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Physical activity and exercise training in Postural orthostatic tachycardia syndrome - physiological mechanisms and clinical implications - a narrative review

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Abstract

Background: Postural orthostatic tachycardia syndrome (POTS) is a disorder of autonomic cardiovascular regulation associated with orthostatic intolerance, fatigue, and reduced exercise tolerance, substantially affecting daily functioning and quality of life. Although exercise training is considered an important component of non-pharmacological management, optimal exercise prescription remains insufficiently established.

Aim: To examine exercise mechanisms, clinical outcomes and practical implications in POTS.

Material and methods: Material and methods: PubMed was the principal database used to identify publications from 2017–2026, including interventional and observational studies, systematic reviews, narrative reviews, and clinical recommendations. Evidence concerning exercise capacity, cardiovascular responses, symptom severity, quality of life, and exercise prescription was narratively synthesized.

Results: Training improved aerobic capacity in some studies, whereas effects on symptoms, quality of life and daily activity were inconsistent. A recent trial in post-COVID-19 POTS found no quality-of-life advantage and reduced upright time relative to standard care.

Recumbent exercise, resistance training and symptom-guided progression are commonly proposed. Small samples, attrition, co-interventions and limited follow-up restrict interpretation. Proposed rehabilitation models should be distinguished from tested interventions.

Conclusions: Exercise may benefit selected patients with POTS, but improved fitness does not establish improved daily functioning. Prescription should account for orthostatic tolerance and

delayed symptom exacerbation. Trials should assess sustained function, adherence and adverse events alongside physiological outcomes.
Keywords: postural orthostatic tachycardia syndrome; physical activity; exercise training; exercise intolerance; quality of life; rehabilitation.

1 Introduction

Postural orthostatic tachycardia syndrome (POTS) is a chronic syndrome of orthostatic intolerance associated with impaired autonomic regulation of the circulation. Diagnosis requires a sustained increase in heart rate (HR) of at least 30 beats/min in adults or 40 beats/min in individuals aged 12–19 years within 10 minutes of assuming an upright posture, without significant orthostatic hypotension. Symptoms worsen in the upright position, improve when supine, and persist for at least three months. Other causes of sinus tachycardia must be excluded.[1]

POTS predominantly affects adolescents and young adults, particularly women. Palpitations, dizziness, fatigue, cognitive difficulties, and exercise intolerance can limit education, work, and recreational activity.[1,2] Worsening symptoms during movement can lead to reduced activity and secondary deconditioning, which may further impair exercise tolerance but does not explain all abnormalities in POTS.[3,4]

Physical activity encompasses movement associated with energy expenditure, including mobility and everyday tasks. Exercise training is a planned, structured, and repetitive form of physical activity intended to improve or maintain physical fitness.[5] This distinction is relevant when evaluating treatment: greater capacity during an exercise test does not necessarily indicate greater activity outside training sessions.

Previous reviews have described exercise protocols, the need for individualization, and the limitations of evidence on symptoms and functioning.[6,7,8] This review combines an assessment of mechanisms and exercise capacity with an analysis of patient-reported outcomes, daily activity, and program tolerability. It also includes newer studies from 2025–2026 and distinguishes the parameters of clinically tested interventions from recommendations based on expert proposals.

2 Aim and Methods

This review aimed to evaluate the physiological basis of exercise training in POTS, its effects on exercise capacity, symptoms, and functioning, and the potential application of research findings to clinical practice. A narrative synthesis of the literature was conducted. PubMed was

the primary database searched. The search covered publications from 2017 to 2026. Terms related to POTS were combined with terms concerning physical activity, exercise training, exercise intolerance, rehabilitation, and quality of life. English-language interventional and observational studies involving individuals with POTS, reviews, and clinical publications relevant to the review's aim were included. Studies of mixed populations were analyzed with acknowledgment of the limited ability to attribute their findings specifically to POTS. Data on POTS following COVID-19 were presented separately. Findings were organized by exercise capacity and hemodynamics, symptoms, quality of life, daily functioning, and intervention tolerability. Detailed interpretation was based on available full texts; where access was limited, descriptions were restricted to abstract data.

3 Mechanisms of Exercise Intolerance and the Physiological Basis of Exercise Training

3.1 Circulatory Regulation During Upright Posture

Standing causes some blood to shift into the vessels of the lower limbs and splanchnic region, reducing venous return and stroke volume. The baroreflex increases sympathetic activity and reduces parasympathetic activity, helping to maintain blood pressure. In POTS, excessive tachycardia is accompanied by orthostatic intolerance despite the absence of a sustained fall in blood pressure that meets the criteria for orthostatic hypotension. This does not imply a single regulatory defect shared by all patients. Abnormalities in vascular innervation, blood volume, and sympathetic activity may coexist.[1,9]

3.2 Mechanisms Limiting Exercise Tolerance

In the neuropathic phenotype of POTS, impaired peripheral vascular regulation promotes blood pooling in the upright position. Hypovolemia further limits cardiac filling. Both mechanisms may reduce stroke volume and increase the compensatory HR response, particularly during upright exercise. Excessive sympathetic activation may exacerbate palpitations and other symptoms even at low workloads. These phenotypes may overlap and should therefore not be treated as mutually exclusive categories explaining every patient's response.[2,9,10]

Reduced stroke volume does not necessarily result in reduced cardiac output. Hogwood et al. found lower stroke volume in seven of ten studies assessing this parameter, whereas reduced cardiac output was reported in only one. Preserved cardiac output suggests partial compensation through tachycardia but does not establish normal exercise tolerance or adequate perfusion of all tissues. Some studies also reported ventilatory abnormalities, hypocapnia, and changes in cerebral blood flow.[4]

Reduced activity may lead to secondary deconditioning and exacerbate existing circulatory limitations. However, a low VO_2peak does not, by itself, identify the cause of exercise intolerance, and a normal maximal exercise test does not exclude symptoms during daily activity. Patient assessment therefore requires physiological data to be considered alongside symptom characteristics and post-exercise responses.[3,4]

3.3 Potential Mechanisms of Exercise Benefits

The physiological rationale for exercise training includes increased blood volume, improved cardiac filling, and muscular adaptations to repeated exercise. In the study by Fu et al., plasma volume and total blood volume increased after three months of training. Improved quality of life was accompanied by a reduction in HR during upright posture. However, the study included an initial randomized phase of propranolol or placebo treatment, followed by exercise training. It was not a straightforward parallel-group comparison of randomly assigned exercise training and pharmacotherapy.[11]

Lower-limb exercises are intended to support the muscle pump and venous return, while a recumbent position reduces orthostatic stress during a session.[3] In the study by Andrade et al., which included 13 individuals with POTS and 13 healthy participants, the response to six minutes of exercise at 50 W depended on body position. Responses in the two groups were more similar during supine exercise than during exercise in an upright seated position. This provides direct physiological support for selecting an appropriate exercise position but does not establish the superiority of any long-term rehabilitation program.[12]

4 Exercise Capacity and Responses in Clinical Studies

4.1 Aerobic Capacity and the Interpretation of Predicted Values

Cardiopulmonary exercise testing (CPET) allows direct measurement of oxygen uptake and assessment of circulatory and respiratory responses during exercise. Peak oxygen uptake, VO_2peak, can be expressed in mL/kg/min and as a percentage of the predicted value. In tests without gas exchange measurements, exercise capacity is estimated from the workload achieved, including in metabolic equivalents (METs). One MET is conventionally equivalent to 3.5 mL O_2/kg/min. Results obtained using these methods are not fully interchangeable; interpretation requires consideration of the protocol and reference values used.[13,14]

Hutt et al. analyzed treadmill exercise tests in 255 adult patients, of whom 91% were women, with a mean age of 33.5 ± 11.3 years. Mean exercise capacity was 9.2 ± 2.2 METs. In 44% of participants, results were below the average age- and sex-specific reference values. The overall group mean therefore cannot establish whether exercise capacity was normal or reduced in

every participant. Patients with below-normal results were younger than the remaining participants, despite the use of age-specific reference values. The authors considered a more burdensome course with earlier POTS onset or improvement with age as possible explanations. The cross-sectional design could neither resolve these hypotheses nor establish that younger age reflected a shorter disease duration.[13]

In the same study, reduced exercise capacity was accompanied by a lower SF-36 physical component score: 28.6 ± 9.2 versus 32.4 ± 9.1 points ($p = 0.006$). This questionnaire assesses physical functioning, role limitations, pain, vitality, and mental health, among other domains; results can be summarized as physical and mental component scores. However, an association with the physical component does not establish that improved exercise capacity alone will improve quality of life. A further limitation was the inclusion of both individuals with tachycardia within 10 minutes of assuming an upright posture and those with a later response described as "late POTS".[13]

Loughnan et al. analyzed 98 maximal CPETs. Mean VO_2peak was 28.5 ± 7.0 mL/kg/min, compared with a predicted value of 30.3 ± 5.1 mL/kg/min ($p = 0.005$). Nevertheless, 70.4% of individuals exceeded 84% of the predicted value, the threshold for normal exercise capacity adopted in the study.[14] The difference from the findings of Hutt et al. should not be considered contradictory: the studies used different measurements, different criteria for reduced exercise capacity, and different clinical populations. Both indicate variation in exercise capacity rather than a uniform degree of deconditioning among all individuals with POTS.

4.2 Circulatory and Respiratory Responses

The review by Hogwood et al. included 17 cohorts described in 19 reports, comprising 1321 patients with POTS and 502 controls. HR was higher in POTS in seven of eight studies assessing submaximal exercise. By contrast, five of eight studies comparing peak HR found no between-group difference. The abnormality may therefore involve a rapid rise in HR at a relatively low workload rather than the maximum value itself. Linking this observation to difficulties in daily life remains a physiological interpretation when activity outside the laboratory has not been measured directly.[4]

In the study by Griffith et al., which included 222 adolescents with POTS, other forms of orthostatic intolerance, or neither condition, the clinical groups had higher HR at 10%, 25%, and 50% of the duration of the maximal exercise test and showed slower HR recovery. Some findings combined different orthostatic disorders, limiting their specificity to POTS.[15] Novak et al. described invasive CPET in 16 selected patients with POTS who formed a subgroup of a

larger study. Mean VO_2peak was 78.1% of the predicted value, and 62.5% met the criterion for reduced exercise capacity. The observed cardiac filling abnormalities apply to this selected group and do not establish the prevalence of this mechanism across the POTS population.[16]

Reduced ventilatory efficiency was reported in some participants in the Loughnan study.[14] Together with the heterogeneity of circulatory responses, these findings support the assessment of several contributors to exercise limitation. HR or VO_2peak alone does not capture the patient's full experience.

5 Effects of Exercise Interventions

5.1 Exercise Capacity and Hemodynamic Parameters

In the randomized study by Wheatley-Guy et al., 49 of 60 enrolled participants completed the 12-week follow-up: 26 in the exercise group and 23 in the standard care group. The individualized program included a consultation, eight supervised contacts, and three aerobic sessions per week. Standard care could include exercise advice but did not provide comparable structured support. The mean change in VO_2peak was +3.4 versus −0.2 mL/kg/min ($p < 0.0001$), and the change in peak workload was +19 ± 17 versus 0 ± 10 W. These findings indicate a benefit of this program relative to the comparator used, without separating the effect of exercise itself from the effects of individualization and supervision.[17]

Approximately 92% of participants enrolled in this study had a VO_2peak below 85% of the predicted value. The findings should therefore not be automatically extrapolated to patients with normal exercise capacity. An analysis restricted to study completers may also overestimate benefits if those who withdrew tolerated the intervention less well.[17]

Yanagimoto et al. studied 28 hospitalized adolescents aged 12–15 years, including 19 boys. Seventeen were assigned to a four-week program, and 11 served as controls; allocation depended on the month of admission and was not randomized. In the exercise group, VO_2peak increased from 30.3 to 33.2 mL/kg/min ($p = 0.005$), and test duration increased from 9.6 to 10.8 minutes ($p = 0.002$). Stroke volume during upright posture increased from 61.7 to 73.1 mL, and cardiac output increased from 6.6 to 7.7 L/min. No significant change in the orthostatic HR response was demonstrated. The reported p-values describe changes within the exercise group and do not test the difference in changes between groups. The inpatient setting and population characteristics limit the generalizability of the findings.[18]

5.2 Orthostatic Symptoms and Quality of Life

In the Wheatley-Guy study, improvement in the orthostatic domain of COMPASS-31 was greater after exercise training than after standard care (−1.98 versus −0.81 points; $p = 0.0219$).

However, no advantage was demonstrated for the change in the total questionnaire score ($p = 0.0925$). The SF-36 physical component score improved by 7.03 versus 0.40 points ($p = 0.0055$), whereas no significant between-group difference was found in the change in the mental component score or in a separate assessment of self-reported functional ability. These findings relate to specific outcome measures; a lack of statistical significance does not establish equivalence between groups or the absence of any benefit.[17]

Gibbons et al. evaluated a six-month home-based program. Of 77 individuals invited to participate, 48 began exercising and 43 completed the program. The comparison group of 29 comprised 19 individuals who declined exercise training and 10 who were lost to follow-up. After six months, 23% of the group that undertook training met the orthostatic tachycardia criterion, compared with 93% of the comparison group. Fewer syncopal episodes and an increase in self-rated health on the EuroQol visual analogue scale (VAS) from 61 to 71 points were also reported. Interpretation is limited by self-selection into the program and the imputation of missing outcomes using the last available observation. No longer meeting the HR criterion is not equivalent to resolution of all symptoms, and the EuroQol VAS does not establish improvement in specific activities.[19]

The PULSE study randomized 44 individuals to remote rehabilitation or standard care. The program combined online group exercise, recumbent cycling at home, and behavioral support. Outcomes showed a favorable direction of change: at four months, submaximal test duration was 7.0 ± 2.7 versus 6.0 ± 1.7 minutes, and the change in COMPASS-31 was -6 versus $+1$ points. However, the study was designed to assess feasibility rather than establish efficacy; 29 participants completed the four-month assessment. Program acceptability and the feasibility of planning a larger trial should be distinguished from demonstrated clinical benefit.[20]

5.3 Daily Activity and Functional Outcomes

Rich et al. reported the outcomes of a multicomponent rehabilitation program completed by 19 women. Eight weekly sessions combined education, physical activity, and work on responding to personal difficulties with self-compassion. The available abstract described improvements in daily tasks, walking speed, grip strength, fatigue, and quality of life between baseline and follow-up. These data extend outcome assessment beyond CPET but do not separate the effects of exercise from those of the other program components. Details of participant selection and attrition require assessment of the full text.[21]

Svensson et al. obtained different results in a randomized trial involving individuals with POTS following COVID-19. An analysis of 60 participants after 16 weeks found no advantage of

exercise training plus standard care over standard care alone in quality of life. Time spent upright was 31 min/day shorter in the intervention group (95% CI: −57 to −6). Some secondary outcomes improved in both groups. The available abstract therefore indicates that the expected improvement in the main outcomes was not observed, but it does not explain the reduction in activity. This finding applies to a specific population and intervention.[22]

5.4 Program Completion and Maintenance of Benefits

In the registry reported by George et al., 103 of 251 individuals, approximately 41%, completed a three-month program of exercise training and lifestyle modification. Among completers, 71% no longer met the criteria for POTS, but this proportion cannot be applied to all enrolled participants. Follow-up at 6–12 months included only 31 individuals. Concurrent recommendations on fluid and salt intake also make it difficult to isolate the effect of exercise alone.[23]

In the 2024 feasibility study by Svensson et al. involving POTS following COVID-19, 25 of 26 individuals completed the protocol. Reported adherence was 76%, but this estimate was based on the available exercise diaries rather than complete records for the entire group. The program included weekly support from a physiotherapist. Reported symptoms included headaches and episodes of worsened well-being; physiotherapists also recorded falls or syncope during unsupervised exercise. High retention therefore does not imply an absence of tolerability problems.[24] In the Wheatley-Guy study, two withdrawals from the exercise group were associated with exacerbations of autonomic symptoms.[17] Program evaluation should include outcomes, intervention completion, and reasons for discontinuation. Selected primary studies of exercise capacity and intervention effects are summarized in Table 1.

Table 1. Selected primary studies of exercise capacity and training outcomes in POTS

Study	Design and population	Assessment or intervention	Main findings	Completion and interpretation
Hutt et al. 2020 [13]	Retrospective cross-sectional study; n = 255 adults; 91% women	Bruce or Cornell treadmill test; estimated METs; SF-36	9.2 ± 2.2 METs; 44% below age/sex norms. Physical SF-36: 28.6 vs 32.4 in lower vs normal capacity groups.	Estimated capacity, not measured VO_2. Included tachycardia after 10 min ("late POTS"). Association is not causation.
Loughnan et al. 2021 [14]	Clinical case series; n = 98 maximal adult CPETs	Direct gas exchange; comparison with predicted VO_2peak	VO_2peak 28.5 ± 7.0 vs predicted 30.3 ± 5.1 ml/kg/min; 70.4% achieved >84% predicted.	Clinical selection and reference equation matter; normal peak capacity does not exclude daily symptoms.
Novak et al. 2024 [16]	Selected invasive-CPET subgroup; n = 16 with POTS	Invasive CPET; cardiac filling and oxygen uptake	Mean VO_2peak 78.1% predicted; 62.5% below the study threshold; abnormal cardiac filling.	Subgroup of a larger study; cannot estimate mechanism prevalence in all POTS.

Study	Design and population	Assessment or intervention	Main findings	Completion and interpretation
Griffith et al. 2026 [15]	Pediatric study; n = 222 across POTS, other OI and healthy groups	CPET; HR during exercise and recovery	Higher HR at 10%, 25% and 50% of test duration; lower aerobic fitness and slower HR recovery in clinical groups.	Mixed diagnoses; some results are not POTS-specific. Detailed subgroup methods not assessed.
Fu et al. 2011 [11]	19 POTS completers; randomized drug phase followed by training	4-week propranolol/placebo phase; then 3 months of exercise	Blood/plasma volume and selected SF-36 domains improved after training; standing HR decreased.	Sequential design; not a parallel randomized exercise-versus-drug comparison.
George et al. 2016 [23]	Community registry; n = 251 enrolled	3 months of endurance and strength training plus salt/fluid advice	71% of completers no longer met POTS criteria; quality of life improved.	103/251 completed (41%); later follow-up n = 31. Selection and co-interventions limit inference.
Gibbons et al. 2021 [19]	Pragmatic nonrandomized study; n = 77 invited	6-month home program; 48 started; 29 comparison participants	Orthostatic tachycardia criterion: 23% vs 93%; EuroQol VAS 61 to 71 in the exercise group.	43/48 completed. Comparison: 19 declined, 10 lost to follow-up. Missing data used last observations.
Wheatley-Guy et al. 2023 [17]	Randomized trial; 60 recruited; 49 completed (26 training/23 usual care)	12 weeks; individualized aerobic training; 8 supervised contacts	ΔVO_2peak +3.4 vs −0.2 ml/kg/min; physical SF-36 +7.03 vs +0.40; total COMPASS-31 difference not significant.	92% had baseline VO_2peak <85% predicted. Completer analysis; usual care could include exercise.
Yanagimoto et al. 2025 [18]	Nonrandomized inpatient study; n = 28; age 12–15; 19 boys	4 weeks; 17 training/11 control; recumbent ergometer	VO_2peak 30.3 to 33.2 ml/kg/min; standing SV 61.7 to 73.1 ml; no significant orthostatic HR change.	Allocation by admission month. Values describe within-training-group changes, not comparative treatment effects.
McGregor et al. 2025 [20]	PULSE feasibility RCT; n = 44 (23 intervention/21 control)	12-week online group rehabilitation, home recumbent cycling and behavioral support	At 4 months: exercise-test duration 7.0 vs 6.0 min; COMPASS-31 change −6 vs +1.	29/44 assessed at 4 months. Not powered to establish clinical efficacy; descriptive findings.
Rich et al. 2026 [21]	Multimodal program report; 19 female completers	8 weekly 50-minute sessions: education, movement and self-compassion	Reported improvements in daily tasks, gait, grip strength, fatigue and quality of life.	Exercise contribution cannot be separated. Enrollment and attrition unavailable in accessed abstract.
Svensson et al. 2026 [22]	Randomized trial in post-COVID-19 POTS; n = 60 analyzed	16 weeks; tailored exercise with weekly supervision plus usual care vs usual care	No quality-of-life advantage; upright time difference −31 min/day (95% CI −57 to −6).	Population-specific result; detailed attrition and safety assessment unavailable in accessed abstract.

CPET, cardiopulmonary exercise testing; HR, heart rate; MET, metabolic equivalent; OI, orthostatic intolerance; RCT, randomized controlled trial; SV, stroke volume; VAS, visual analogue scale; VO_2peak, peak oxygen uptake.

6 Practical Implications for Planning Physical Activity

6.1 Selection of Exercise Position and Type

The initial position should be selected according to orthostatic tolerance and functional ability. The Fu and Levine protocol initially used recumbent cycling, rowing, or swimming, followed by the introduction of more upright activities.[3] The study by Andrade et al. supports the physiological importance of body position, but no single type of activity has been shown to be

superior in terms of sustained clinical outcomes.[12] Choosing swimming also requires an individual assessment of the risk of fainting in water.

Ziaks et al. propose assessing tolerance of body position and workload so that the program can begin at a level matching the patient's current abilities. A person who tolerates sitting does not necessarily need to complete the same initial phase of recumbent exercise.[25] For patients with severe limitations, Trimble et al. describe an initial focus on tolerating sitting, brief periods of standing, and moving around the home. These are proposed approaches to organizing rehabilitation rather than treatment protocols validated in comparative studies.[6]

6.2 Exercise Dose and Principles of Progression

The parameters of a program found effective in a particular study do not constitute a universal exercise dose for all individuals with POTS. Fu and Levine describe an initial schedule of three to four aerobic sessions per week, lasting approximately 25–30 minutes each, at an intensity of approximately 75% of predicted maximal HR and a rating of perceived exertion of 13–15 on the Borg 6–20 scale.[3] Wheatley-Guy et al. used three sessions per week, initially with approximately three-minute exercise intervals interspersed with rest, progressing gradually to 30 minutes of continuous exercise. The range of 75–85% referred to the peak HR measured during the exercise test, while breathing and symptoms took priority in determining workload.[17]

Predicted maximal HR and measured peak HR are not equivalent reference values. Medication, body position, and symptom severity may further alter the HR response. HR monitoring should therefore be combined with assessment of perceived exertion, symptoms during sessions, and recovery. The intensive schedule in the Yanagimoto study, comprising five weekly sessions during hospitalization, describes a specific pediatric intervention and should not be directly applied to home-based treatment in adults.[3,17,18]

In the model proposed by Ziaks et al., the initial workload for individuals with low exercise tolerance may correspond to approximately 2 points on a 0–10 rating of perceived exertion scale. The authors base progression of intensity in the current position on minimal symptom exacerbation during and after exercise, maintenance of the selected HR or perceived exertion range for at least 20 minutes without substantial workload adjustment, and consistent tolerance across three sessions per week or three consecutive sessions. Progression to a more upright position requires a separate assessment. These criteria facilitate planning but have not been established as the optimal progression model in randomized comparisons.[25]

6.3 Resistance Training and Adjunctive Measures

Resistance exercises usually target the lower limbs and trunk, with positions selected to limit orthostatic stress. In the Fu and Levine protocol, resistance training began with one weekly session lasting 15–20 minutes and progressed to two sessions of 30–40 minutes.[3] Ziaks et al. propose strength training on at least two nonconsecutive days, adapted to the position and intensity tolerated.[25] However, studies of multicomponent programs do not establish the independent effect of resistance exercise on POTS symptoms.

Hydration, sodium intake, and compression garments may support orthostatic tolerance, but their use depends on clinical status, current treatment, and contraindications.[1,3] They are also co-interventions that should be recorded when evaluating program outcomes. The specific parameters of selected protocols and the status of the supporting evidence are presented in Table 2.

Table 2. Exercise protocols and proposed rehabilitation approaches in POTS

Source and evidence	Modality and starting point	Frequency and duration	Intensity and progression	Clinical interpretation
Fu & Levine 2018 [3] Narrative review of a structured program	Initially recumbent cycling, rowing or swimming; later upright activity; lower-limb/core resistance work	Aerobic: initially 3–4 sessions/week, 25–30 min. Resistance: 1 session/week, 15–20 min, progressing to 2 sessions, 30–40 min.	Approx. 75% predicted HRmax; Borg RPE 13–15 (6–20 scale). Increase duration and introduce upright modalities as tolerated.	Protocol parameters, not dose-finding evidence. HR targets require individual interpretation and do not override symptoms.
George et al. 2016 [23] Prospective registry	Semirecumbent progressing to upright endurance work; strength training; salt/fluid advice	3-month program; endurance 3–5 sessions/week, 30–45 min/session	Mild-to-moderate endurance exercise; physician oversight; progressive posture and workload.	Completion was 41%. Multiple components prevent attribution of benefit to one exercise element.
Wheatley-Guy et al. 2023 [17] Randomized trial	Usually semirecumbent initially; upright cycling or treadmill as tolerated	12 weeks; 3 aerobic sessions/week; 8 supervised contacts. Initially 20–30 min of intervals; target 30 continuous min.	Approx. 3-min work intervals, longer work/shorter recovery over time. Suggested 75–85% measured peak HR; breathing and symptoms guide intensity.	Measured peak HR is not predicted HRmax. Evidence concerns the complete individualized, partly supervised program.
Yanagimoto et al. 2025 [18] Nonrandomized inpatient study	Supine ergometer in weeks 1–2; semisupine in weeks 3–4	4 weeks; 5 sessions/week; 30 min/session: 5-min warm-up, 20-min pedaling, 5-min cool-down	Initial power based on the CPET workload 1 min before the anaerobic threshold; optional 10-W increments at participant request.	Tested in hospitalized adolescents aged 12–15; not established as a general outpatient adult prescription.
Svensson et al. 2024 [24] Single-arm feasibility study	Post-COVID-19 POTS; individualized endurance and lower-limb/abdominal strengthening	12 weeks; endurance 3 times/week; strength 2 times/week; weekly physiotherapist contact	Aerobic Borg RPE 11–14; strength RPE 13–15 (6–20 scale). Posture and duration adapted to tolerance.	Feasibility does not prove efficacy. Symptoms and falls/fainting during unsupervised exercise were reported.

Source and evidence	Modality and starting point	Frequency and duration	Intensity and progression	Clinical interpretation
Ziaks et al. 2024 [25] Proposed clinical framework	Starting posture selected by physiological and symptom tolerance; coordinated aerobic/resistance work	Strength on at least 2 nonconsecutive days/week. Progression criteria include ≥20 min in the target zone and 3 sessions/week or 3 consecutive sessions.	Low starting effort may be approx. 2/10 on a 0–10 RPE scale. Progress intensity within the current posture only after repeatable tolerance with minimal symptom increase; reassess posture separately.	Expert proposal, not a validated progression algorithm. The 20-min criterion is not an obligatory initial exercise dose.
Trimble et al. 2024 [6] Narrative review and clinical experience	For severe functional limitation: tolerating sitting, brief standing and short movements at home before structured exercise	No fixed universal session duration or progression schedule	Individualized home-based rehabilitation; adapt to daily function and delayed symptom response; pacing when PEM is present.	A practical approach requiring comparative validation. Daily tasks are rehabilitation goals, not proven outcomes for every patient.

HRmax, maximum heart rate; peak HR, highest heart rate measured during an exercise test; RPE, rating of perceived exertion. Borg 6–20 and 0–10 RPE scales are not interchangeable. Reference numbers match the accompanying manuscript.

6.4 Monitoring Symptoms and Post-Exertional Exacerbations

Before planning physical activity, assessment should cover orthostatic tolerance, the person's existing activity level, medications affecting HR, and the nature of post-exercise deterioration. Dizziness and palpitations during a session should be interpreted in relation to workload and baseline status. Syncope, new chest pain, or marked breathlessness require exercise cessation and medical assessment. An increase in HR alone does not determine the safety or effectiveness of exercise training.[1,25]

Post-exertional malaise (PEM) should be distinguished from ordinary exercise-related fatigue. Its onset may be delayed, and it may persist beyond the exercise session. Good tolerance of exercise on a given day therefore does not exclude deterioration during recovery. When PEM is present, the plan should account for the total demands of daily activities, rest, and management of activity within available energy, known as pacing. A prior clinical assessment does not justify automatic progression despite worsening symptoms.[6,25]

Program monitoring should cover not only HR and completed sessions but also delayed deterioration, interruptions, workload adjustments, and a goal that matters to the patient, such as tolerating meal preparation or attending classes. These are suggestions for functional monitoring; they do not imply that available studies have demonstrated improvement in each of these activities.

7 Discussion

Evidence on exercise training in POTS is most convincing for improvements in selected measures of exercise capacity in specific populations. However, it does not provide a consistent

picture of the effects on symptoms, quality of life, and daily activity. Distinguishing these outcomes prevents a single physiological parameter from replacing an assessment of functioning. A higher VO_2peak may represent a beneficial adaptation even without normalization of orthostatic HR, but it is insufficient evidence of the effectiveness of the overall management approach.[7,17,18]

Participant selection is one source of divergent findings. Cross-sectional studies used different reference values and POTS criteria, while exercise trials included groups differing in baseline exercise capacity, age, and treatment setting.[13,14,17,18] Findings in a population with reduced VO_2peak cannot predict the response of a patient with normal CPET results and severe PEM (post-exertional malaise). Similarly, hospitalization may improve exercise adherence and control of co-interventions in ways that are difficult to reproduce at home.

The choice of comparator and completeness of follow-up also matter. Trials comparing a therapist-supported program with standard care evaluate the entire approach to delivering treatment. Nonrandomized self-selection into a program may be associated with differences in motivation and health status. Analyses restricted to completers and imputation of missing measurements using the last available result introduce further limitations.[17,19,23] Interpretation should prioritize between-group differences in change and confidence intervals, while findings across multiple secondary domains should be treated cautiously. A nonsignificant difference does not establish equivalence, and statistical significance does not automatically indicate the clinical magnitude of a benefit.

Newer data allow more direct assessment of functioning. Measures of walking and daily tasks complement questionnaires, while the randomized controlled trial in POTS following COVID-19 shows that an anticipated functional benefit may not occur.[21,22] At the same time, the study by Seeley et al. documents substantial impairments in quality of life, including mobility, self-care, and daily activities.[26] This supports the selection of goals that matter to patients without assuming that improvement in a single questionnaire domain represents a return to work or education.

Exercise adherence is part of the treatment outcome. In the mixed-methods study by Walsh et al. and the survey by Levine et al., patients described fatigue, dizziness, tachycardia, and post-exertional deterioration as barriers to activity. Self-reported data do not establish causality but identify experiences that may hinder participation in a program.[27,28] Retention, reasons for withdrawal, and reported symptom exacerbations should be reported alongside outcomes, rather than attributing noncompletion solely to a lack of motivation.

The durability of benefits remains poorly established. Long-term follow-up in the exercise registry included only a small subgroup.[23] The study by Bourne et al., examining the course of POTS after more than two decades, indicates that symptoms may persist for many years but does not assess the effectiveness of exercise training.[29] Studies are needed that combine measures of exercise capacity with time spent in upright activity, participation in work or education, achievement of individual goals, and sustained participation in the program.

The limitations of this review include narrative source selection, the use of one main database, language restrictions, and the absence of a formal risk-of-bias assessment. Access to some of the most recent studies was limited to abstracts, restricting the assessment of methods and safety. This synthesis should therefore not be regarded as a comprehensive estimate of effectiveness or a basis for establishing a single exercise dose. Its practical value lies in distinguishing measured effects from inferred effects and identifying which recommendations still require comparative validation.

8 Conclusions

Individualized exercise training may improve exercise capacity and selected clinical outcomes in some individuals with POTS. Benefits are not uniform across populations or outcome measures. Improved VO_2peak does not establish normalization of orthostatic responses, increased daily activity, or sustained recovery of independence. Program planning should account for tolerance of body position, current abilities, medications, and delayed symptom exacerbations. The parameters of specific protocols should be clearly distinguished from expert proposals. Treatment evaluation should be based on physiological outcomes, symptoms, functioning, and intervention tolerability. Further studies should compare exercise dosing and support strategies, report reasons for withdrawal and adverse events, and determine whether benefits in daily life are sustained.

Disclosure

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