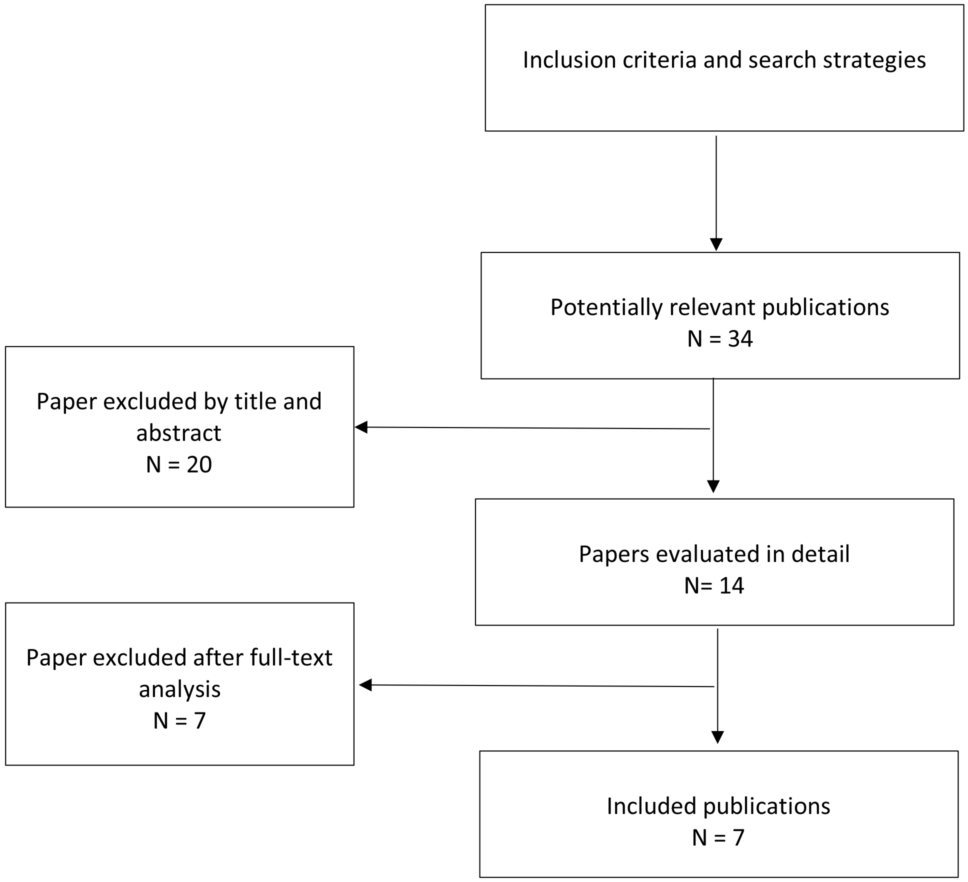

Figure 1 Study search and exclusion process.

The studies on exercise and its side effects varied in terms of the types of exercises conducted. In 2005, Winker et al reported a RCT where participants in the "training group" exercised according to their personalized training HR at 60% of their maximum performance capacity, which was determined as a percentage of the predicted workload value, based

Table 1 Study Characteristics

Author, Year	Title	Country	Patients	Age, sex	Type of study
Winker et al, 2005[23]	Endurance Exercise Training in Orthostatic Intolerance: A Randomized, Controlled Trial	Austria	Intervention group: n=16, Control group: n=11	Trained group: age 20.6 (±2.6); Control group age 22.3 (±2.2)	Randomized controlled trial
Gibbons et al, 2021[24]	Cardiovascular exercise as a treatment of postural orthostatic tachycardia syndrome: A pragmatic treatment trial	USA	Intervention group: n=48 (baseline); Control group: n=29 (baseline)	Treated group: 43 F (90%), 5 M (10%) age 26.3± 6.6; Control group 26 F (90%), 3 M (10%) age: 26.0±5.3	Non-randomized clinical trial
Richardson et al, 2017[25]	Using an exercise program to improve activity tolerance in a female with postural orthostatic tachycardia syndrome: A case report	USA	1 female with POTS exacerbation	One 34-year-old female	Case report

(*Continued*)

Table 1 (Continued).

Author, Year	Title	Country	Patients	Age, sex	Type of study
George et al, 2016[13]	The international POTS registry: Evaluating the efficacy of an exercise training intervention in a community setting	USA	251 patients with POTS	POTS (216 female, 35 male) age 26± 11	Non-randomized clinical trial
Fu et al, 2011[26]	Exercise Training versus Propranolol in the Treatment of the Postural Orthostatic Tachycardia Syndrome	USA	19 POTS patients; 15 age-matched healthy controls	POTS patients (18 women, 1 man)- age 27±9; 15 healthy individuals (14 woman, 1 men) age 31±10	Non-randomized clinical trial with two age-matched groups
Shibata et al, 2012[15]	Short-term exercise training improves the cardiovascular response to exercise in the postural orthostatic tachycardia syndrome	USA	19 POTS patients; 10 age-matched healthy sedentary controls	POTS patients (18 women, 1 man) age 27 ±2; Control age 30± 2	Non-randomized clinical trial
Fu et al, 2010[27]	Cardiac Origins of the Postural Orthostatic Tachycardia Syndrome	USA	27 POTS patients; 16 healthy control	POTS Patients (n =26 Women, 1 Man)- age 26 (21, 33) Healthy Controls (n =15 Women, 1 Man)- age 28 (23, 35)	Non-randomized clinical trial

on standardized tables for sex, age, and body surface area.[23] Regarding the exercise workload, it increased each 2 minutes in steps by 25 W increments, starting at 25 W and continuing until exhaustion. The program included 3 training cycles, each lasting 4 weeks, beginning with 30 minutes and increasing to 50 minutes of jogging per week. The trained group experienced significant improvements in symptoms such as blurred vision, lightheadedness, dizziness, hand tremors, headache, and concentration difficulties (Table 2). After completing training program, only six out of 16 individuals exhibited orthostatic intolerance compared to 10 out of 11 in the control group (p=0.008). The average symptom score for the training group improved markedly from 1.79±0.4 to 1.04±0.4, while the control group showed no significant change, with scores of 2.09±0.6 and 2.14±0.5. The study concluded that endurance exercise training significantly improved symptoms in most patients with POTS (Table 3).

In 2021, Gibbons et al conducted a study of unsupervised exercise training using recumbent bikes, offering alternatives like rowing machines or swimming for those without recumbent bikes for the first 12 weeks.[24] From the 13th week onwards, upright exercises such as walking, running, treadmill or elliptical exercises were included. The treated group showed a significant reduction in the frequency of syncope and the severity of orthostatic lightheadedness, compared to the control group, which showed no such reduction. Additionally, the severity of postural dizziness decreased in the treated group but not in the control group (Table 2). After six months, only 23% of individuals in the treated group met the HR criteria for POTS compared to 93% of the control group ($P < 0.0001$). Furthermore, the treated group also experienced a decrease in the frequency of syncope ($P < 0.001$) and an improvement in the perceived quality of life (Table 3).

George et al implemented a 3-month program based on the predicted maximal and resting HRs.[13] Patients were instructed to train 3–4 times per week for 30–40 minutes per session, engaging in activities such as swimming, rowing, or a recumbent bike. However, 59 patients (40%) stopped the training since they found it too difficult. The study evaluated the efficacy of the program by measuring two endpoints: change in HR by the stand test and quality-of-life. As a result, 71% of patients were in remission and no longer qualified for POTS. The increase in HR from supine to 10-minute stand and the quality of life improved significantly after the intervention. The study concluded that this exercise program was effective in treating POTS and can be applied in community setting with physician supervision.

Table 2 Exercise Description

Author, Year	Title	Exercises	Side Effects
Winker et al, 2005[23]	Endurance Exercise Training in Orthostatic Intolerance: A Randomized, Controlled Trial	The individual working capacity was calculated as a percentage of the predicted (100% workload) Watt value (derived from the tabulation and standardized for sex, age, and body surface). The workload was increased every 2 minutes in steps of 25 W, beginning with 25 W and going until the point of exhaustion. - All subjects of the "training group" exercised according to their individual training heart rate, at 60% of the maximum performance capacity - The program consisted of 3 training cycles, each for a duration of 4 weeks. - First training cycle: 4 weeks (3 30 minutes jogging/week) - Second training cycle: 4 weeks (3 40 minutes jogging/week) - Third training cycle: 4 weeks (3 50 minutes jogging/week)	The trained group had a significant improvement on dizziness, headache, blurred vision, lightheadedness, tremor in hands, and concentration difficulties.
Gibbons et al, 2021[24]	Cardiovascular exercise as a treatment of postural orthostatic tachycardia syndrome: A pragmatic treatment trial	- Unsupervised training. - Subjects began exercising on a recumbent bicycle for 10 min/d, 6 d/wk and each week added 3 minutes of exercise until they reached 45 minutes. - After 12 weeks, participants were exercising for a total of 45 min/d, 6 d/wk on a recumbent bicycle. - If subjects did not have access to a recumbent bicycle, a rowing machine or swimming was offered as an alternative option. - Starting on week 13, subjects added 10 minutes of upright exercise on a treadmill or elliptical machine per day (or brisk walking/ running outdoors if no equipment was available), 6 d/wk and reduced the time on the recumbent bicycle by an equal amount.	- There was a significant decrease in the frequency of syncope in the treated group (median [interquartile range] 0 [0–2] events/mo in the treated group vs 3 [2–4] events/mo in the control group; P= 0.001). - After 6 months the severity of orthostatic lightheadedness, as measured by the Boston Autonomic Questionnaire, was reduced in the exercise group (8 ± 2 vs 7 ± 2 after 6 months; P >0.01) but not in the control group (8 ± 2 vs 8 ± 2 after 6 months; P = 0.81). - Similarly, the severity of postural dizziness was diminished in the exercise group (8±2 vs 5 ± 2 after 6 months; P <0.001) but not in the control group (8±2 vs 8±2 after 6 months; P= 86). The differences between groups were significant.

Richardson et al, 2017[25]	Using an exercise program to improve activity tolerance in a female with postural orthostatic tachycardia syndrome: A case report	Frequency: - Physical Therapy: 1 time per week sessions (4 total visits over 4 weeks) - Home program: 4 times per week - Endurance training sessions 1–2 times per week Intensity: - Endurance training: Ideal target HR range: 159–170 bpm (75–85% HR max); and/or; BORG RPE scale (6–20):11–12 for warm up and cool down; 13–16 during endurance training. - Strength training: 2–3 interval circuits with each exercise done for 30–40 seconds followed by rest for 20–30 seconds Time: - Endurance training: Target duration of 30–45 min (10 min warm up and cool down) - Time: Strength training: Target duration of 20–40 min Type: - Endurance training: The patient only had access to an elliptical trainer at home. Since the patient safely performed the 1-MWT, the physical therapist felt that this was a safe option that would improve patient adherence. - Strength training: The physical therapist collaborated with the patient to design an interval resistance program of 9–11 general exercises that progressed from semi-recumbent to upright positions and addressed the hip and trunk weakness	- POTS exacerbation: fever for 4 days; malaise; fatigue - Dyspnea; dizziness; poor energy - Difficulty getting out of the bed - Occasional light headedness - Lower extremities "heaviness" walking short distances
George et al, 2016[13]	The international POTS registry: Evaluating the efficacy of an exercise training intervention in a community setting	- The training program consisted of 3 months of daily schedules. - Based on the predicted maximal heart rate and resting heart rate, training zones were determined (ie, recovery, base pace, and maximal steady state or "threshold"). - Approximately 70%–75% of maximal predicted heart rate and the Rating of Perceived Exertion of 13–15 corresponding to the words "somewhat hard" to "hard". - Initially, patients were requested to train 3–4 times per week for 30–40 minutes per session by using rowing, swimming, or a recumbent bike.	- Fifty-nine patients (40%) stopped because the training was considered "too difficult."

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Table 2 (Continued).

Author, Year	Title	Exercises	Side Effects
Fu et al, 2011[26]	Exercise Training versus Propranolol in the Treatment of the Postural Orthostatic Tachycardia Syndrome	- The majority of the training sessions, particularly during the early phases were prescribed as "base training" with target heart rate equivalent to ~75–85% of maximal. - Initially, patients trained 2 to 4 times per week for 30–45 minutes per session by using a recumbent bike, rowing, or swimming. - Upright exercise was added gradually as tolerated, though usually not until the second or third month. By the end of the training, patients were exercising 5–6 hours per week, and they were encouraged to use an upright bike, or walk on the treadmill, or jog.	-Upright heart rate was normalized to the level of healthy controls after 4 weeks of treatment, but patient quality of life remained unchanged, suggesting that chronic propranolol treatment cannot improve patients' overall well-being as opposed to exercise training.
Shibata et al, 2012[15]	Short-term exercise training improves the cardiovascular response to exercise in the postural orthostatic tachycardia syndrome	- 'base training' with target HR equivalent to ~75% of maximal. - Initially, patients trained 2–4 times per week for 30–45 min per session by using a recumbent bike, rowing, or swimming. - As the patients became relatively fit, the duration of the base training sessions was prolonged, and subsequently sessions of increased intensity (ie maximal steady-state) were added. - Upright exercise was added gradually as tolerated, though usually not until the second or third month. - By the end of the 3-month training, patients were exercising 5–6 h per week. - HR was monitored during every session using a Polar monitor in all the patients and their physical activity level was quantified every 2 weeks. - In addition to the endurance training, resistance training using weight lifting was also undertaken from once a week, 15–20 min per session to twice a week, 30–40 min per session.	- This process may induce a downward spiral of hypovolemia, cardiac atrophy (~1%/week in bed), worsening orthostatic intolerance and physical disability which can be quite profound.

Fu et al, 2010[27]	Cardiac Origins of the Postural Orthostatic Tachycardia Syndrome	- Most of the training sessions, particularly during the early phases, were prescribed as base training, with the target HR equivalent to approximately 75% to 85% of maximal. - Initially, patients trained 2 to 4 times per week for 30 to 45 min/session by using a recumbent bike, rowing, or swimming. - As the patients became relatively fit, the duration of the base training sessions was prolonged, and subsequently sessions of increased intensity (ie, maximal steady state) were added first once and then twice per week, and were always followed by recovery sessions. - Upright exercise was added gradually as tolerated, although usually not until the second or third month. By the end of the training, patients were exercising 5 to 6 h per week, and they were encouraged to use an upright bike, to walk on the treadmill, or to jog. - In addition to the endurance training, resistance training such as weight lifting was also used. - Weight lifting started from once weekly, 15 to 20 min/session and gradually increased to twice weekly, 30 to 40 min/session.	- hypertension or other intolerable side effects may develop in some patients.

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Table 3 Intervention and Outcomes

Author, Year	Title	Outcomes	Results	Conclusions
Winker et al, 2005[23]	Endurance Exercise Training in Orthostatic Intolerance: A Randomized, Controlled Trial	- Assessing the effectiveness of the therapy was defined prospectively as the number of subjects who had OI cured 3 months after the training compared with the control group. - The change in questionnaire scores and in some physiological characteristics (hemodynamic and autonomic variables) were compared between the 2 groups.	- After training, only 6 individuals of 16 still had orthostatic intolerance compared with 10 of 11 in the control group. The Fisher exact test showed a highly significant difference in diagnosis between the 2 groups (P 0.008) - Analysis of the questionnaire-score showed significant interaction between time and group (P 0.001). - The trained subjects showed an improvement in the average symptom score from 1.79±0.4 to 1.04±0.4, whereas the control subjects showed no significant change in average symptom score (2.09±0.6 and 2.14±0.5, respectively).	- Endurance exercise training leads to an improvement of symptoms in the majority of patients with orthostatic intolerance. The endurance training should be considered in the treatment of orthostatic intolerance patients. - Although the majority of patients will benefit from therapy, the symptoms may persist in individual cases. In such instances, the only solution is to retrain the patient for a job in a sitting position to avoid orthostatic stress.
Gibbons et al, 2021[24]	Cardiovascular exercise as a treatment of postural orthostatic tachycardia syndrome: A pragmatic treatment trial	- autonomic function testing - symptom scores - activities of daily living	- After 6 months, 23% individuals in the treated group met heart rate criteria for POTS compared with 27 of 29 (93%) in the control group (P <0.0001). - The frequency of syncope decreased in the treated group (P <0.001). - An improvement in the EuroQol perceived quality of life scale score was detected in the treated group after 6 months, P<0.001)	- There was an associated improvement in symptoms and quality of life. - The positive benefits of cardiovascular exercise in the treated group were robust, while the control group was largely unchanged after 6 months. - The exercise protocol may be clinically beneficial across all subtypes of postural tachycardia syndrome, although additional study is needed for confirmation.
Richardson et al, 2017[25]	Using an exercise program to improve activity tolerance in a female with postural orthostatic tachycardia syndrome: A case report	- HR variability - 1-Mile Track Walk Test (1-MWT) also known as the Rockport Fitness Test to predict the maximal aerobic capacity (estimated VO2 max)	- One-mile track walk test (1-MWT) estimated VO2max improved from the 45–50th percentile to the 65–70th percentile at 8 weeks post-discharge. - The patient demonstrated clinically meaningful improvements in estimated VO2max after the "reconditioning" training	- The patient was able to make significant gains during 4 weeks of physical therapy and continued improvement 8 weeks after discharge. - This type of improvement is consistent with what has been found in the literature. -This patient's outcomes are similar to results reported by Fu et al (2011) and Shibata et al (2012).

George et al, 2016[13]	The international POTS registry: Evaluating the efficacy of an exercise training intervention in a community setting	- The efficacy of exercise/lifestyle intervention with 2 endpoints: objective quantification of change in heart rate by the stand test and subjective evaluation with the SF-36 quality-of life questionnaire.	– 71% no longer qualified for POTS and were thus in remission. - The increase in heart rate from supine to 10-minute stand was markedly lower before intervention; P <0.001) - Patient quality of life was improved dramatically after intervention (P < 0.001)	- In the POTS registry, the vast majority of patients who completed 3 months of exercise training/lifestyle intervention no longer qualified for POTS criteria and were thus effectively in remission. Quality of life was improved significantly after training in virtually all patients. - These results suggest that this training program can be implemented in the community setting with physicians' supervision and is effective in the treatment of POTS. -It remains to be determined whether exercise can be an effective long-term treatment strategy for this condition, though the patients should be encouraged to maintain an active lifestyle indefinitely.
Fu et al, 2011[26]	Exercise Training versus Propranolol in the Treatment of the Postural Orthostatic Tachycardia Syndrome	- A 2-hour standing test was performed before and after drug treatment and training. - hemodynamics - catecholamines - plasma renin activity - aldosterone were measured supine and during 2-hour standing	- Both propranolol and training significantly lowered standing heart rate. Standing cardiac output was lowered after propranolol treatment (P=0.01), but was minimally changed after training. - The aldosterone-to-renin ratio during 2-hour standing remained unchanged after propranolol treatment P=0.46, but modestly increased after training (P=0.05). - Patient quality of life, assessed using the 36-item Short Form Health Survey, was improved after training P<0.01, but not after propranolol treatment P=0.73.	- These results suggest that for patients with POTS, exercise training is superior to propranolol at restoring upright hemodynamics, normalizing renal-adrenal responsiveness, and improving quality of life.

(*Continued*)

Table 3 (Continued).

Author, Year	Title	Outcomes	Results	Conclusions
Shibata et al, 2012[15]	Short-term exercise training improves the cardiovascular response to exercise in the postural orthostatic tachycardia syndrome	- Cardiovascular responses during maximal exercise testing were assessed in the upright position before and after training. - Resting left ventricular diastolic function was evaluated by Doppler echocardiography.	- A lower SV resulted in a higher HR in POTS at any given oxygen uptake (VO2) during exercise while the cardiac output (QC)–VO2 relationship was normal. - VO2peak was lower in POTS than controls P<0.001 due to a lower peak P =0.009. - After training in POTS, HR became lower at any given VO2 due to increased SV without changes in the QC-VO2 relationship. -VO2peak increased by 11% (P<0.001) due to increased peak SV (P=0.021) and was proportional	- These results suggest that short-term exercise training improves physical fitness and cardiovascular responses during exercise in patients with POTS.
Fu et al, 2010[27]	Cardiac Origins of the Postural Orthostatic Tachycardia Syndrome	- autonomic function tests and blood volume measurements; - neurohumoral regulation during 2-h standing; - cardiac magnetic resonance imaging (MRI) assessments.	- Upright heart rate and total peripheral resistance were greater, whereas stroke volume and cardiac output were smaller in patients than in controls. - The baroreflex function was similar between groups. - Exercise training increased left ventricular mass and blood volume by approximately 12% and approximately 7% and decreased upright heart rate by 9 beats/min - Ten of 19 patients no longer met POTS criteria after training - Patient quality of life assessed by the 36-item Short-Form Health Survey was improved in all patients after training.	- Short-term exercise training increased cardiac size and mass and expanded blood and plasma volume, and thus improved or even cured POTS. - These results suggest that POTS per se is indeed a consequence of deconditioning and that carefully prescribed exercise training can be used as an effective non drug therapy for POTS patients.

Fu et al targeted an exercise intensity of 75–85% of maximal HR.[26] Patients trained in sessions of 30–45 minutes 2–4 times per week by rowing, swimming, or using a recumbent bike, and upright exercise was gradually added as tolerated. Upon completing the training, patients were encouraged to transition to using an upright bike, walking on a treadmill, or jogging. The study assessed outcomes through a 2-hour standing test pre- and post-training, evaluating hemodynamics, catecholamines, plasma renin activity, and aldosterone levels in supine and standing positions. The key finding was that both pharmacologic treatment and training significantly reduced standing HR. Standing cardiac output minimally changed after training, conversely drug therapy significantly reduced the HR. The aldosterone-to-renin ratio during 2-hour standing remained stable following drug treatment ($P=0.46$) but showed a slight increase after exercise ($P=0.05$). Patient quality of life improved following exercise training ($P<0.01$) but not after drug treatment ($P=0.73$). These findings suggest that for POTS patients, exercise training is superior to drug therapy with propranolol.

Shibata et al (2012) implemented an exercise regimen similar to Fu et al regarding intensity, type of exercises included, and progression from lying/recumbent to standing position.[15] Shibata et al also included resistance training using weights once a week. The results suggested potential risks of hypovolemia, cardiac atrophy (about 1% per week in bed), worsening orthostatic intolerance, and significant physical disability (Table 2). Outcomes were measured by evaluating cardiovascular responses in the upright position before and after the training, as well as resting left ventricular diastolic function using Doppler echocardiography. During exercise, POTS patients experienced a higher HR due to lower stroke volumes at any oxygen uptake, while cardiac output was constant. VO2 peak was significantly lower in POTS patients compared to controls. After training, POTS patients' HRs decreased at any given VO2 because of an increased stroke volume without changes in the QC–VO2 relationship. Peak oxygen uptake improved by 11% ($P < 0.001$) due to an increase in peak stroke volume ($P = 0.021$) and was proportional. These findings suggest that short-term exercise training can enhance aerobic and cardiovascular responses during exercise in patients with POTS. Please refer to Table 3 for more details.

Fu et al recruited patients exhibiting orthostatic intolerance who participated in a training regimen 2 to 4 times a week for 30 to 45 minutes a session.[27] The exercise protocol included activities such as rowing, swimming, using a recumbent bike, and resistance training with weights, targeting a HR of 75% to 85% of maximal. Common side effects experienced by some patients included hypertension or other intolerable conditions. Assessments included blood volume measurements, autonomic function tests, and cardiac magnetic resonance imaging. Baseline results indicated that POTS patients had higher upright HR and total peripheral resistance, but lower stroke volume and cardiac output compared with controls. Despite the differences, baroreflex function remained similar across groups. Exercise training led to a 12% increase in left ventricular mass and 7% increase in blood volume, along with a reduction in upright HR by 9 beats/min. Notably, after the training 10 out of 19 patients still met the criteria for POTS. Additionally, the quality of life improved for all patients after training. According to the study, it was found that POTS may be a result of deconditioning, and that a carefully prescribed exercise training program can be an effective non-drug therapy option for patients with POTS.

The protocol followed by Richardson et al involved one physical therapy session per week for four weeks, a home program to be followed four times per week, and endurance sessions on the elliptical machine for one to two times per week.[25] The participants were instructed to maintain a HR between 75% and 85% of their maximum HR or a Borg RPE scale of 13–16 during endurance exercise. The study participants also underwent strength training with 9–11 exercises, progressing from semi-recumbent to upright positions. However, some patients encountered side effects such as fever, malaise, fatigue, dyspnea, dizziness, low energy, difficulty getting out of bed, occasional light-headedness, and heaviness in the lower extremities when walking short distances (Table 2). The most notable outcome of the study was the improvement in HR variability and performance on the one-mile track walk test which estimates maximal aerobic capacity (VO2 max). Results indicated that eight weeks post-discharge the VO2max increased from the 45–50th percentile to the 65–70th percentile. The patients exhibited significant enhancements in VO2max following the reconditioning training. The study concluded that the patients achieved significant progress during the four-week treatment and continued to improve even eight weeks after discharge (Table 3).

Most of the studies stated aerobic exercise training significantly improved symptoms in the majority of patients with orthostatic intolerance.[5,28] Some programs included strengthening and relaxation exercises.[29,30] The exercise protocols vary from 30 to 40 minutes 2–4 times a week, with a target heart rate (HR) equivalent to approximately 70–75% of maximal.[31,32] The exercise progression can be based on the patient's symptoms and exercise tolerance; the Borg scale for

Rating of Perceived Exertion (RPE) is also recommended to target exercise intensity. The exercise program starts with supine positions and, when possible, proceeds with recumbent or upright exercises based on the individual patient's tolerance. Patients must be followed closely due to variable responses to exercise with the goal of avoiding symptom increases during and after the exercise.

Though each case of patients with POTS may have a unique constellation of symptoms, triggers, and underlying comorbidities,[33,34] based on our review, a generalized clinical workflow for individualized physical rehabilitation for patients with POTS has been summarized in Figure 2. Once the POTS diagnosis is confirmed and underlying etiology is established based on the POTS diagnostic panel and clinical assessment, the patients undergo a comprehensive physical therapy evaluation. During the evaluation, the initial level of exercise intensity is determined based on personalized HR zone and assessment of individual symptom responses to aerobic and strengthening exercises in supine, recumbent, and upright positions. An adaptable personalized exercise program is prescribed together with a training calendar tailored to individual patient preferences and cardiorespiratory capacity. The patient's performance is carefully monitored to ensure that the exercise program does not increase symptoms during and after the exercise. Periodic re-evaluation aims to find optimal timing for the gradual increase of exercise intensity to higher HR zones and change from supine, recumbent, and eventually upright exercise positions. The clinical pathway for prescribing a POTS exercise program is summarized in Table 4, with specific exercises recommended for POTS rehabilitation in Table 5.

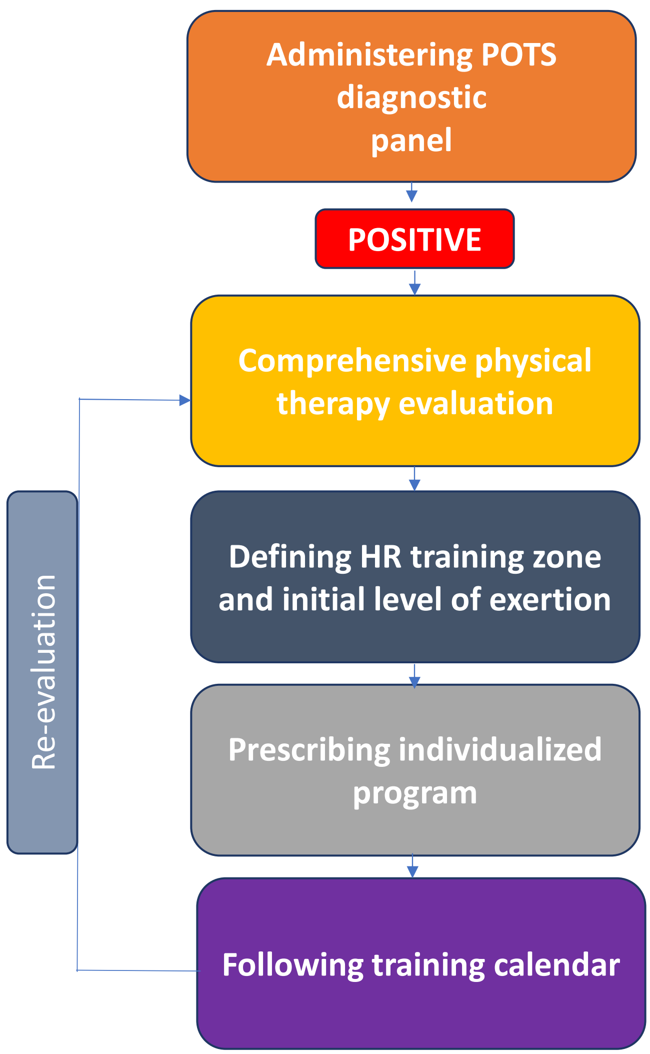

Figure 2 Individualized physical rehabilitation for patients with POTS.

Table 4 Clinical Pathway for POTS Exercise Program

Steps	Description	Time frame	Key Activities and Considerations
Initial Assessment	Evaluate the patient's medical history, symptoms, and perform diagnostic tests to confirm POTS and establish a safe starting point for exercise.	Before the Exercise Program	**Medical History and Physical Examination**: Evaluate the patient's symptoms, medical history, and physical condition to rule out other conditions **Baseline Tests**: Conduct baseline tests such as a tilt table test, blood tests, and ECG to confirm the POTS diagnosis and assess the patient's cardiovascular status
Starting the Exercise Program	Introduce low-intensity, recumbent exercises to build cardiovascular fitness while minimizing orthostatic stress.	1–3 months	Some examples of possible exercises for this step: ● Recumbent Biking: Helps improve cardiovascular fitness while keeping the body in a reclined position ● Rowing Machine: Strengthens the heart and improves endurance ● Swimming or Kickboard Laps: Provides a full-body workout without the strain of standing
Gradual Progression	Transition to upright exercises slowly, increasing endurance and strength as the patient adapts to standing activities.	4–6 months	**Month 4**: Start with upright biking **Month 5**: Progress to elliptical training (without using arms initially) and treadmill walking on a flat grade **Month 6**: Continue building exercise tolerance, potentially progressing to jogging or stair stepping if symptoms allow
Strength Training	Incorporate targeted strength exercises to improve lower body and core muscles, enhancing circulation and stability.	7–9 months	Some examples of possible exercises for this step: ● Seated Leg Press, Leg Curl, and Leg Extension: Strengthen the legs ● Calf Raises and Seated Row: Improve muscle tone and upper body strength.
Monitoring and Adjustment	Track progress and symptoms, adjusting intensity and duration as needed to ensure safety and optimal outcomes.	During all the Exercise Program	**Regular Monitoring**: Track the patient's progress and symptoms. Adjust the exercise intensity and duration based on their response **Heart Rate Zones**: Use heart rate monitors to ensure the patient stays within safe heart rate zones during exercise
Support and Education	Provide education on symptom management, hydration, and salt intake while fostering a supportive environment to maintain motivation.	During all the Exercise Program	**Patient Education**: Educate the patient about the importance of hydration, salt intake, and recognizing their body's signals **Support Systems**: Encourage the involvement of family, friends, or a physical therapist to provide support and motivation
Long-Term Maintenance	Emphasize consistency and adaptability in the exercise program to sustain fitness and symptom management over time.	After the Exercise Program	**Consistency**: Emphasize the importance of regular exercise to maintain improvements in cardiovascular fitness and symptom management **Adaptation**: Adjust the exercise program as needed based on the patient's progress and any changes in their condition

Table 5 Specific Exercises Recommended for POTS Rehabilitation

Type of Exercise	Specific Exercise	General Recommendations
Recumbent Exercises	**Recumbent Biking**: This helps improve cardiovascular fitness without the strain of standing.	• **Start Slowly**: Begin with short durations and low intensity, gradually increasing as tolerated. • **Consistency**: Aim for regular exercise, even if it's just a few minutes each day. • **Hydration**: Stay well-hydrated before, during, and after exercise. • **Monitor Symptoms**: Pay attention to how your body responds and adjust accordingly.
	Rowing: Using a rowing machine can strengthen your heart and improve overall endurance.	
	Swimming: Swimming or using a kickboard in the pool provides a full-body workout while keeping you in a horizontal position.	
Strength Training	**Seated Leg Press**: Strengthens the lower body, which helps with blood circulation.	
	Leg Curl and Leg Extension: Focuses on the hamstrings and quadriceps.	
	Calf Raises: Improves muscle tone in the calves, aiding in blood return to the heart.	
	Chest Press and Seated Row: Strengthens the upper body and core.	
Core Exercises	**Abdominal Crunches**: Strengthens the core muscles.	
	Back Extensions: Helps improve posture and back strength.	
Flexibility and Balance	**Pilates-Based Exercises**: Any Pilates exercises that can be done on the floor are beneficial.	
	Seated Ball Exercises: Sitting on an exercise ball and performing leg lifts or marches can improve balance and core strength.	
	Straight Leg Raises: Helps strengthen the thigh muscles and improve leg stability.	

Discussion

The scoping review found that exercise was an effective treatment for POTS patients, leading to improvements in symptoms and quality of life.[24] In some cases, patients who underwent exercise therapy had complete remission of POTS,[13,27] as well as improvements in physical fitness and cardiovascular responses during exercise.[15,26,27] These findings advocate for the early incorporation of exercise as a non-pharmacological intervention in treating POTS. A typical POTS physical rehabilitation program starts with aerobic exercises in a supine position and proceeds under careful supervision to exercises in recumbent and upright position. The training can be enhanced by the inclusion of strengthening and relaxation exercises to facilitate the functional recovery of patients with POTS.[20]

The research protocols used in the reviewed studies primarily consisted of recumbent bike exercises. In cases where a recumbent bike was not available, patients were allowed to use a rowing machine or swimming as an alternative. Upright exercises were gradually introduced as a strategy if they were tolerated by the patients. The duration of treatments also increased gradually from 30 minutes to 45 minutes. The initial exercise intensity was individually determined based on the HR range between 70% and 85% of the maximal predicted HR and the Borg RPE in the range of 13–16. Strength training was gradually added in a few studies and was well tolerated by the patients. These strategies were well accepted and associated with improvements in symptoms and quality of life. Although these findings were positive and effective in the treatment of POTS, additional studies are needed to confirm their effectiveness.[13,24]

Similarly to our study, Peebles et al emphasize the necessity for careful adaptation of exercise routines due to challenges such as fatigue and post-exertional malaise. Their review advocates for a gradual, progressive approach that begins with recumbent exercises before advancing to upright activities.[35] This strategy accommodates the unique needs of young adult patients experiencing joint hypermobility, chronic pain, or fatigue. Such a nuanced approach supports the present review's recommendation for supervised, adaptable, and individualized exercise regimens, particularly for POTS patients with additional comorbidities, where early intervention can lead to symptom reduction and improved cardiovascular responses.

Fu et al suggest that POTS may lead to deconditioning due to its effect on physical activity in these patients, and exercise training, when prescribed with care, can be an effective non-pharmacological therapy for POTS. In clinical practice, close monitoring of exercise safety and adherence is essential for POTS patients due to the potential side effects associated with the exercise training. Most studies included in this review have reported potential cardiac and blood pressure responses, which could result in syncopal episodes, lightheadedness, postural dizziness, fatigue, and fatigue.[15,24,25,27]

Several studies have underscored limitations in the long-term effectiveness of exercise for treating POTS.[13] Additionally, while it has been proposed that exercise protocols might benefit all subtypes of POTS,[13,24] further research is necessary to substantiate this claim. To achieve a better understanding of how to incorporate exercise rehabilitation programs specific to this population, studies with well-structured methodologies, clinical outcomes, sufficient sample size, and standardized exercise protocols are needed.

Though the reviewed literature confirms that exercise can be an effective treatment for POTS, additional research is required as underscored by Raj et al who noted the traditional challenges patients with POTS face in adhering to exercise recommendations. When recommended a regular exercise program, many patients with POTS are unable or unwilling to follow this advice, ultimately leading to the patient becoming deconditioned. Patients who did exercise, however, showed better functioning over time than those who did not. Moving forward, the challenge is to discover ways to better assist POTS patients in initiating and maintaining an exercise program.[17]

Most existing clinical trials on exercise interventions in POTS patients were conducted in small samples and could have been underpowered. It is important to conduct randomized controlled trials to further assess the effectiveness of exercises as a treatment for POTS with representative samples of POTS patients stratified by underlying etiology. Only one study[23] was found to use the RCT design. The review by Raj et al corroborated our conclusion that additional well-designed randomized controlled trials are necessary to further explore non-pharmacological treatment modalities in POTS patients.[17]

Previous studies demonstrated a significant impact of outpatient rehabilitation in patients recovering from COVID-19.[36,37] Access to optimal rehabilitation programs for patients affected by post-COVID conditions may be affected by socio-demographic and geographic factors.[38] For instance, Svenson et al demonstrated that tailored exercise programs, with adaptations based on individual tolerance, are not only safe but also effective in reducing symptom burden and enhancing physical and psychological functioning.[39] Moreover, their study incorporated both in-person and remote support, demonstrating a scalable solution for broader patient populations, especially those in remote or underserved areas.

Telerehabilitation interventions have the potential to widen access to evidence-based rehabilitation programs,[40] however, limited evidence exists on their efficacy and acceptance.[41] Future research should include a thorough evaluation of post-COVID telerehabilitation in both rural and urban environments, adhering to the consensus guidance on assessing and treating autonomic dysfunction in patients with sequelae of COVID-19.[42] Activity trackers[43] and digital health apps[44] have been shown to be effective in supporting patient self-management and can be considered as potential means for facilitating POTS rehabilitation in the future. As patient engagement is a crucial component for supporting exercise adherence,[45] novel approaches incorporating virtual reality[46] or interactive chatbots[47] powered by generative artificial intelligence (AI) may play a role in individualized and adaptable POTS rehabilitation programs. Recent studies demonstrated significant potential in predicting exercise exertion levels using AI-supported analysis of vital signs collected from wearable devices.[48–50] The development of algorithms predicting a rapid increase in heart rate or escalation of POTS symptoms in near real-time can help implement proactive alert systems that would allow early recognition and prevention of POTS symptom escalation. [50,51]

Conclusion

Based on this scoping review, previous articles found that a specialized set of exercises prescribed for patients with POTS can be beneficial and feasible. However, methodological limitations such as small sample size, quasi-experimental design, and short-term follow-up limited the generalizability of these studies. Additional research is essential to determine the optimal methodologies, protocols, and strategies to enhance clinical practice for treating POTS patients using exercise interventions.

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Disclosure

The authors report no conflicts of interest in this work.

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