Acute effects of body-weight resistance exercises on blood pressure and glycermia in middle-aged adults with hypertension

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\textbf{ABSTRACT}

\textbf{Objective}: The purpose of the present study was to evaluate the acute effects of single session of body-weight resistance exercises on blood pressure (BP) and glycermia in middle-aged adults with hypertension. \textbf{Methods}: Twenty-three participants took part in this trial with crossover design and performed two experimental sessions in a random order: Body-weight resistance exercise session (BWR) and a control session without exercise. BWR was composed of four exercises: inverted row, squat, and sit-ups. The participants performed 3 sets of 30 \textit{s}, in which they were instructed to perform as much repetitions as possible and as fast as possible. After each session, BP and glycermia were measured continuously for 60 min. \textbf{Results}: Systolic BP decreased after BWR when compared with control at post 45\textdegree: \textit{−7 (95\%CI:−11 to −2) mmHg, p = .003 and post60\textdegree: −7 (95\%CI:−12 to −3) mmHg, p = .003. Diastolic BP decreased after BWR when compared with control at post 15\textdegree: \textit{−6 (95\%CI:−9 to −3) mmHg, p < .001; post 30\textdegree: −6 (95\%CI:−9 to −2) mmHg, p = .001; post45\textdegree: −5 (95\%CI:−9 to −2) mmHg, p = .005; and post60\textdegree: −6 (95\%CI:−8 to −3) mmHg, p < .001. No significant difference was found in glycermia between BWR and control sessions. \textbf{Conclusion}: BWR acutely reduces BP in middle-aged adults with hypertension without effects on usual glycermia responses. This alternative form of resistance training could facilitate access, adherence, and reduce health costs related to exercise programs.

\textbf{Introduction}

Hypertension is an important risk factor for developing cardiovascular disease and type 2 diabetes (1), along with vascular and overall mortality (2), with increased prevalence throughout the lifespan (3). Physical exercise has become a cornerstone intervention to counteract many age-related processes and has been recommended as initial therapy to prevent, treat, and control hypertension (4). Results of a systematic review suggest resistance exercise as a stand-alone therapeutic exercise option for individuals with hypertension (5). Besides, resistance exercise is an excellent strategy to reduce functional decline in aging adults (6–8).

Chronic reductions in BP with regular exercise appear to stem from the summation of acute decreases in blood pressure that occur following a single bout of exercise, a phenomenon termed post-exercise hypotension (PEH) (9,10). PEH is a physiological effect that is associated with chronic BP reduction (11) and for this reason plays a major role in BP management. This phenomenon offers a feasible therapeutic lifestyle option for BP control among individuals with hypertension, and its magnitude and duration is related to the volume, intensity, and type of exercise performed (12). Findings from a systematic review and meta-analysis suggest reduction in BP of \textit{≈3 mmHg after 1 h of traditional resistance exercise compared to the control session} (13).

Although different studies have investigated PEH following traditional resistance exercise protocols at different intensities in middle-aged and older hypertensive participants (13–17), at the best of authors knowledge, no previous studies have investigated PEH phenomenon in response to a body-weight resistance exercises protocol (BWR) among hypertensive individuals. BWR is an interesting training option in order to improve the neuromuscular function, when the access to resistance exercise equipment/facilities is not possible, as could happen in geriatric residences, hospitals, low-income house families, lockdown situations, among others.

Patients with hypertension are at greater risk of diabetes developing than are normotensive individuals (18,19) because common aspects of the pathophysiology are shared by both conditions (19). This scenario reinforces the importance to better understand how patients at high risk for diabetes development, such as hypertensive individuals, adapt to new exercise strategies. Acutely, anaerobic exercises can cause an increase rather than a reduction in glycermia and resistance exercise may offer an interesting way of preventing the rapid fall in glyceremia normally observed during and after moderate-intensity aerobic exercise (20,21). Although acute glycermic response has been investigated following traditional resistance exercise, data on post-exercise glyceremic behavior using BWR are scarce and warrant further investigation.

Based on the above-mentioned gaps, it seems relevant to determine some physiological responses to BWR such as BP
and glycemic responses, especially in chronic patients as hypertensive individuals. Moreover, it remains uncertain if a single session of BWR acutely decreases BP, as well as induces a glycemic behavior compared to traditional resistance exercises among these patients. Therefore, the purpose of the present study was to evaluate the acute effects of single session of BWR on BP in middle-aged adults with hypertension. As a secondary outcome, we also assessed glycemia throughout the study.

Methods

Participants

Twenty-three physically active individuals (i.e., engaged in regular resistance training in the last 3 months 2–4 times per week) aged 40 to 65 years participated and completed this trial. They were recruited through social media and banners. The main inclusion criteria was the use of hypertensive medications or the diagnosis of hypertension by a physician, which was confirmed in two separate visits in laboratory with casual BP measures (22). We excluded from the study smokers, individuals with contraindication to perform the proposed exercises, or presented resting BP values equal to or greater than 160/110 mmHg.

The participants were informed of the benefits and risks of the investigation prior to signing an institutionally approved informed consent document to participate in the study. The study protocol was conducted according to the principles of the Declaration of Helsinki, in compliance with the Brazilian legal and regulatory framework for research involving human beings (NR 466/12) and was approved by the Institutional Review Board of Hospital de Clínicas de Porto Alegre, Brazil (number 3.313.746).

Experimental design

A randomized crossover trial was used to evaluate the effects of BWR on blood pressure and glycemia. Participants attended two experimental sessions in a randomized order: BWR session and a non-exercise control session at seated rest. A computer-generated simple randomization sequence was used to define the order of the experimental sessions, which was accessed only at the first day of experimental sessions. Participants and investigators were blinded regarding the order of exercise sessions and the sequence of randomization.

The study was conducted from June 2019 to January 2020 and consisted of one familiarization session and two experimental sessions performed at the same time of day. The environmental conditions (e.g., room temperature at 21–23°C) were kept constant throughout the study.

Familiarization and preliminary assessment

In the first session, anthropometric measures were collected from all participants to assess body mass, height, and body mass index. Resting BP was assessed after a 5 min seated rest. After that, a familiarization using the four resistance exercises (i.e., inverted row using a bar, squat, push-up, and sit-up) that composed the experimental protocol was performed. This session aimed to standardize the execution technique and to determine the intensity of each exercise. A rating of perceived exertion scale was used for setting exercise intensities (23) and a training zone of 5–7 (i.e., moderate to heavy) was adopted for all exercises. When necessary, adjustments in range of motion and body position were made to find these target intensities.

Experimental sessions

All participants performed two experimental sessions in randomized order: body-weight resistance exercise and a time-matched control session without any exercise. They were instructed not to exercise within 24 hours prior to experimental sessions, to maintain similar sleep patterns, and to abstain from caffeine or any stimulant substance during the 12 hours preceding each session. Moreover, they were instructed to avoid strenuous physical exercise and to keep usual dietary intake throughout the study. Participants who were taking antihypertensive medications were requested to maintain their current treatment throughout the course of the investigation.

A standardized meal (i.e., breakfast) matched for energy/calorie content was provided to participants to consume on both experimental days. They were instructed to consume the same meal and record the timing of the meals on both days to better replicate the dietary controls prior to the experimental sessions. The standard breakfast composed of a whole-grain bread sandwich with chicken breast and cottage cheese filling, and a box of 200 ml of unsweetened apple juice was provided to the participants on the day before each experimental session. They were instructed to have breakfast 2 h before the experimental sessions.

All experimental sessions started between 8:00 and 10:00 AM (at the same time of day to account for potential diurnal variation in BP) and lasted approximately 2 h. The interval between the experimental sessions was 4–7 days. Each participant was advised to not drink water during the experimental sessions. Both sessions were composed of 20 min of rest before, 30 min of exercise or seated rest, and 60 min of rest thereafter. BP and glycemia were collected before and after each experimental session at 15-min intervals throughout 60 minutes. Reading materials (magazines and newspapers) were available to individuals during this period.

BWR session was composed by a warm-up set of 5 repetitions plus 3 sets of 30 seconds in four different exercises: inverted row using a bar, squat, push-up, and sit-up were the selected exercises. Exercise intensity was based on body-weight only, without any other device. They were instructed to perform the maximum number of repetitions during each set, using volitional velocity during each repetition, and do not perform Valsalva maneuver during the execution of exercises. The interval rest between sets was 120 seconds, in which the participants remained seated. Intrasession BP and glycemia measurements were assessed in seated position, immediately after the last set of each exercise to ensure the safety of the protocol applied. During the non-exercising control session, the participants were oriented to remain at seated rest for 30 min.
BP measurement was always performed by the same evaluator, using a portable oscillometric device (Omron HEM 7113, São Paulo, Brazil), and participants remained seated with their legs uncrossed and their right arm resting at the level of the heart (22). Firstly, BP was measured on both arms with a time difference of 1 minute between procedures, and after twice in the arm with the highest BP values. The mean of these BP values was used to represent baseline BP. The arm with the highest BP values was used for the subsequent assessments. Blood glucose was always measured immediately after the BP using a clinical glucometer (Accu-Chek Performa, São Paulo, Brazil), which assesses glycemic levels in approximately 5 seconds, and a lancet device (Accu-Chek Multiclix, Sao Paulo, Brazil). Both the automatic oscillometric BP device and the clinical glucometer were chosen in order to eliminate the investigator bias.

**Statistical analyses**

Sample size was estimated according to the results of a previous study using a similar study design (24). A sample size of 24 individuals with hypertension, allowing a dropout rate of 10%, would be able to detect a difference of 5 mmHg in systolic BP among interventions, with 80% of statistical power and a type I error rate of 5%. WinPepi software calculator was used to estimate the sample size.

Data were entered in duplicate by two different researchers and expressed as means and standard deviation for variables with normal distribution or medians and interquartile range for non-normal distributions and 95% confidence intervals (95%CI). Generalized Estimating Equations (GEE) analysis was used to compare the main effects between experimental sessions. Post-hoc comparisons were analyzed by Bonferroni test. All statistical analyses were performed using SPSS Statistics for Windows, version 22.0 (IBM corp., Armonk, NY, USA).

**Results**

A total of 28 participants were initially enrolled in the trial. Four were excluded based on inclusion criteria and one withdrew from the study before the first experimental session for personal reasons. Participants’ characteristics are shown in Table 1.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male/Female (n)</td>
<td>15/8</td>
</tr>
<tr>
<td>Age, years</td>
<td>53.2 ± 10.5</td>
</tr>
<tr>
<td>Body mass, kg</td>
<td>84.1 ± 18.7</td>
</tr>
<tr>
<td>Height, m</td>
<td>1.69 ± 0.1</td>
</tr>
<tr>
<td>Body Mass Index, kg.m⁻²</td>
<td>29.3 ± 5.3</td>
</tr>
<tr>
<td>Systolic blood pressure, mmHg</td>
<td>132 ± 14</td>
</tr>
<tr>
<td>Diastolic blood pressure, mmHg</td>
<td>79 ± 10</td>
</tr>
<tr>
<td>Glycemia, mg/dl</td>
<td>112 ± 35</td>
</tr>
<tr>
<td>Antihypertensive medications (n)</td>
<td>3</td>
</tr>
<tr>
<td>β blockers/ACE inhibitors/ARBs</td>
<td>16</td>
</tr>
</tbody>
</table>

Values are described in mean ± standard deviation.

ACE, angiotensin-converting enzyme

ARB, angiotensin receptor blocker

<table>
<thead>
<tr>
<th>Table 1. Participants’ characteristics.</th>
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**Table 2. Intrasession blood pressure, glycemia, rating of perceived exertion, and number of repetitions performed in each set of the body-weight resistance exercise protocol.**

<table>
<thead>
<tr>
<th>Variables</th>
<th>Inverted row</th>
<th>Squat</th>
<th>Push-up</th>
<th>Sit-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systolic BP, mmHg</td>
<td>151 ± 23</td>
<td>161 ± 20</td>
<td>149 ± 19</td>
<td>141 ± 16</td>
</tr>
<tr>
<td>Diastolic BP, mmHg</td>
<td>75 ± 10</td>
<td>79 ± 10</td>
<td>82 ± 11</td>
<td>77 ± 10</td>
</tr>
<tr>
<td>Glycemia, mg/dl</td>
<td>109 ± 30</td>
<td>105 ± 31</td>
<td>104 ± 24</td>
<td>104 ± 23</td>
</tr>
<tr>
<td>RPE (n)</td>
<td>7 ± 1</td>
<td>4 ± 2</td>
<td>6 ± 2</td>
<td>5 ± 1</td>
</tr>
<tr>
<td>Total repetitions – Set 1 (n)</td>
<td>16 ± 4</td>
<td>21 ± 4</td>
<td>20 ± 4</td>
<td>27 ± 4</td>
</tr>
<tr>
<td>Total repetitions – Set 2 (n)</td>
<td>14 ± 3</td>
<td>23 ± 4</td>
<td>19 ± 5</td>
<td>26 ± 6</td>
</tr>
<tr>
<td>Total repetitions – Set 3 (n)</td>
<td>12 ± 4</td>
<td>26 ± 4</td>
<td>17 ± 6</td>
<td>26 ± 6</td>
</tr>
</tbody>
</table>

Values: mean ± SD; BP, blood pressure; RPE, rating of perceived exertion.

To the best of our knowledge, this is the first study assessing BP and glycemia responses after a body-weight resistance exercise protocol. The main findings of the present study were BP reductions throughout 1 h after the exercise session when compared to pre intervention and to the control session. In addition, there was a similar glycemic behavior after the exercise and control sessions. These results suggest that an acute bout of BWR produce PEH and prevent exercise-induced hypoglycemia, emerging as an interesting option for middle-aged adults with hypertension and other cardiometabolic risk factors.
The benefits of traditional resistance exercise using free-weights or plate-loaded machines are widely known in hypertensive adults (i.e., basal BP reductions and PEH) (5,13,25) and the aging process itself reinforces the importance of resistance training to these populations (26). Nevertheless, in some environments, such as hospitals, geriatric residences, or lockdown situations (i.e., procedure adopted in several countries due to the COVID-19), the necessity to access well-equipped facilities could limit many participants to perform exercise. In this regard, BWR is an excellent alternative form of resistance training since it does not depend on specific equipment or facilities, and it may facilitate exercise adherence in the abovementioned situations. In the present study, we assessed PEH following a resistance exercise session based on exercises using only the body-weight as workload, a protocol that could be performed in any environment. We observed BP decreases of 5–7 mmHg in systolic BP and 5–6 mmHg in diastolic BP after BWR when compared to the control session. In the present study, the participants had resting BP within the normotensive range controlled by anti-hypertensive medications, and considering that initial BP level influences PEH magnitude and duration in hypertensive participants (27), the magnitude of reduction would be even greater if our patients had higher resting BP.

The use of this new alternative of resistance training to reduce BP limits comparisons with other studies using a similar design. When we look at the results of traditional resistance exercise protocols, PEH is presented in most of the studies (13) but controversial results were found when comparing different intensities of exercise. Similar PEH was found after a resistance training session at 40% of maximal dynamic strength (1RM) and 80% of 1RM in overweight elderly women.
(14) and a greater PEH was found after resistance exercise performed at 80% of IRM when compared to 50% of IRM in trained hypertensive women (15). Based on these discrepant results, the total overload (sets x repetitions x load x exercises) (28) seems to be more important than intensity itself to induce PEH. In this regard, our bodyweight resistance exercise protocol (i.e., 16 sets of 30s using 4 different exercises) provides sufficient stress to decrease BP after exercise in middle-aged individuals with hypertension.

Some resistance training protocols could present exaggerated BP elevations during the session (29–31), which can increase the acute cardiovascular load, especially in hypertensive participants. To ensure the safety of our protocol, we assessed BP throughout the BWR session and found slight BP increments between exercises and immediately after exercise session (Table 2). This finding, associated to the PEH resulted from our exercise protocol, highlights the use of body weight resistance training as a safe and efficacious therapeutic modality to acutely reduce BP in hypertensive individuals.

Anaerobic activities can increase the rate of glucose appearance to a greater extent than the rate of glucose utilization during exercise (32), raising glycemic levels during and immediately after exercise (21). In this regard, resistance exercise can be an advantageous alternative, improving glycemic stability and delaying post-exercise hypoglycemia. We were the first to assess glycemic responses through a BWR protocol using a sample composed of middle-aged adults with hypertension, among which ≈80% were overweight/obese and ≈50% also presented high glycemic levels (>100 mg/dl), two important risk factors for diabetes. The similar decrease in glycemia throughout 1 h after exercise when compared to a usual day without exercise suggests our BWR protocol as a new option in reducing the duration and severity of post-exercise hypoglycemia (21). Studies assessing glycemic responses of BWR in individuals with diabetes can bring results of greater clinical relevance and should be further investigated to confirm this finding.

Some limitations should be addressed in the present study. Firstly, the absence of longer monitoring in BP and glycemia (i.e., 24 h ambulatory blood pressure and continuous blood glucose monitoring, respectively). Second, this study did not evaluate hemodynamic mechanisms responsible for BP reductions in response to body-weight resistance exercise sessions, and future studies need to be conducted in order to better understand these mechanisms. Another possible limitation was that our participants performed a specific protocol of body-weight resistance exercises and comparisons among other protocols might produce results completely different. However, our study provides important implications for the exercise prescription targeted to middle-aged individuals with essential hypertension. BWR acutely decreases BP in patients who have well-controlled BP. Moreover, our low-cost resistance exercise protocol could be performed at home, park, hospital, or any other place, which may facilitate a better compliance to exercise.

In summary, a 30 min resistance exercise session composed of 4 body-weight exercises acutely decreased BP in middle-aged adults with hypertension, without effects on usual glycemic responses. We provide an effective and feasible alternative of resistance training that can be performed anywhere and proved to be a sufficient stimulus to acutely decrease BP in this population. It should be mentioned that, although our exercise protocol presented positive results among hypertensive patients, the fact that this type of resistance training does not require equipment does not eliminate the relevance of a professional who prescribes and supervises this training approach. Ultimately, this alternative form of resistance training could facilitate access and adherence and reduce health costs related to exercise programs.

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Disclosure statement
All the authors declare no conflict of interest.
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