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Review

Isometric Exercise Training: A Review of Hypothesized Mechanisms and Protocol Application in Persons with Hypertension

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ABSTRACT

International Journal of Exercise Science 14(2): 1261-1276, 2021. According to the American Heart Association 116.4 million, or 46% of US adults are estimated to have hypertension. Although, traditional moderate intensity aerobic exercise training is associated with reducing blood pressure by 5-8 mmHg, barriers to this modality of exercise training exist. Thus, the purpose of this review is to evaluate the mechanisms and incorporation of isometric exercise training (IET) as an adjunctive mode of exercise in a population with HTN. Based upon the articles reviewed from the years 2000-2020 which incorporated IET and provided clear protocols lasting 4 or more weeks, meaningful reductions in blood pressure occurred following IET (SBP, -9.7 ± 3.3 mmHg; DBP, -4.8 ± 2.6 mmHg) which support the need to increase adoption of this exercise form into practice to help treat hypertension. Specifically, an IET program of 12-20 minutes per day, 3 times per week, could improve blood pressure reduction in those with hypertension. IET has the potential to produce significant and clinically meaningful blood pressure reductions and could serve as an adjunctive exercise modality alongside the established exercise prescription for those with hypertension.

KEY WORDS: Blood pressure, high blood pressure, exercise guidelines, application, static exercise

INTRODUCTION

Hypertension (HTN) was a primary or contributing cause of over 490,000 American deaths in 2018 and current trends indicate that nearly half of adults in the U.S. have HTN (9). Additionally, HTN is associated with a variety of complex cardiovascular comorbidities that interact with one another to increase cardiovascular disease risk and complications (48). Specifically, HTN is associated with a significant increased risk for the development of cardiovascular and renal complications. These complications include, but are not limited to, heart failure (42), left ventricular hypertrophy (24), ischemic stroke (11), intracerebral hemorrhage (11), and chronic kidney disease (10, 18). Current treatment programs in HTN can involve manipulation of the patient's lifestyle, through exercise and nutritional factors, antihypertensive drug therapy, or a combination of these interventions (42).

Exercise training is a frequently used lifestyle modification for individuals suffering from HTN, and researchers have reported significant reductions in blood pressure associated with periods of exercise training (47). Specifically, it's been demonstrated that traditional moderate intensity continuous aerobic exercise has resulted in reductions in blood pressure (BP) of 5 - 8 mmHg (35). Although these improvements in BP (35), body composition (14), cardiorespiratory fitness (14, 35), and reduction of metabolic risk factors (6) have been shown to be significant, there are barriers involved with participation in moderate intensity continuous aerobic exercise (42). Some of these barriers include the time commitment required, and the intensity associated with aerobic exercise training may not be the most appropriate for individuals who are affected by comorbidities associated with HTN (48). However, isometric exercise training (IET) has recently been identified as a potential modality for lowering systolic blood pressure (SBP) and diastolic blood pressure (DBP), that may have less risk compared to traditional continuous aerobic exercise training (8, 16, 19).

In an effort to compare exercise interventions to pharmaceutical interventions, Naci and colleagues conducted a network meta-analysis to examine and make a comparison of how intensities of exercises compared to different doses and classes of medication (32). Naci *et al* un observed that in individuals with resting SBP of ≥ 150 mmHg, exercise interventions have resulted in a mean reduction of 11 mmHg compared to antihypertensive medications with a mean reduction of 9 mmHg (32). Although the forms of traditional exercise have been successful in reducing BP, even beyond that of antihypertensive pharmacological agents (35), there is evidence that IET can have similar effects on blood pressure reduction compared to aerobic exercise in one-third of the weekly time commitment (8, 16, 19). While there are literature reviews on isometric exercise and its effects on BP reduction, there are limited reviews pertaining to the adoption of these protocols into practice. Specifically, there is little known about the specific exercise prescription, using the FIIT-VP principle (Frequency, Intensity, Time, Type, Volume, and Pattern), that practitioners can use not only in the general population, but also with those with diagnosed HTN. Furthermore, there is limited work that is focused on the translation of the work from clinical research to practice in those with HTN.

Thus, the purpose of this systematic review is to 1) confirm what others have reported on the effects of IET on BP in HTN, 2) identify the potential mechanisms associated with the reductions in SBP and DBP caused by isometric exercise, 3) summarize the current evidence for specific IET protocols including safety precautions, and 4) provide recommendations for including IET in the treatment and management of persons with HTN as adjunctive therapy to traditional continuous aerobic exercise.

HYPERTENSION AND ISOMETRIC EXERCISE

HTN is defined within a staging system indicative of rising blood pressure as suggested by the 2017 American College of Cardiology/American Heart Association. A SBP of 130 – 139 mmHg or a DBP of 80 – 89 mmHg is classified as stage 1 HTN, while stage 2 HTN is SBP of at least 140 mmHg or a DBP of at least 90 mmHg (48). The magnitude of blood pressure elevation above optimal is associated with the degree of target organ damage developed over time. (10, 18, 31). In addition, blood pressure elevation itself is an indicator of cardiovascular dysregulation that can occur through a multitude of pathophysiological mechanisms (8, 21, 42) that will be discussed in this review.

An isometric or static muscle contraction is defined as sustained muscle recruitment and activity with an increase in tension, that is accompanied by no change in the length of the recruited muscle tissue or change in joint angle (30). Thus, the act of incorporating a isometric training activity could be performed with minimal cost and advanced equipment compared to other strength training programs, increasing accessibility (42). Also, investigations have used handgrip dynamometry and leg extension torque as reliable and valid isometric assessments of muscular strength and function in practical settings (25). The use of these handgrip dynamometry-based devices is relatively cost effective when compared to other assessments of muscle strength such as a Biodex or 1-RM testing (25). In coordination with assessing isometric strength, isometric exercise can be used in community-based centers with limited equipment, and may result in similar phenotypical improvements as other exercise programs (35, 42).

METHODS AND ARTICLE SELECTION

To include the most recent investigations into isometric exercise, we chose to review articles (meta-analyses, randomized control trials [RCTs], between the years of 2000 – 2020. Articles were selected from EBSCO-Host, PubMed and Google Scholar utilizing the following keywords: <isometric exercise>, <hypertension>, <isometric exercise training>, <isometric resistance training>. Inclusion criteria for chosen articles had to: 1) incorporate isometric exercise as an intervention tool, 2) clear isometric exercise protocols were provided, where interventions were at least 4 weeks-time 3) with ages ranging from 18 – 75 years of age and include males and females. This research was carried out fully in accordance to the ethical standards of the International Journal of Exercise Science (33). Data extraction included pulling info from all studies reviewed that are displayed in Table 1. Specifically, information gathered included authors, year, age, blood pressure, study protocol modality, and findings. The studies included in this review used participants with diagnosed HTN at different levels which are reported in Table 1. As BP guidelines and classification of HTN has evolved over recent years, Table 1 also aims to highlight the important trials used in this review, as well as the exact BP ranges that describe each study sample. Data items screened were primarily focused on the parameters of both systolic and diastolic blood pressure. To reduce the risk of bias in article selection, the PRISMA flow diagram was utilized and is displayed in Figure 1.

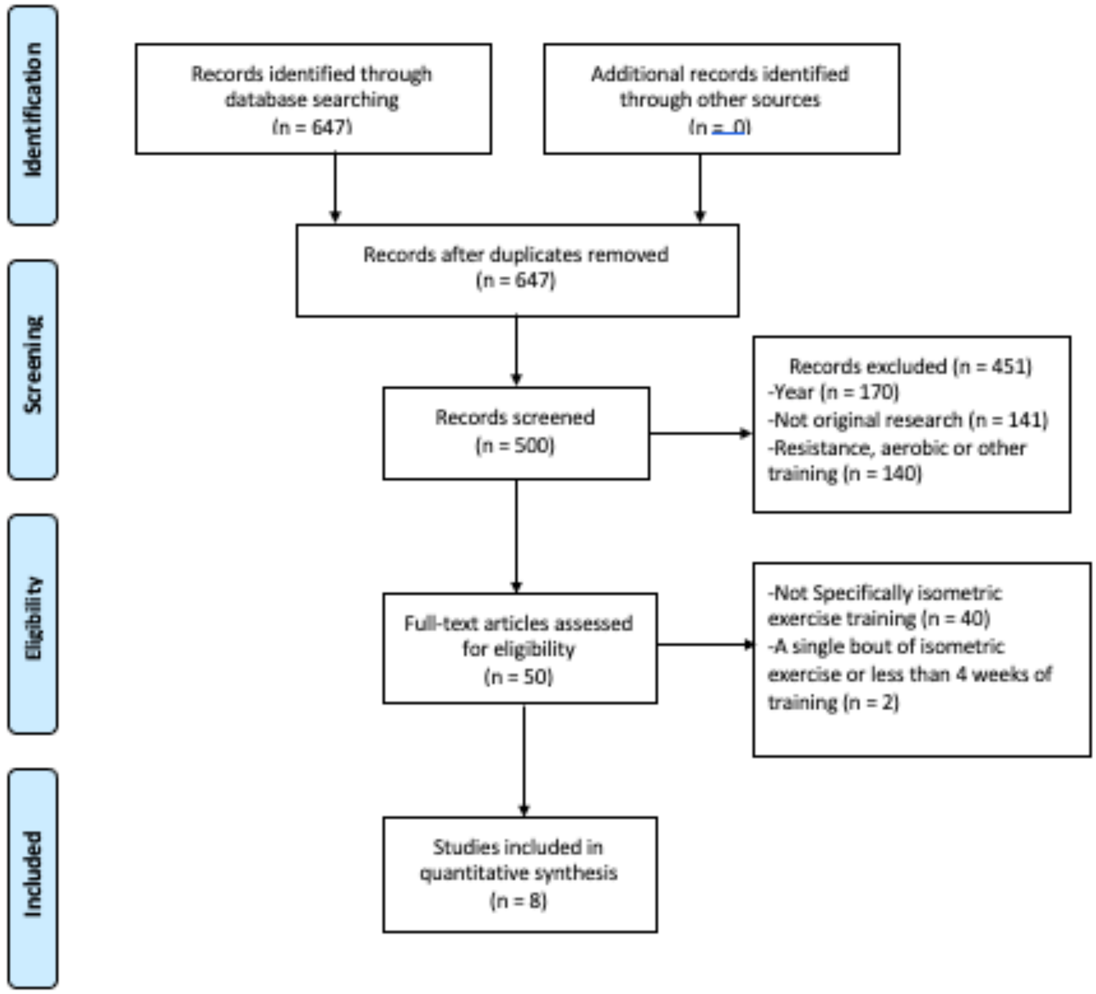

Figure 1. PRISMA flow diagram for article selection process.

DISCUSSION AND SUMMARY OF FINDINGS

ISOMETRIC EXERCISE TRAINING PROTOCOLS

A few reviews and meta-analyses have been conducted which aimed to synthesize the findings from RCTs of IET (8, 19). The protocols of isometric exercise training for RCTs included in the current review are reported and summarized in Table 1.

Table 1. Protocols of isometric exercise training in those with hypertension and reductions in resting blood pressure.

Authors, Year	Age	Blood Pressure	Modality & Posture	Protocol	Findings (mmHg)
Baross et al., 2012	45–60 years	SBP 137 ± 6mmHg DBP 81 ± 11mmHg	Knee extension, seated, dual leg	Four, 2-minute contractions at 70 and 85% HRpeak (~8-14% MVC) interspersed with 2-minute rest periods. 3x/week for 8 consecutive weeks	SBP ↓ 11 MAP ↓ 5
Taylor et al., 2003	60–80 years	Resting SBP of ≥ 140 mmHg and/or ≥85 mmHg DBP	Handgrip, bilateral, posture not indicated	Four, 2-minute contractions at 30% MVC interspersed with 1 minute rest periods. 3x/week for 10 consecutive weeks	SBP ↓ 19 MAP ↓ 11
McGowan et al., 2007	55-75 years	SBP: 133.9 ± 5.0 mmHg DBP:73.2 ± 3.2 mmHg	Handgrip, bilateral group & unilateral with dom. arm group, posture not indicated	Four, 2-minute contractions at 30% MVC interspersed with 1 minute rest periods for bilateral group and 4-minute rest periods for unilateral group. 3x/week for 8 consecutive weeks	Bilateral SBP ↓ 15.4 Unilateral SBP ↓ 9.2
Millar et al., 2013	55–80 years	Controlled HTN; SBP 125 ± 12mmHg DBP 78 ± 2mmHg	Handgrip, unilateral non-dom. arm, posture not indicated	Four, 2-minute contractions at 30% MVC interspersed with 4-minute rest periods. 3x/week for 8 consecutive weeks	SBP ↓ 5 MAP ↓ 3
Badrov et al., 2016	18-28 years	Resting SBP of <140 mm Hg f and/or <90 mm Hg DBP	Handgrip, bilateral, posture not indicated	Four, 2-minute contractions at 30% MVC interspersed with 1 minute rest periods. 3x/week for 10 consecutive weeks	SBP ↓ 8 DBP ↓ 5 MAP ↓ 6
Blackwell et al., 2017	52 ± 5 years	SBP: 138 ± 4.2mmhg DBP: 93 ± 2.7mmHg	Handgrip, unilateral dom. arm, standing, anatomical position	Four, 2-minute contractions at 30% MVC interspersed with 2-minute rest periods. 3x/week for 4 consecutive weeks	SBP ↓ 16 ± 3 DBP ↓ 9 ± 3
Gordon et al., 2018	49 ± 2 years	SBP: 137.4mmHg DBP:87.4 mm Hg	Handgrip, details not indicated	Four, 2-minute contractions at 30% MVC interspersed with 1 minute rest periods. 3x/week for 12 consecutive weeks	Supervised SBP ↓ 9.1 DBP ↓ 2.8 Unsupervised SBP ↓ 8.7 DBP ↓ 2.2
Cahu Rodrigues et al., 2020	61 ± 2 years	Baseline resting of IHG group SBP 135 ± 4, DBP 73 ± 2 (medicated HTN)	Handgrip, unilateral alternating arms, posture not indicated	Four, 2-minute contractions at 30% MVC interspersed with 1 minute rest periods. 3x/week for 12 consecutive weeks	SBP ↓ 16 ± 2 DBP ↓ 8 ± 2

One of the earliest reviews of IET was conducted by Kelley & Kelley who indicated improvements in BP using isometric handgrip dynamometer interventions lasting between 8 – 10 weeks. Studies analyzed by Kelley & Kelley utilized a protocol consisting of 3 x per week, of 4 sets of 2-minutes bilateral contractions separated by 1 – 3-minute rest, at an intensity of 30-40% of maximal voluntary contraction (MVC). Specifically, researchers observed reductions of approximately 10% for both resting SBP and DBP in the intervention group. The mean difference for SBP was 13.4 mmHg (95% CI, -15.3 to 11.0 mmHg; $p < .01$) and DBP was 7.8 mmHg (95% CI, -16.5 to -3.0 mmHg; $p < .01$). Although the data resulting from this meta-analysis included normotensive, pre-hypertensive, and those with HTN, the researchers indicated a significant plausibility of isometric exercise improving blood pressure in persons with HTN. These results are confirmed in another work by Carlson *et al* who reported significant mean differences in SBP, DBP, and mean arterial pressure (MAP) of 6.77 (95% CI, -7.93 to -5.62 mmHg; $p < .001$), 3.96 (95% CI, -4.80 to -3.12 mmHg; $p < .001$), and 3.94 (95% CI, -4.73 to -3.16 mmHg; $p < .001$) mmHg, respectively. Furthermore, the researchers suggest that the effects of isometric exercise on blood pressure reduction may depend on the clinical status of the population studied, slight differences in administration of the exercise protocol, along with different isometric exercise modalities (8). Therefore, promoting the need for a review detailing the specific differences in isometric exercise protocols, and how to apply these findings to practice. Specifically, the randomized trials that were included in this initial review are highlighted here with a greater focus on the program used to improve adoption of IET.

In general, these RCT's of IET tend to differ in the modality of exercise utilized. Lower extremity exercise, such as dual knee extension, has been studied, showing significant reductions in SBP (11 ± 8 mmHg, $p < 0.05$) and MAP (5 ± 7 mmHg, $p = < 0.05$) in those with pre-HTN after 8 weeks of training (3). Specifics of the protocol utilized by Baross *et al* are included in Table 1. Baross *et al* utilized an isokinetic dynamometer (System 3 Pro; Biodex Medical Systems, Inc, NY, USA) which is an advanced system that is not only costly but also, not commonly found in fitness or community health centers. Furthermore, some populations may gain greater benefit through improving upper-body strength that can help improve physical function and performance of activities of daily living (ADLs) (25). The adoption of handgrip dynamometry is a cost effective and portable means of training the upper extremity without changes in the joint angle, especially when compared to other forms of strength training (42). However, evidence of how the device is used as a supplement to a training program outside of the laboratory or research setting is setting is limited.

The work by Taylor et al and McGowan et al aimed to address the question of if handgrip dynamometry is a practical and successful modality for the implementation of isometric exercise both in a supervised laboratory setting and an in-home setting (26, 45). Specifically, the program by Taylor et al included a 4, 2-minute contractions at 30-50% MVC interspersed with 1-3 minute rest periods completed 3x/week for 4–12 weeks (2, 5, 13, 26, 29, 44). With the application of a 10-week IET program, Taylor *et al* observed decreased SBP (156 ± 9.4 mm Hg to 137 ± 7.8 mm Hg, $p < .001$); translating to a mean change of 19 mmHg. Similarly, in just 8 weeks of the utilization of a bilateral isometric handgrip (IHG) protocol, McGowan *et al* also observed dramatic reductions in SBP where baseline values in controlled hypertensive subjects were 133.9

± 5.0 mmHg were reduced to 118.5 ± 4.0 mmHg ($p < .05$). McGowan *et al* also observed similar changes in resting SBP in the unilateral IHG training group (141.6 ± 3.8 mmHg baseline, to post training 132.4 ± 4.4 mmHg, $p < .05$) (26). In summary, the adoption of IET seems to show improvements in BP, but how these programs can be manipulated by focusing on bilateral or unilateral movements was not reported in either Taylor or McGowan *et al's* work.

Specifically, unilateral and bilateral training have been completed in other studies where the reductions in SBP, DBP, and MAP have been more modest (2, 29). Millar *et al* conducted a study of both bilateral and unilateral isometric contractions. Both bilateral and unilateral groups, indicated as the "training groups" observed SBP reductions of 5 mmHg and MAP reductions of 3 mmHg (SBP: 125 ± 3 mmHg to 120 ± 2 mmHg, $p < 0.05$); MAP: 90 ± 2 mmHg to 87 ± 2 mmHg, $p < 0.05$). Although Badrov *et al* utilized only bilateral contractions, they too observed modest, and significant changes in resting SBP and MAP after 10 consecutive weeks of IET (SBP: Δ 8 ± 6 mmHg; DBP Δ 2 ± 3 mmHg; MAP Δ 4 ± 3 mmHg, all $p < 0.05$). Thus, it seems as though manipulating the IET programs through bilateral and unilateral contractions can significantly impact the BP reductions seen in HTN.

However, this could allow IET programs to become individualized depending upon the population in question, and could even supplement a more generalized training program. A benefit of including isometric exercise into a program to manage HTN is the ability to complete it at-home. Blackwell *et al* compared three exercise programs; 1) high intensity interval training (HIT) in-lab, 2) HIT in-home, and 3) an in-home isometric handgrip training (H-IHGT). In 4 weeks consisting of 4 sets of 2 minutes of an isometric handgrip at 30% of MVC with 2-minute rest periods, Blackwell *et al* observed significant reductions in SBP and DBP across all groups (SBP: 139 ± 4 to 123 ± 3 mmHg, after training; $p < 0.01$; DBP 93 ± 3 to 82 ± 3 mmHg, $p < 0.05$). Although there was no significant difference in the reduction of resting BP between the groups, the authors suggested that those with stage 1 HTN had similar BP reductions following isometric exercise as compared to HIT training, with isometric exercise being more time efficient (5).

IET has demonstrated clinically significant reductions in resting BP when completed for upwards of 8 – 12 weeks; regardless of modality (leg extension, wall squat, or handgrip (3, 45), setting (supervised laboratory or in-home) (5, 12), and whether the contractions are completed bilaterally or unilaterally (2, 26, 29). Additionally, IET has been shown to have comparative effects at lowering resting blood pressure in those with HTN, or even controlled HTN, when compared to high-intensity interval training and traditional moderate intensity continuous aerobic exercise (5). However, more research needs to be completed to confirm and substantiate this hypothesis. Furthermore, IET is also seemingly more cost effective and portable when compared to other strength training options, and could be a strong addition to an aerobic training program to receive multifaceted benefits (42).

MECHANISTIC UNDERPINNINGS OF ISOMETRIC EXERCISE TRAINING BLOOD PRESSURE REDUCTION

The underlying mechanisms responsible for the observed reductions in BP following IET have not been elucidated (8, 15, 21, 34, 42) . Carlson *et al*, Lawrence *et al*, and Souza *et al* proposed an array of potential mechanisms by which isometric exercise may impact the physiological regulation of BP acutely and chronically as depicted in Figure 2. One of these potential mechanisms underlying the effects of BP reduction is thought to be due to an increase in the production of nitric oxide (NO) that others have reported following exercise (21, 34, 42).

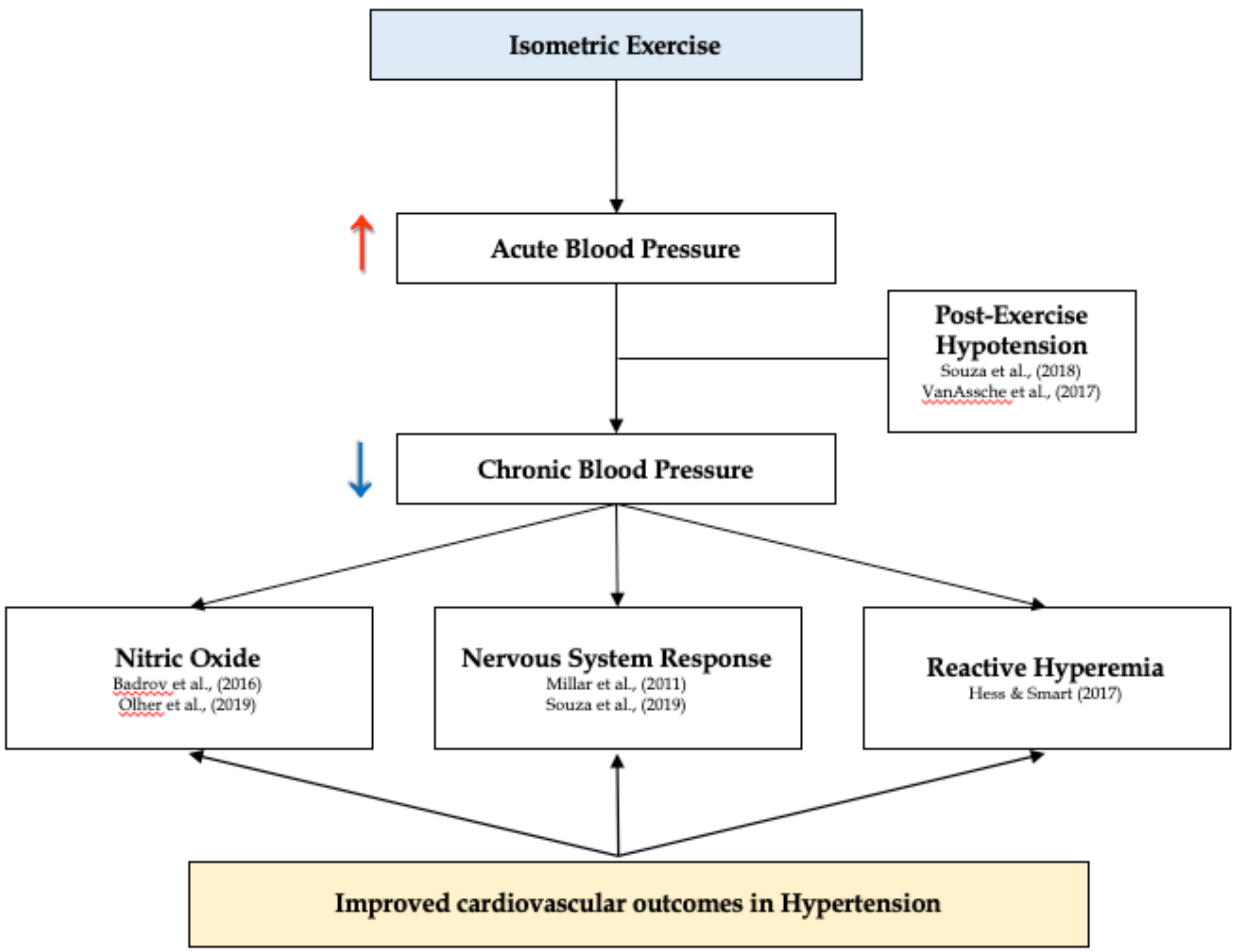

Figure 2. Proposed pathway of isometric exercise impact on resting blood pressure reduction.

Isometric exercise has been reported to increase endothelial-dependent vasodilation; resulting in increased NO production (34). Researchers have reported that increased levels of NO are associated with; 1) improved endothelial function, 2) increased vasodilation in active blood vessels, and 3) reduction of arterial stiffness and improved hemodynamics (2, 26, 34, 42). Although isometric exercise and NO show a strong relationship, there may be other factors that explain the variation seen in improved BP as a result of isometric exercise.

One of those plausible mechanisms could be due to reactive hyperemia, or an increase in blood flow brought about by an increased demand of muscular tissue, which takes place during the muscle contraction (16). With isometric exercise, there is no change in the length of the muscle across the joint, which seems to differentiate isometric exercise from dynamic resistance training or traditional aerobic exercise through an altered length-tension relationship (30).

The release of an isometric contraction elicits an influx of blood to the active muscle tissue, which not only brings more NO and oxygen into the area, but other vasodilating properties that can impact vasodilation and peripheral resistance; this is one of the main pathological underpinnings that may lead to improved blood pressure following exercise participation (16, 42). Some of the other vasodilating properties are alterations in baroreceptor reflex, adenosine, epinephrine, and endothelial substances. These vasodilating substances also are hypothesized to underly the mechanisms of chronic reduction in resting BP due to IET.

Adjunctive to hyperemia, acute isometric exercise leads to an increase in muscle ischemia, intramuscular pressure, and metabolite release (including ATP, hydrogen ions, and lactate) which activates both mechanoreceptors and metaboreceptors, known as skeletal muscle afferents type III and type IV, respectively (21, 39). These two types of skeletal muscle afferents control muscle sympathetic nerve activity (MSNA) traffic to the central nervous system (CNS), relaying information about the skeletal muscle environmental conditions. This exercise pressor reflex results in an increase in BP (41). With IET training, the MSNA response is attenuated, therefore reducing the BP response to activated skeletal muscle afferents type III and IV (39, 41). Specifically, Rondon *et al* identified that individuals with higher resting BP have a magnified exercise pressor reflex. The sensitivity of the metaboreceptor or skeletal muscle afferents type IV may be the reason for higher resting BP. Rondon *et al* suggested that changes in the metaboreceptors following IET could contribute to the reductions in resting BP.

In addition to changes in NO bioavailability and skeletal muscle afferents, post-exercise hypotension (PEH) has been observed immediately post-isometric exercise and although only observed acutely, has been indicated as a potential mechanism for chronic BP reduction in those with HTN. Occurrence of PEH has been reported following participation in aerobic exercise, resistance training, and other alternative exercise methods (4, 36, 40).

An isometric hold increases blood to the area being contracted. Due to this, vessels are further vasodilated, leading to the potential acute PEH observed in those with HTN. The mechanisms responsible for PEH that occur after a session of isometric exercise should directly influence cardiac output (CO) and/or systemic vascular resistance (SVR). Chronic reduction in resting BP as seen in IET may be due to the acute occurrence of PEH. Researchers have demonstrated the possible mechanisms involved in PEH of elderly, hypertensive individuals (27, 28, 43, 47).

Van Assche *et al* utilized a four, 2-minute sustained contraction of 30% MVC observed a reduction in SBP of 5.4 ± 7.3mmHg 7 hours after a single bout of isometric handgrip exercise in those with stage 1 HTN. Van Assche *et al* also measured the heart rate (HR) of subjects and noted a trend of lower HR after isometric exercise was completed. Researchers suggested that this may be indicative of the improvement in cardiac autonomic balance as seen in chronic IET studies, although the aim of these researchers was not to explore mechanisms associated with BP reductions and this study only assessed changes in SBP after a single, acute bout of IET (47). Increased vagal activity and/or a decrease in sympathetic activity are indicative of improved neurocardiac autonomic regulation, and have been observed immediately after just one bout of isometric handgrip exercise (27, 28). Improvements in cardiac vagal activity have also been observed even after low intensity IET lasting 8 – 10 weeks (3, 8, 44).

Conversely, no effect on PEH has also been observed with acute bouts of isometric exercise. McGowan *et al* conducted an acute bout of isometric handgrip exercise with individuals with HTN, performing a similar protocol (4 x 2 min contractions at 30% MVC with 1-3 minute rest), however BP was not found to be reduced following the training session. McGowan *et al* concluded that an isometric handgrip session does not elicit PEH in medicated hypertensive individuals. Due to lack of research, acute PEH after isometric exercise has not been consistently observed, but is maintained as a potentially viable mechanism for the reduction of BP in those with HTN.

SAFETY PRECAUTIONS

To maintain or improve muscular fitness, a combination of aerobic training and dynamic resistance training has been recommended to those with controlled HTN and no other overt cardiovascular or renal complications (36). In individuals with HTN, there is some hesitation in suggesting resistance exercise due to a blood pressure response potentially reaching upper limits (49, 50). An exaggerated pressor response of isometric exercise presents a safety concern, especially in those with suboptimal BP control. Suggestion of an excessive SBP response to exercise may contribute to ischemic cardiac events leading to myocardial infarction, or even a stroke (36). The cardiovascular response to isometric exercise relies on the mode of the exercise and inevitably the amount of muscle mass involved (i.e. handgrip or leg extension), the rest periods between the bouts, and the number of bouts carried out in training (3, 42). Thus, it is vital to provide adequate recommendations for monitoring and prescribing isometric exercise in those who do not have controlled BP (50).

A study conducted by Wiles *et al* aimed to provide an evidence-based approach to promote the incorporation of IET into populations of individuals who suffer from HTN, and those who are newly diagnosed with HTN. Incorporation of IET into these populations was conducted without confounding factors associated with a pharmacological intervention. Wiles *et al* utilized an incremental test that included decreasing knee joint angles to elicit a target of 95% HR_{peak}. By completing this incremental test, researchers were able to assign an intensity which elicited the HR and BP response while maintaining safety for those with HTN in terms of estimating myocardial oxygen consumption in comparison to other testing procedures. Results indicated that myocardial oxygen consumption (MVO_2), a measure of myocardial work, was significantly lower during isometric training when compared to a previously conducted study by Simonson & Wyatt where individuals completed maximal aerobic exercise testing on both a treadmill and supine cycle ergometer testing (8, 50). During isometric exercise there is an increase in DBP which may facilitate increased blood flow to the myocardium, potentially increasing oxygen content, removal of carbon dioxide, and other by-products. Due to the lower myocardial work, it can be extrapolated that isometric exercise may be safer for those with HTN or others with impaired cardiovascular function (49, 50).

Furthermore, BP elevation during the isometric exercise protocol did not reach the ACSM guidelines for exercise termination (SBP > 250 mmHg) (50). Importantly, in some participants, DBP did briefly rise above 115 mmHg, which may be detrimental in some populations. It is also important to mention that the HR response during IET in the study conducted by Wiles *et al* was considerably lower than the ACSM exercise test attainment of 85% predicted maximum HR (149 bpm vs 105 bpm) (48). Taken together with lower myocardial work and improved myocardial perfusion during diastole (23), isometric exercise may be as safe as completing aerobic and/or traditional resistance training (49, 50). Others have reported that the incorporation of light IET has been shown to illicit beneficial effects with very limited adverse events in those with cardiovascular disease. (20). The use of IET and strength training has been shown to be effective with limited risk for patients as Gordon et al reported no clinically significant cardiovascular events after determining an appropriate exercise intensity for the training programs (38). However, it should be noted that the exaggerated pressor response seen in IET may not appropriate for adoption in those with significant CVD or coronary artery disease (13).

CLINICAL APPLICATIONS

Reductions in BP due to chronic IET discussed in this review mirror the clinical relevance of small decreases in resting BP (~3 mmHg) that can reduce the risk of coronary disease by 5%, stroke by 8%, and all-cause mortality by 4% (42). IET training in persons with HTN or at risk of developing HTN, therefore can be identified as a means to controlling, treating, and potentially preventing HTN (42). IET has the capability of being a possible alternative mode of exercise for those with HTN with less time commitment and can be more easily adopted in an in-home program that traditional exercise (5, 42). Both of these circumstances can help limit the barriers to exercise participation seen in certain populations. Lesser time commitment and incorporation of in-home programing, that is both mobile and convenient, can help with improving the rates of BP control in the HTN population, as more than half of hypertensives do not have BP under control (42). Thus, isometric exercise may fill this gap and assist persons with HTN to better manage their BP. Table 2 contains frequency, intensity, type and time (FITT) for both traditional aerobic exercises along with isometric exercise additions that is suggested based on the conclusions of the studies included in this review.

Table 2. Suggested guidelines for implementation of isometric exercise training in persons with hypertension.

FITT* Principle	ACSM* Exercise Prescription Guidelines for those with Hypertension (HTN)	Isometric Exercise Training for those with Hypertension
Frequency (How Often?)	Most, preferably all days of the week	If novice or uncontrolled HTN; < 3 d/wk Not novice or controlled HTN; ≥ 3 d/wk
Intensity (How Hard?)	Moderate	If novice or uncontrolled HTN; Low (20-30% MVC*) Not novice or controlled HTN; Moderate (40-50% MVC)
Time	30 – 60 min/d	12 – 20 min/d If conducting 1 min rest periods; 12 min total/d If conducting 3 min rest periods; 20 min total/d *Same total contraction time of 8 min regardless of rest period length*
Type (What Kind?)	Aerobic	Bilateral Handgrip or Bilateral Leg Extension
Adjuvant 1	Muscle Strengthening ≥ 2 d/wk (non-consecutive) Moderate to vigorous intensity 8 – 10 exercise; ≥ 1 set of 8 – 12 repetitions	4 sets of 2 min contractions with 1 – 3 min rest between sets. If novice or uncontrolled HTN; longer rest Not novice or controlled HTN; shorter rest
Adjuvant 2	Flexibility ≥ 2 d/wk At least 10 min/d	
Adjuvant 3	Balance if at substantial risk of falling	If novice, or at substantial fall risk; Seated posture with elbow at 90˚ angle for handgrip Not novice, or not at substantial fall risk; Seated or standing posture (patient preference) with elbow at 90˚ angle for handgrip
Special Considerations	Encourage patients to exercise in the morning to benefit from the immediate blood pressure lowering effects throughout the day. Emphasis should be on aerobic exercise activities.	Isometric exercise training is encouraged to be added as an addition to traditional aerobic exercise guidelines (if tolerated) as displayed in the preceding column. Intensity and number of sets/reps should be low at first, and ideally completed with longer (>2 min) rest periods. Handgrip exercise should be utilized as first order modality, then with steady progression and controlled BP, wall squats or bilateral leg extension can be completed if tolerated, preferred, or available.

*ACSM exercise prescription guidelines for those with hypertension. *FITT = frequency, intensity, time, and type; *ACSM = American College of Sports Medicine; *MVC = Maximal Voluntary Contraction, HTN= Hypertension

FUTURE RESEARCH

Although there is potential for isometric exercise to improve systemic vascular resistance in those with HTN, it is important to identify that the results are heterogeneous in nature (1, 32). Both aerobic exercise and dynamic resistance training have resulted in BP reduction (17, 35). This review does not intend to discount the impact of these modalities, nor insinuate that these modalities should be replaced by isometric exercise training. Furthermore, a combination of exercise programming, both aerobic and isometric exercise, with other lifestyle changes and pharmaceutical interventions may provide synergistic benefits in the treatment of HTN. This systematic review highlights isometric training as an adjunctive exercise modality that compliments others and could be used in those who have physiological limitations or other barriers limiting participation in traditional forms of exercise.

Furthermore, there is a need for future research to focus on the use of IET in diverse populations, especially those with the highest rates of HTN such as African Americans, Hispanic, and others (46). The articles included in this review did not share specific information regarding study sample characteristics so this supports the need for future research in the adoption and efficacy of IET in these populations.

CONCLUSION

This systematic review investigated the plausibility of incorporating isometric exercise programing in the treatment and management of persons with HTN. All 8 of the RTC's, and 2 reviews analyzed showed significant improvements in BP management, and demonstrated the efficacious components of isometric exercise in mid-life individuals with HTN. In addition, the mechanistic underpinning of isometric exercise seems to be associated a multitude of mechanistic factors that should be investigated in greater rigor in future studies. Protocols for application of IET have been outlined in this review and can be completed safely and effectively alongside the recommended ACSM physical activity guidelines for those with HTN.

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The results of the study are presented clearly, honestly, and without fabrication, falsification, or inappropriate data manipulation.

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