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Special Communication

Adaptive Approaches to Exercise Rehabilitation for Postural Tachycardia Syndrome and Related Autonomic Disorders

Lauren Ziaks, PT, DPT, ATC [a,1], Kathryn Johnson, PT, DPT [b,c,1], Kelsi Schiltz, PT, DPT [d], Ryan Pelo, PT, DPT, PhD [d], Guillaume Lamotte, MD, MSc [b], Claudia Dal Molin, DO, RMSK [e], Tae Chung, MD [f], Melissa M. Cortez, DO [b]

[a] *Park City Hospital, Intermountain Health, Canyons Region, Park City, UT.*
[b] *Department of Neurology, University of Utah, Salt Lake City, UT.*
[c] *Orthopedic Center, University of Utah, Salt Lake City, UT.*
[d] *Department of Physical Therapy and Athletic Training, University of Utah, Salt Lake City, UT.*
[e] *Department of Orthopedics, University of Maryland School of Medicine, Baltimore, MD.*
[f] *Department of Physical Medicine and Rehabilitation, Johns Hopkins University School of Medicine, Baltimore, MD.*

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Abstract Exercise is a well-documented, nonpharmacologic treatment for individuals with autonomic dysfunction and associated orthostatic intolerance, such as postural tachycardia syndrome and related disorders. Exercise has been shown to increase blood volume, reverse cardiovascular deconditioning, and improve quality of life. Current first-line standard of care treatment for autonomic dysfunction combines graded approaches to exercise with medications and lifestyle modifications. However, current exercise rehabilitation protocols for postural orthostatic tachycardia syndrome contain rigid timelines and progression paradigms that often threaten tolerability and adherence. In addition, they fail to account for clinical variables potentially critical to care and lack guidance for individualization, limiting accessibility to patients with co-morbidities that affect exercise appropriateness and safety. Therefore, we introduce an adaptive approach to exercise prescription for orthostatic intolerance that allows patient-specific modifications to meet functional goals for a wider spectrum of patients, thus improving adherence. The proposed approach integrates iterative physiological and symptomatic

List of abbreviations: ANS, autonomic nervous system; bpm, beats per minute; PEM, post exertional malaise; POTS, postural orthostatic tachycardia syndrome; RPE, rating of perceived exertion.

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[1] co-first authors.

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assessments to provide flexible, yet structured, exposure to aerobic exercise and strength training to improve functional capacity and tolerance of daily activities for patients with postural tachycardia syndrome and related autonomic disorders.

The autonomic nervous system (ANS) is a complex neural network that coordinates central (brain and spinal cord) and peripheral (ganglia and nerves) pathways to regulate involuntary (automatic) bodily functions in response to environmental changes and activity. These functions include heart rate, blood pressure, breathing, pupillary function, digestion, temperature regulation, sweating, and urinary function.[1] The ANS is further integrated with endocrine, immune, and behavioral responses to maintain homeostasis. Symptoms of ANS dysfunction, commonly referred to as dysautonomia, arise when one or more of these systems is disrupted. Dysautonomia can result from a wide array of primary neurogenic disorders (eg, pure autonomic failure and Parkinson disease), and secondary causes of autonomic dysfunction (eg, postviral syndromes, systemic autoimmune conditions, and metabolic disorders).[2] A hallmark symptom of dysautonomia and a key contributor to disability, is orthostatic or exercise intolerance.[3-6] Postural tachycardia syndrome (POTS) is perhaps one of the most widely recognized dysautonomias associated with chronic orthostatic intolerance, which is characterized by symptomatic, excessive orthostatic tachycardia, often accompanied by symptoms of multisystemic autonomic dysfunction.[7-10]

Broadly speaking, clinical management of autonomic dysfunction, including POTS, includes a combination of pharmacologic and nonpharmacologic interventions that focus on symptom targeted care.[11,12] Comprehensive management often requires collaboration across multiple health care disciplines because of the broad spectrum of clinical manifestations.[11,13] Current literature supports the use of cardiovascular exercise as a cornerstone of nonpharmacologic intervention.[3,14,15]

Most published therapeutic exercise protocols for POTS and related chronic orthostatic intolerance[6,14,16,17] include a combination of strength training (focusing on lower extremities and core muscles) and graded cardiovascular exercise to gradually improve gravitational (upright) tolerance over time. Such programs typically begin with supine or recumbent aerobic and strengthening activities and gradually progress toward more upright modes of exercise over time. Despite the recommendation of exercise for patients with autonomic dysfunction, reported adherence or completion rates for established protocols can be well below 50%.[5,16] Reasons for poor adherence with exercise protocols include interference by hospitalizations, lack of access to equipment, perception that the program is too difficult, post exertional malaise (PEM), fear of physical activity (kinesiophobia), pain, or other comorbid medical conditions.[14,16] In addition, patients often attempt to engage exercise on their own, whereas referral to physical therapy has been shown to result in the most appropriate or better individualized prescriptions for intensity, duration, mode of exercise, and body mechanics.[18] Finally, there are a number of co-morbidities that commonly occur with POTS, along with other conditions associated with chronic orthostatic intolerance, many of which can affect participation, recommended approach, and response to exercise.[10,19-48]

Clinically, the heterogenous nature of autonomic dysfunction, spectrum of co-morbidities, and the oftentimes limited tolerability of rigidly scheduled progression paradigms represent critical limitations for the currently accepted graded exercise programs commonly used for POTS treatment. Furthermore, existing programs do not consider current functional status, individual functional goals, access to specific equipment, or relevant co-morbidities that affect exercise responses. These factors should be considered when prescribing an exercise program to improve adherence, engagement, tolerability, and overall effect. There is growing interest in physiologically informed, personalized exercise prescriptions, with the potential to improve long-term health outcomes over standard methods alone.[49-52]

Key conceptual advances

To address these needs, we propose a series of conceptual advances to improve current approaches to autonomic rehabilitation. Drawing from existing standards in exercise physiology and rehabilitation science,[53] we suggest 4 key advances with the purpose of making autonomic rehabilitation more individually driven and adaptable to patient needs and physiological responses to activity (fig 1), as follows: (1) Comprehensive evaluation, composed of physiological and functional metrics to inform exercise prescription and rehabilitation goals, while screening for barriers and appropriateness of exercise therapy paired with serial reassessments; (2) Individualized program entry and initial exercise prescription; (3) Patient-driven criteria to advance within the program, including progression within each stage, and transition between modes of exercise (eg, progression of heart rate target zone within current exercise mode; and transition from supine to upright mode of exercise); and (4) Adaptation to patient needs, including consideration of intervals of work and rest, modifying to account for equipment factors, etc. (see fig 1).

Although this approach is framed around previously published exercise protocols for POTS treatment,[6,14,16,17] which are currently widely used; these 4 conceptual advances are not currently included in existing protocols and have the potential to address weaknesses of existing approaches, while broadening the application of adaptive therapeutic exercise to this clinical context. These principles are incorporated into a novel exercise program, the Utah Autonomic Disorder *adaptive* Physical Therapy (ADaPT) program, which is currently undergoing formal clinical validation data to be

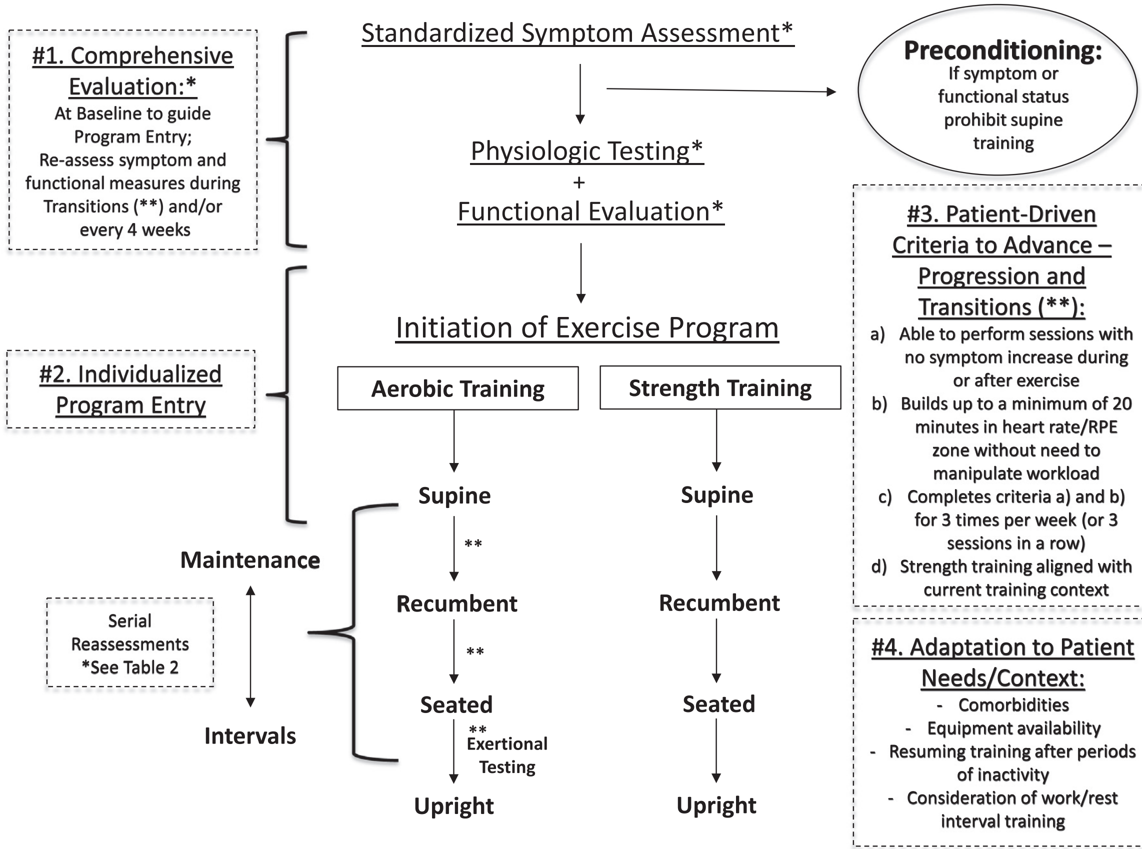

Fig 1 Conceptual advances. (1) Comprehensive evaluation; (2) individualized program entry; (3) patient-driven criteria to advance; and (4) adaptation to patient needs.

published separately. The purpose of this manuscript is to introduce the aforementioned core conceptual advances and their rationale, illustrating gaps and opportunities to advance rehabilitation for POTS and related disorders of chronic orthostatic intolerance.

Methods and rationale

Building on current standard of care approaches to autonomic rehabilitation

Existing literature outlining exercise rehabilitation for POTS and related autonomic disorders is based on several core tenants, as follows: (a) initial utilization of supine or recumbent positioning for training, while gradually introducing gravitational challenge[6,14,16,17]; (b) combination of aerobic and strength training to reverse or prevent cardiovascular deconditioning while building a healthy biomechanical foundation of movement for injury prevention[14,16]; and (c) regular, near-daily activity to improve and maintain activity tolerance, typically requiring 3 or more sessions per week.[6,14,16-18] Programs of this nature are typically built around training in 4 cardinal body positions (supine, recumbent, seated, and upright), shown in fig 1, around which exercise prescriptions (program entry and transitions) can be oriented. Building on these core tenants and graduated progression through body positions, we suggest the following conceptual advances to move toward an adaptable model:

Conceptual principle #1: comprehensive evaluation

A key challenge with the established graded exercise protocols for POTS is the lack of flexibility to meet the needs of these often medically complex patients.[6,14,16,17] A comprehensive program should provide parameters for clinical decision-making throughout, providing the clinician flexibility and guidance in prescribing appropriate exercise frequency, intensity, and dosage. Furthermore, based on published consensus statements,[11] and our experience drawing on collective expertise across a variety of disorders associated with chronic orthostatic intolerance, including POTS and its commonly related comorbid conditions, it is clear that exercise rehabilitation must also consider relevant comorbid or contributing conditions when approaching exercise prescriptions.

We propose to accomplish this through a multidimensional assessment at program initiation and at intervals throughout the program (table 1),[54-74] allowing for therapist-led selection of tools directed at the quantification of baseline symptom burden and function, which can be used to guide exercise dosage (position, intensity, and duration) and progression over time. Such an approach is generally intended to be led by a physical therapist using common cardiovascular and strengthening equipment available in most outpatient clinics, with re-evaluation and follow-up

Table 1 Examples* of useful tools for symptomatic, physiological, and functional assessments to guide autonomic rehabilitation.

Assessment	Tools
Symptom evaluation*	• Top 3 worst symptom ratings and visual analog scale[54] • Postexertional malaise screening[55-57] • Dizziness handicap inventory[58] • Orthostatic symptoms questionnaires, developed for orthostatic hypotension, though have been modified for use in orthostatic intolerance syndromes[59,60]
Physiological testing	• Orthostatic testing—active stand test[61-63] • Hypermobility screening[64] • Neurologic examination for peripheral neuropathy or small fiber neuropathy[65](ref) • Submaximal or maximal exercise testing such as: Buffalo concussion treadmill test,[66] Buffalo bike test,[67] cardiopulmonary exercise testing[68,69]
Functional assessment	• Patient-specific functional scale[70] • 6-min walk test[71,72] • 5 × sit to stand[73,74]

* Very few disease-specific symptom assessment tools have been validated for this use. Thus, the suggested tools focus on disability driving symptoms, rather than disease-specific metrics, and selection may vary based on a therapist's expertise and patient's needs.

assessments timed according to usual treatment schedules. This allows for both the patient and clinician to monitor for negative effects of exercise, so that a safe and tolerable exercise regimen can be established (see below for further discussion on tolerability of exercise) (table 1).

Screening for tolerability. The graded exercise program concepts reviewed here, including previously published exercise protocols for POTS,[6,14,16,17] focus on the treatment of patients with chronic orthostatic intolerance who can presumably tolerate low to moderate steady state exercise without significant symptom increases. However, certain types of exercise may not be appropriate for all patients with autonomic symptoms. One such factor that must be considered is PEM, often associated with myalgic encephalomyelitis/chronic fatigue syndrome. The PEM is an exacerbation of symptoms after minimal cognitive, emotional, or physical activity,[75] and can occur in conjunction with chronic activity intolerance and symptoms of dysautonomia. Although exercise therapies are relatively well-studied for patients with POTS, optimal dosing and progression parameters for therapeutic exercise for patients with orthostatic intolerance associated with significant PEM requires further investigation.[27,76-78] Concerns regarding the potential for long-term consequences resulting from exacerbating activities (such as cardiopulmonary exercise) for individuals with myalgic encephalomyelitis/chronic fatigue syndrome has been introduced;[79,80,81] however, these assertions require further investigation to better understand the underlying mechanisms, and to what extent exercise with a pacing approach can be safely used. In our experience, many patients may be able to effectively minimize the effect of mild to moderate symptom exacerbation related to exercise by entering an exercise program at a very low dose, both in intensity and duration, though those with significant postexercise related symptoms may be best served by focusing on principles of energy conservation[82,83] (described further below).

With these considerations in mind, we recommend symptom screening tools to screen for PEM and alert the therapist to use caution when prescribing cardiopulmonary exercise. Based on our experience and established myalgic encephalomyelitis/chronic fatigue syndrome literature, we suggest a preconditioning state (see fig 1) for patients with marked symptom exacerbation who are working toward building tolerance to a 20-minute bout of supine or recumbent exercise.[55] Techniques such as pacing or fatigue management, functionally-driven range of motion and strengthening, vision or vestibular therapies (as indicated by examination), manual therapy for pain mitigation, and down regulatory strategies (breathing, meditation, and counterpressure maneuvers) should be considered in the formulation of a comprehensive treatment plan.[84] A detailed overview of these principles is beyond the scope of this article, though expert reviews can be found elsewhere.[83,85]

Serial physiological and functional assessments. Physiological testing can be used to evaluate individual cardiovascular responses to active standing and exercise, including heart rate response to exertion, recovery, and correlated exertional ratings with heart rate increases.[61,63] These physiological parameters may be useful to monitor and guide entry into, and progression throughout, exercise. Orthostatic vital signs are a widely used, and are a simple assessment of heart rate responses to standing.[61-63] Similarly, exertional testing, such as the buffalo concussion treadmill test[66] (or the corresponding modified bike test)[47] might also be used to semiquantitatively evaluate baseline and follow-up physiological responses to exercise in the upright or seated position and determine readiness for walking (or seated biking) based exercise.[86-88]

Determination of intensity. We propose that a patient's individual heart rate (or rate of perceived exertion, RPE) in each body position might be useful to parameterize the intensity and progression of exercise for a particular body position. Using this approach, prescription of exercise intensity can be derived by using resting heart rate (taken after 3-5 min) in the intended body position (eg, supine, recumbent, seated, and upright) as the starting point to determine target workload. In addition, RPE (scored on a 0-10 scale for ease of patient-led use), can be used as an added dosing

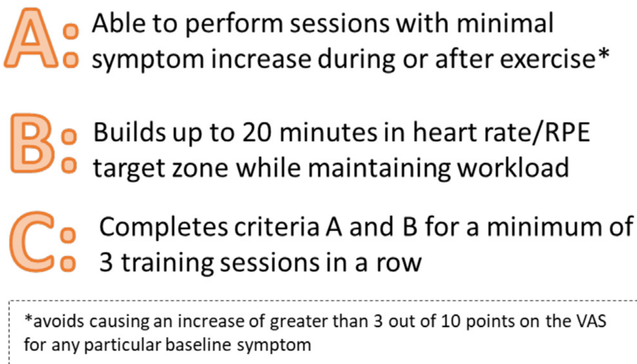

Fig 2 ABC's. Three key concepts to guide assessment of readiness to progress intensity of exercise (heart rate or rate of perceived exertion target zone) within a patient's current stage (mode of exercise or body position).

target for activity in a given body position. The RPE provides the advantage of being independent of heart rate, which may be useful for patients where heart rate responses are altered or unreliable, such as those who are on medications that blunt heart rate responses to activity (eg, β-blockers).[89,90]

Based on this model of using patient-specific metrics (heart rate or RPE) to guide selection of a training intensity, we suggest identifying a position-specific target zone at which each patient would initiate exercise. In our experience, exercise that generates a heart rate of 15-20 beats per minute (bpm) above their baseline resting heart rate in their starting position (eg, supine, recumbent seat, upright bike, etc) serves as an appropriate training target zone. Alternatively, targeting a 2 out of 10 RPE (very light effort) has also served as a well tolerated target zone for initiating exercise at an intensity that maintains the goal of training below the usual threshold of significant symptom exacerbation (defined below and in fig 2).

Prespecified criteria can then be used to help guide the therapist and patient when to increase intensity (ie, transition to a higher heart rate or RPE target zone) within a given body position, while minimizing the risk of overtraining, which can lead to set-backs (eg, missed days of training because of prolonged postexercise related symptom exacerbation). We propose the following criteria (ABCs) as helpful guides to identify when a patient is ready to progress the intensity of aerobic exercise (heart rate/RPE zone) within their current mode (body position) (see fig 2): Able to perform sessions with minimal symptom increase during or after exercise (eg, avoids causing an increase of greater than 3 out of 10 points on a visual analog scale for any particular baseline symptom); Builds up to a minimum of 20 minutes in heart rate/RPE zone without need to manipulate workload (eg, does not need to speed up or slow down dramatically to control heart rate response); Completes criteria A and B for a minimum of 3 times per week (or 3 training sessions in a row). These ABCs are considered during each instance of aerobic exercise prescription throughout the program. As described above, the aerobic exercise prescription adjustments, also guide strength training prescription and progression; meaning, strength training is to be performed in the same body position and intensity as aerobic exercise and should not progress until the patient meets their aerobic ABCs first (see fig 2).

Conceptual principle #2: individualized program entry
Existing standards in POTS exercise treatment[6,14,16,17] utilizing gradual exposure to cardiovascular stress are thought to help re-establish appropriate interplay between the sympathetic and parasympathetic nervous system functions, leading to improved cardiovascular autonomic responses to daily activities.[14,17,18] A critical feature of this approach is to begin with activity (position and intensity) that generates effort at a threshold that is below that which markedly increases symptoms (ie, select an intensity or position for exercise at a sub-symptom threshold). However, existing programs generally lack patient-specific assessments to guide selection of initial body position and dosage.

Program entry and transition to maintenance. In our experience, the body position in which a patient enters an exercise program is best determined by a combination of the patient's subjective report of symptoms, medical history, functional goals, and results of vital signs as introduced above (see fig 1; table 1). All patients should be biomechanically assessed for injury risk at entry, with any deficits in the kinetic chain added to the plan of care. Available modes of exercise should be taken into consideration. Ideally, this is facilitated by referral to a physical therapist for semi-supervised rehabilitation.[18]

Although fig 1 illustrates 4 progressive positions (or modes) for exercise, it is not required that each patient begin in supine and sequentially work through each position to end in upright activity. Rather, standardized evaluations —such as symptom, physiological, and functional assessments (table 1)—might be used as guides to help identify the most appropriate starting body position and exercise intensity for each patient. Similarly, patients can enter a maintenance program at any position that aligns best with their functional or fitness goals and physical capabilities. For example, a patient may be able to achieve tolerable exercise for maintenance using upright stationary cycling, but co-morbidities (eg, hypermobility related arthralgia) or environmental challenges (eg, climate) may preclude them from progressing to a walking program. In this scenario, the patient would transition to a maintenance (or interval-based) program consisting of stationary cycling as the mode of exercise, skipping walking, with the option to initiate interval training in a seated posture (see conceptual principle #4 for more regarding the role of interval training).

Finally, most patients will reach a stage where transition to a maintenance program will be both physiologically and functionally appropriate. We have considered patients ready to enter a maintenance phase when they can achieve at least 20-30 minutes of exercise that is between 65%-75% of their age expected heart rate maximum without symptom exacerbation for a minimum of 3 days per week. This is in keeping with previous authors' suggested initial goal of 20 minutes of cardiovascular aerobic activity at least 3 days per week.[18,91] This recommendation also aligns with the current American College of Sports Medicine's Guidelines for Exercise Prescription[92] of ~150 minutes of moderate intensity exercise per week (eg, 30 min 3 $\times$ /wk of aerobics and 30 min 2 $\times$ /wk of strength training). However, in our experience, consistency is key; thus, whenever possible, we recommend working toward a goal of exercising 4 to 5 days per week to minimize periods of inactivity.

Conceptual principle #3: patient-driven criteria to advance

Progression and transitions. To introduce gradual increases in gravitational challenge through each body position, the patient must first be able to build endurance in their current body position (according to the ABCs outlined above; see fig 2). Once a patient has been able to enter the exercise program and achieve tolerable exercise intensity in their starting body position (adhering to their heart rate/RPE target zone), as described above, the next step is to gradually progress their heart rate (or RPE) target zone upward to prepare to transition to the next, more upright, body position. To do this, we suggest increasing the heart rate target zone by increments of 5 bpm (ie, 90-95 bpm progresses to 95-100 bpm) or increasing by 1 RPE level, which can be completed 3 to 5 times (until satisfying the ABC criteria) before considering transition to the next more upright body position—working toward tolerable exercise within a target zone of 30-35 bpm above the resting heart rate in that position or an RPE of 5 out of 10 (moderate intensity). Using this strategy, the time that patients will spend in each body position is dependent on their ability to meet the criteria of duration, workload, and tolerance. Basing criteria to progress within each stage on patient-specific parameters and response, rather than a set duration, allows for an individualized exercise prescription for each patient.

Beyond orthostatic heart rate responses and RPE, we have found exertional testing (table 1) to be a helpful way to provide individualized assessment of tolerance to specific body positions. In our experience, submaximal exercise testing,[93] as opposed to maximal exercise testing,[68] provides a good balance between technical complexity (eg, widely accessible equipment), ability to identify clinically relevant tolerability thresholds (heart rate or RPE based training target zones) for prescription of exercise dosing, and tolerability for this patient population. Such testing might be particularly useful in determining readiness for the transition from seated exercise to walking.[86-88] For example, the buffalo concussion treadmill test[66] was developed to perform to failure, or more specifically, symptom increase by more than 3 out of 10 points on a visual analog scale, an RPE of 19/20, or achievement of 85% age expected maximum.[94] Analogously, the buffalo concussion bike test[67] performs similar parameters within a recumbent or seated position. When prescribing individualized graded exercise prescriptions, baseline, and follow-up submaximal exercise testing (treadmill or bike based) might be useful as a clinical decision-making aid by helping to determine a patient's readiness for seated or standing upright exercise. In this application, once the patient is able to complete the first minute (stage) of the submaximal exercise test protocol at a heart rate that is below their prescribed heart rate (or RPE) target zone in that position, they might be considered ready to transition to seated bike or walking (depending on the position evaluated) using the 20-minute recommended initial duration as a guide. This type of testing is also helpful for assessing heart rate recovery kinetics, and when completed during follow-up sessions, could be used to semi-objectively evaluate for evidence of improved cardiovascular autonomic response to exercise[46] or readiness for transition to interval training, as described in further detail below.

Role of strength training in autonomic rehabilitation. As in previously published protocols for POTS,[6,14,16,17] the staged approach to aerobic training discussed above is ideally paired with strength training at least 2 nonconsecutive days per week to avoid muscle injury and overuse. We, and others,[14,16] focus on strengthening exercises using the same body position as is used during cardiovascular exercise (see fig 1). In a patient with reduced tolerance to repetitive motions, circuit training exercises may be used to build cardiovascular tolerance in the preconditioning stage. As exertional tolerance improves, a goal of 15-20 minutes (in addition to cardiovascular training) of strengthening exercises are recommended at the sub-symptom threshold, which should generally be performed at an intensity that remains below the patient's current target heart rate and RPE for cardiovascular training.

In this context, strengthening exercises should generally target core and lower limb muscles to improve intrinsic muscle pump function through stronger contractions[14] and resting tone. Per our clinical experience, compound (multijoint) strength exercises are recommended to incorporate larger and more complex muscle groups, rather than isolated repetitions of small muscle groups (eg, bridges or squats, rather than straight leg raises) as these may serve to reduce the overall burden of minutes of exercise and improve tolerability.[95] Generally speaking, 2-3 sets of 10-12 repetitions are recommended.[92] However, individualization is of particular importance.

Conceptual principle #4: adaptation to patient needs and context

A key element of an exercise prescription for POTS and related disorders is the determination of the starting body position and criteria for transition to new modes (more upright body positions) of exercise. For those with significant deconditioning or complex medical history, we propose the use of a low starting intensity on the RPE scale (rather than using a heart rate driven target), which can help to orient intensity around symptom-related responses to exercise. This approach may be particularly helpful in patients with significant non-PEM related fatigue, joint pain/hypermobility, postural instability, dizziness, shortness of breath, tachycardia, and/or chest pain.

After a period of inactivity, patients may have difficulty resuming their previous position and intensity of exercise. In this event, physiological re-assessment, as outlined in table 1, might again be helpful to re-assess starting position and intensity for patients who have resumed exercise after a period of inactivity. Temporary periods of inactivity can occur for a variety of reasons, and previous protocols have reported that missing as few as 2 or 3 consecutive days of aerobic conditioning may lead to regressions.[14] As a starting point, some authors suggest that if a patient is unable to resume exercise in their previously tolerated body position, re-entry might be attempted using a previous training position (ie, if the patient previously tolerated seated exercise, then re-entry might then be attempted using recumbent activity). We propose that physiological assessments might also be helpful to guide re-entry, including exercise intensity and body position as outlined above.

A commonly reported factor that may limit a patient's progression through graded exercise programs is a lack of access to necessary equipment required by the program.[16] While purchasing gym memberships, borrowing equipment, and buying second-hand equipment is preferred, it is not always possible. If this is the case, physical therapists may support patients to skip or adapt a particular stage. For example, a patient may have easier access to an upright bike versus a recumbent bike. This patient may benefit from modifications to the equipment (eg, a chair in front or back of an upright bike to replace a recumbent bike), or working with their therapist toward a slower transition between supine and upright (bike) exercise sessions. Finally, a patient may self-report a desire to remain in their current body posture for a longer period, perhaps because of a preferred activity. In our experience, this commonly occurs between seated exercise and walking, when patients may opt to remain with seated activity because of personal preference or available equipment. We believe this remains a beneficial option, as continued (maintenance) exercise in this body position can still assist in maintaining and improving activity tolerance in daily life.

Finally, given the predefined scope of existing exercise programs for dysautonomia and POTS, the myriad of co-morbidities and their functional affects are not always accounted for by a simple cardiovascular and strength training program. To this effect, we encourage clinicians to consider additional assessments and referrals to meet individual rehabilitation needs as clinically indicated. Given the prevalence of comorbid migraine or potential for postviral or head trauma related triggering of POTS and related chronic orthostatic intolerance, dizziness may originate from a variety of nonorthostatic origins; in such cases, patients may benefit from visual, vestibular, and orthopedic examination to address visual complaints or dizziness related to motion intolerance. Clinicians are also encouraged to promote additional nonpharmacological strategies as appropriate, such as volume expansion (water intake and sodium supplementation) and compression with exercise, as one portion of a multifaceted approach to recovery.[14,16]

Role of interval training in autonomic rehabilitation. Another often overlooked tool for progression, which is somewhat conceptually buried amid current POTS-targeted exercise protocols,[16] is the use of interval training. In our experience, this approach first appears in the preconditioning phase in a modified low-intensity sense, where short bouts of low to moderate intensity exercise might be alternated with periods of rest to gradually build endurance toward tolerating a 20 minute bout of steady state effort (eg, preconditioning as in fig 1).[96–99] Intervals, using true work and recovery sets might also be helpful later in the program, once patients reach the ability to achieve short-term heart rate recovery, to further challenge the ANS responses to exercise and enhance endurance (eg, adaptation as in fig 1). These applications differ practically from the more widely used high-intensity interval training in exercise science to improve cardiac and overall athletic performance,[92] though are used here in these modified forms for similar goals. Thus, we propose the use of interval training—specifically of work and rest or recovery sets that are based on a patient's response to exercise within a prescribed body position—as another potentially adaptive feature of exercise rehabilitation for autonomic disorder.[100]

As noted above, alternation of rest and work sets can be particularly helpful in cases where steady state exercise is limited by physical deconditioning or severe orthostatic intolerance. In this setting in particular, we suggest that the duration and ratio of work and recovery sets can be tailored to individual clinical metrics (heart rate, RPE, and symptoms of exercise intolerance) and adjusted as progress is made. Depending on the level of disability, work sets can be as short as 10-30 seconds if needed, with double the amount of time for recovery.

In addition, to aiding in initial phases of rehabilitation, interval training may also help with transitioning to the higher-intensity and longer duration activities that are outlined in the adaptive progression criteria (see fig 2 ABCs) described above. As cardiovascular training ensues, heart rate control generally improves,[101] which enables progression toward longer durations of steady state activity and higher-intensity intervals. Specifically, we recommend considering more conventional approaches to interval training once patients are able to achieve an exercise threshold and capacity for heart rate recovery that allows for a difference of 20 bpm (or more) between work and recovery intervals. At this phase, consider starting interval training 1-2 $\times$ / week, alternating with slightly lower intensity steady state exercise sessions within the prescribed body position (see fig 1).

Building on our experience and common applications of conventional interval training methods, we recommend first prescribing intervals in a 1:1 ratio, using a 3-5-minute duration for the work and recovery intervals (somewhat longer than those typically used in high-intensity interval training). As noted above, a work set can be as short as 30 second and as long as 5 minutes, though keep in mind that the recovery interval duration may be dictated by the duration necessary for a patient's heart rate to recover toward baseline, signaling readiness to engage the next work set.[102,103] If well tolerated, this can build to a more conventional 2:1 ratio with longer work sets. In our experience, this duration and ratio appear to allow sufficient time for the ANS to respond and stabilize before transitioning between work or recovery target zones. More directed investigation is needed to define the precise prescription for work or recovery intervals and duration of sets that is most physiologically appropriate for this setting.

Conclusions

In summary, drawing from published protocols[6,14,16,17] and existing standards in exercise physiology and rehabilitation science, we propose 4 key conceptual for future consideration in rehabilitation programs for POTS and related disorders: (1) comprehensive evaluation; (2) individualized program entry; (3) patient-driven criteria to advance; and (4) adaptation to patient needs. The use of physiologically informed and patient-driven metrics to guide and adapt exercise prescription in this setting has the potential to improve adherence, engagement, tolerability, and overall functional improvement.

Effect statement

Cardiovascular exercise is a cornerstone of nonpharmacologic management for individuals with autonomic dysfunction. Despite these benefits, current established exercise protocols have adherence rates below 50%. We propose 4 conceptual principle that fill gaps in existing exercise protocols for these disorders, setting the stage for the development of adaptive exercise protocols that consider patient-driven and physiologically guided exercise prescription.

Corresponding author

Melissa M. Cortez, DO, Department of Neurology, University of Utah, 729 Arapeen Dr., Salt Lake City, UT 84112. *E-mail address:* melissa.cortez@hsc.utah.edu.

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