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Review

Effect of combined aerobic and resistance training versus aerobic training on arterial stiffness

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ABSTRACT

Background: While aerobic exercise training may decrease arterial stiffness, the impact of combined aerobic and resistance training is unclear. Therefore, the aim of this study was to systematically review and quantify the effect of combined aerobic and resistance training on arterial stiffness, as determined by arterial pulse wave velocity (PWV), and compare it with aerobic training.

Methods: MEDLINE, EMBASE and Web of Science were searched through November 2013 for randomized controlled trials evaluating the effect of aerobic or combined aerobic and resistance training on PWV. A meta-analysis was performed to determine the standardized mean difference (SMD) in PWV between exercise and control groups. Subgroup analyses were used to study potential moderating factors.

Results: Twenty-one randomized controlled trials comparing exercise and control groups (overall $n = 752$), met the inclusion criteria. After data pooling, PWV was decreased in aerobic trained groups compared with controls (10 trials, SMD = −0.52, 95% CI = −0.76, −0.27; $P < 0.0001$) but did not reach statistical significance in combined trained groups compared with controls (11 trials, SMD = −0.23, 95% CI = −0.50, 0.04; $P = 0.10$). The effect in aerobic trained groups did not differ compared with combined trained groups ($P = 0.12$). In addition, aerobic training resulted in significantly lower SMD in PWV compared with combined training in interventions including a higher volume of aerobic training or assessing carotid–femoral PWV.

Conclusions: These data suggest that combined aerobic and resistance training interventions may have reduced beneficial effects on arterial stiffness compared with control interventions, but do not appear to differ significantly with aerobic training alone.

1. Introduction

Arterial stiffness is associated with high risk of cardiovascular morbidity and mortality and its prevalence is increasing rapidly [1,2]. Due to its clinical significance, several indices have been developed during the last two decades to assess arterial stiffness in a non-invasive manner [3,4]. The measurement of pulse wave velocity (PWV) in central arterial segments (i.e., aorta and its main branches) is considered as the 'gold-standard' estimate of arterial stiffness [4]. In brief, proximal and distal (pressure or distension or Doppler) sensors are placed on the skin at the ends of the arterial segment of interest. PWV is calculated as the (corrected) distance traveled by the pulse wave divided by the transit time [4]. PWV is an independent predictor of cardiovascular events in patients with established cardiovascular disease as well as in healthy adults [5,6].

There is a growing interest in therapeutical strategies aiming at reducing arterial stiffness [1]. Among them, regular aerobic exercise such as walking, jogging or cycling is known to prevent or even reverse arterial stiffening in healthy adults [7–12]. Arterial remodeling, decreased sympathetic tonus, enhanced endothelial function and improved profile of circulating factors have been suggested as changes underlying the beneficial impact of aerobic exercise training on arterial distensibility [8,13,14]. In contrast, resistance exercise training, which is associated with increased blood pressure that exceeds that expected due to oxygen requirements during exercise and sympathetic activation [15–17], does not appear to reduce arterial stiffness [18–24]. On the other hand, resistance training induces gains in strength and lean body mass, as well as greater increases in bone density compared with aerobic training [25,26]. Thus, prescribing aerobic and resistance training in conjunction is proposed as an optimum strategy to target cardiovascular as well as musculoskeletal functions in adults [27]. However, most previous randomized control trials that have measured the effect of combined aerobic and resistance training on PWV had small sample sizes and reported variable results [28–36]. Therefore, the main objective

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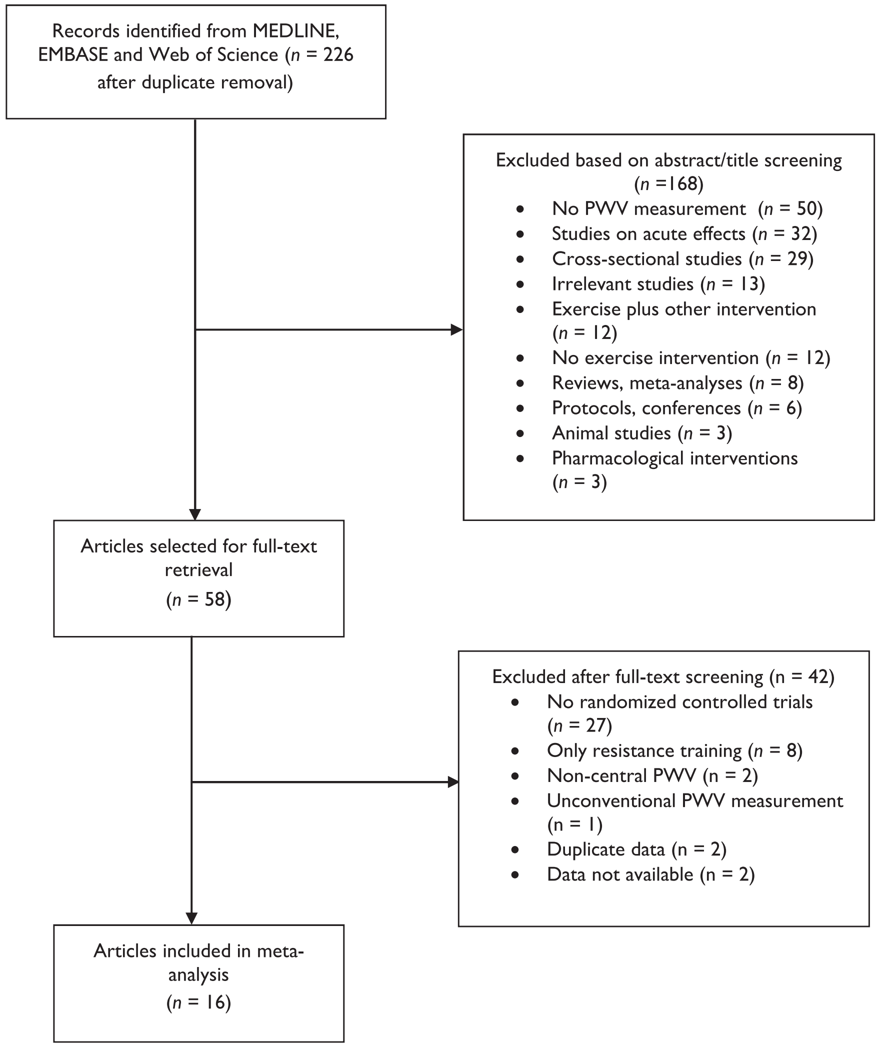

Fig. 1. Flow diagram of the process of study selection.

of this study was to use the meta-analysis procedure to determine the effect of combined aerobic and resistance training on PWV and compare it with aerobic training.

2. Methods

This study is reported according to the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines [37].

2.1. Data sources and searches

The search strategy was developed to identify all relevant randomized controlled trials assessing central or central–peripheral PWV that included a structured aerobic or combined aerobic and resistance exercise intervention and a parallel non-exercising control group. Our systematic search included MEDLINE, EMBASE and Web of Science, since their inceptions until November 2013. We used combinations of the subject headings "pulse wave velocity", "exercise", "training", "intervention" and "program"; the search strategy for MEDLINE is shown in Supplemental Fig. 1. We also performed hand searching in reference citations of identified reviews and research articles selected for full-text retrieval.

2.2. Study selection

To be included in our analysis, an original research article had to meet the following criteria: (i) the research had to be a randomized controlled trial; (ii) central or central–peripheral PWV values had to be reported in relation to an aerobic or combined aerobic and resistance exercise training intervention; and (iii) the duration of the exercise intervention had to be ≥8 weeks. Studies following the above criteria but including other interventions deemed likely to influence PWV were excluded. In the event of multiple publications pertaining to the same research, the first published or more comprehensive study was included. Inclusion of studies in our analysis was not limited by publication status or language.

2.3. Data extraction and quality assessment

The following variables were extracted into a pre-formatted spreadsheet: authors, year of publication, characteristics of study participants (n, age, gender, height, weight, body mass index (BMI), brachial systolic (SBP) and diastolic blood pressure (DBP), smoking subjects, morbidities, medication status), exercise training characteristics (modality, session length, intensity, frequency, duration of the intervention, timing of aerobic and resistance exercise, post-exercise time interval prior to assessment,) and vascular variables (arterial segment evaluated, type of pulse wave sensor, pre- and post-intervention PWV, change in PWV). In the majority of studies, the measure of variability of the change in PWV was not reported [28,31–33,38–44]. Thus, the formula $SD_c = \sqrt{[(SD_{pre})^2 + (SD_{post})^2 - (2 \times corr_{pre,post} \times SD_{pre} \times SD_{post})]}$ was used for the calculation [45]. SD_c, SD_{pre} SD_{post} and $corr_{pre,post}$ represent the standard deviation of the change, the standard deviation of the pre-intervention value, the standard deviation of the post-intervention value, and the correlation coefficient between pre- and post-intervention values, respectively. We assumed a conservative $corr_{pre,post}$ of 0.5 between the pre-intervention and post-intervention PWV values. The methodological quality of each included trial was evaluated using a validated 10-point scale to rate randomized controlled trials [46–48].

2.4. Data synthesis and analysis

The meta-analysis and subgroup analyses were performed using Review Manager software (RevMan 5.2, Cochrane Collaboration, Oxford, UK). In each study, the effect size was calculated by the change (post- minus pre-intervention) mean difference in PWV between the exercise trained and control groups. Analysis of the change was preferred over that of post-intervention values because a significant difference was detected in pre-intervention values between aerobic exercise trained and control groups ($P = 0.03$).