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Blood pressure response between resistance exercise with and without blood flow restriction: A systematic review and meta-analysis

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ABSTRACT

Aim: The aim of this study was to compare, by means of a systematic review and meta-analysis, the effects of resistance training with and without blood flow restriction (BFR) on blood pressure (BP).

Materials and methods: This review was composed according to the preferred Reporting items for Systematic Reviews and Meta-Analyses guidelines. Searches were carried out in the databases PubMed, SPORTDiscus, and Web of Science. BP was the main outcome for the analysis of the acute, post-exercise, and chronic effect of resistance exercise with and without BFR. Search results were limited to studies investigating the effect of resistance training with and without BFR on acute or chronic BP, published in a scientific peer-reviewed journal in English.

Key findings: Seventeen references were eligible. During exercise, the diastolic BP (DBP) was higher in exercise with BFR (ES = 17.84) in comparison to traditional exercise with loads ≥60% 1RM (ES = 5.53; $P < 0.01$); and the systolic BP (SBP) and DBP were higher during exercise with BFR in hypertensive individuals (ES = 69.83 and 43.66) in comparison to traditional exercise with loads < 60% 1RM (ES = 48.05 and 28.37; $P < 0.05$). In the post-exercise analysis, exercise with BFR presented lower values for SBP (ES = −5.13; P = 0.02) and DBP (ES = −4.70; $P < 0.01$).

Significance: Although resistance exercise with BFR resulted in greater post-exercise hypotension than traditional exercise, higher SBP and/or DBP values were observed during exercise with BFR compared to traditional exercise, especially in hypertensive individuals. Thus, exercise with BFR should be prescribed with caution when BP control is necessary during exercise.

1. Introduction

Resistance training with blood flow restriction (BFR) is indicated to improve both strength and muscle mass [1]. This model of exercise, by using a relatively light load, is recommended for people with limitations to perform traditional exercise with moderate/high load (> 60% 1RM), such as hypertensive patients [2]. In this context, in addition to the results on strength and muscle mass, it is important to analyze other physiological variables, such as blood pressure (BP).

During traditional exercise with moderate/high load, BP tends to increase according to the load and/or volume of exercise (repetitions or sets) [3]. This is explained by two reasons; the increased load causes increased compression of the muscles on the blood vessels, increasing vascular resistance and BP; and the prolonged time of execution of the exercise, which, although not necessarily causing great vascular compression, causes the accumulation of metabolites to activate the chemoreceptor mechanism, causing an increase in BP [4]. In relation to exercise with BFR, the main characteristic is to reduce or interrupt the flow of blood to a particular muscle group. Muscle contraction performed with low blood flow elevates metabolic stress and may increase the muscle pressure or reflex to the cardiovascular control center, causing exaggerated sympathetic nervous activity [5]. The increase in sympathetic activity may influence the increase in peripheral vascular resistance and, consequently, increase BP during exercise [3–5].

In this context, the relatively low exercise load with BFR may not be the only variable that influences BP during execution. On the other hand, studies that analyzed BP behavior during exercise with BFR compared with traditional exercise present different methodological designs (training and clinical status of the sample, BFR value, BFR duration, and exercise volume), hindering a conclusion about this issue [6–9].

In addition, other studies have investigated the behavior of BP after exercise with BFR (with the goal of monitoring post-exercise hypotension) [6,10] or in a chronic way (after weeks of training) [11].

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Regarding traditional exercise with a moderate/high load, the literature presents well-established data on post-exercise hypotension [12] and the chronic effect [13]. On the other hand, information on exercise with BFR is still scarce.

Understanding these issues is important to direct the prescription of the best exercise model when BP control is necessary. Thus, a research strategy in this case is a systematic review of the literature, which allows the inclusion of references following pre-established inclusion criteria; while the meta-analytical model allows integration of the results, identifying potential variables that may influence BP behavior at different moments of the exercise/training. To our knowledge, only one systematic review has addressed this issue [2], but without meta-analytic treatment, which limits the conclusions.

Thus, the objective of this study was to conduct a systematic review of the literature and meta-analysis to compare the effects of resistance exercise with BFR and traditional resistance exercise on acute and chronic BP responses.

2. Materials and methods

This review was composed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.

2.1. Eligibility criteria

The inclusion criteria for this meta-analysis were as follows: (1) randomized, controlled trials (for studies on chronic response); (2) randomized or non-randomized trials (for studies on acute response); (3) trials involving dynamic resistance exercise (i.e., both concentric and eccentric muscular contractions); (4) for acute response studies, in addition to the BFR exercise session, a session or a group with traditional resistance exercise was required; (5) studies with adults (> 18 years) of both sexes, healthy or with hypertension/cardiopathy; (6) a description of the resistance training (frequency and duration), volume and intensity of training (muscle grouping, repetitions, sets, load, and rest interval); and (7) a description of BFR (cuff type, duration of restriction, and value of restriction). Studies with the elderly (> 60 years) or patients on medication which affects cardiovascular stress responses were not included. For the acute response studies, BP measurement was also required, at rest and during or after exercise. For studies on the chronic effect, BP measurement at rest was required both before and after training.

2.2. Literature search

Searches were conducted in the databases PubMed, Web of Science, and SPORTDiscus, without an initial date limit, until December 2017. After the search, analysis, and inclusion process of the articles, one or more authors were contacted (when necessary) to request data not available in the articles. The combination of the following terms was used to compose the search strategy: ("resistance exercise" OR "resistance training" OR "strength exercise OR "strength training") AND ("blood flow restriction" OR "blood flow occlusion" OR kaatsu OR "vascular restriction" OR "vascular occlusion") AND ("blood pressure" OR hemodynamics). Only studies published in the English language were included.

2.3. Study records

Data on the source of the studies, methodological design, study quality, journal impact factor, sample size and characteristics, BFR protocol, exercise protocol, and results of interventions regarding hemodynamic responses were obtained by two authors independently. Concerns were resolved through face-to-face discussion. The data were extracted and entered into an Excel spreadsheet specially created for this purpose.

2.4. Outcomes

The main outcome of the study was the BP response during resistance exercise with BFR, after exercise, or resulting from a training period. For this, only the values of systolic BP (SBP) and diastolic BP (DBP) were considered. The traditional exercise was stratified into loads ≥60% 1RM or loads < 60% 1RM for the purposes of comparison with exercise with BFR. The stratification of the load did not allow the inclusion of an intermediate category.

The variables related to the training were cuff type (*Kaatsu*, traditional cuff, or adapted cuff), cuff pressure (< 100 mm Hg, 120–150 mm Hg, > 150 mm Hg), BFR during exercise (maintained or intermittent), blood pressure (photoplethysmography, auscultatory, or oscillometric), clinical status (healthy or hypertensive), training status (active or sedentary), and muscle mass (upper, lower, or both). For the studies that measured BP during exercise, the measurement moment (during exercise, 1st set, 2nd set, 3rd set, and 4th set) was identified. For studies that measured BP after exercise, the timing of the measurement was < 30 min or 30–60 min post-exertion.

The variables related to the execution of the exercise (number of exercises, number of sets, number of repetitions, recovery interval, and load) were transformed to only one variable denominated work-rest ratio (WRR) [14], calculated by multiplying the number of sets, repetitions, and load and divided by the sum of the recovery intervals.

Evaluation of the quality of the studies was performed independently using the TESTEX scale [15]. The TESTEX scale uses 12 criteria with some criteria having a possible value of more than one point, for a maximum score of 15 points (5 points for study quality and 10 points for reporting). Higher scores reflect better study quality and reporting. All assessments were conducted in duplicate, independent of each other. Disagreements were resolved through consensus. Trials were not excluded on the basis of quality.

2.5. Risk of bias in individual studies

The effect of publication bias was verified through *funnel plot* analysis with the *trim* and *fill* correction of *Duval* and *Tweedie*.

2.6. Statistical analysis

Descriptive analyses were performed using Excel 2013. The meta-analytic statistics were performed using the Comprehensive Meta-Analysis program (version 2.2, Biostat™ Inc., Englewood, NJ, USA). The main outcome was the change in BP during exercise (acute effect), after exercise (hypotensive effect), and after the training period (chronic effect), with data presented as mean and standard deviation (SD). The data were calculated using the random effect model and the effect size was calculated as the difference in the mean using exercise with BFR and traditional exercise (control) data.

For the analysis of subgroups the following were included: moment of measurement (during exercise vs. 1st set vs. 2nd set vs. 3rd set vs. 4th set - only for studies that measured blood pressure during exercise), moment of measurement (< 30 min vs. 30–60 min – only for the studies that measured blood pressure after exercise), type of cuff employed (*Kaatsu* vs. traditional cuff vs. adapted cuff), cuff pressure (< 100 mm Hg vs. 120–150 mm Hg vs. > 150 mm Hg), BFR during exercise (maintained vs. intermittent), blood pressure measurement apparatus (photoplethysmography vs. auscultatory vs. oscillometric), clinical status (healthy vs. hypertensive), training status (active vs. sedentary), and muscle mass (upper vs. lower vs. both). Potential differences between subgroup variables were tested using the Q-test based ANOVA. A fixed effect model was used to combine subgroups and yield the overall effect.

Variations in blood pressure both during and after exercise in relation to the WRR were treated by meta-regression.

The Q statistic was calculated to verify whether the degree of