Hypertension Research (2017) 40, 927–931

www.nature.com/hr

ORIGINAL ARTICLE

# Resistance training alone reduces systolic and diastolic blood pressure in prehypertensive and hypertensive individuals: meta-analysis

Evitom Corrêa de Sousa[1,2], Odilon Abrahin[1,3], Ana Lorena Lima Ferreira[1], Rejane Pequeno Rodrigues[1,3], Erik Artur Cortinhas Alves[1] and Rodolfo Paula Vieira[4]

**The purpose of this study was to evaluate the effects of resistance training alone on the systolic and diastolic blood pressure in prehypertensive and hypertensive individuals. Our meta-analysis, followed the guidelines of PRISMA. The search for articles was realized by November 2016 using the following electronic databases: BIREME, PubMed, Cochrane Library, LILACS and SciELO and a search strategy that included the combination of titles of medical affairs and terms of free text to the key concepts: 'hypertension' 'hypertensive', 'prehypertensive', 'resistance training', 'strength training', and 'weight-lifting'. These terms were combined with a search strategy to identify randomized controlled trials (RCTs) and identified a total of 1608 articles: 644 articles BIREME, 53 SciELO, 722 PubMed, 122 Cochrane Library and 67 LILACS. Of these, five RCTs met the inclusion criteria and provided data on 201 individuals. The results showed significant reductions for systolic blood pressure (–8.2 mm Hg CI −10.9 to −5.5; $I^2$: 22.5% *P* valor for heterogeneity = 0.271 and effect size = −0.97) and diastolic blood pressure (–4.1 mm Hg CI −6.3 to −1.9; $I^2$: 46.5% *P* valor for heterogeneity = 0.113 and effect size = −0.60) when compared to group control. In conclusion, resistance training alone reduces systolic and diastolic blood pressure in prehypertensive and hypertensive subjects. The RCTs studies that investigated the effects of resistance training alone in prehypertensive and hypertensive patients support the recommendation of resistance training as a tool for management of systemic hypertension.**
*Hypertension Research* (2017) **40,** 927–931; doi:10.1038/hr.2017.69; published online 3 August 2017

**Keywords:** blood pressure; randomized controlled trials; resistance exercise; strength training

## INTRODUCTION

Systemic arterial hypertension (SAH) is a chronic disease with low rate control and high prevalence in several populations, especially among sedentary people. SAH is considered as a main risk factor for development of several cardiovascular diseases (that is, encephalic vascular injury and acute heart infarct). In the last decade, millions of deaths associated with SAH were registered; the majority occurring in developing countries.[1]

Diagnosis, treatment and control of SAH are essential for the reduction of cardiovascular events. Although pharmacological treatment is effective, the costs are still high. The international guidelines for the primary and secondary prevention of SAH advise patients to adopt a more active lifestyle, especially regular physical exercise.[1]

Among the non-pharmacological approaches for the prevention and treatment of SAH, physical exercise is possibly the most promising.[2,3] Traditionally, aerobic physical exercise has been the most recommended.[4] On the other hand, resistance training (RT) may also reduce resting blood pressure, possibly by reducing peripheral resistance and improving endothelial function.[5] However, isolated RT, remains excluded from the list of non-pharmacological recommendations to control blood pressure by several cardiology societies. Existing meta-analyzes have not evaluated the effects of chronic RT in either prehypertensive or hypertensive individuals without the addition of other concomitant methods.[2,3,6] Therefore, the aim of this meta-analysis was to evaluate the effects of RT alone on the systolic (SBP) and diastolic blood pressure (DBP) in prehypertensive and hypertensive individuals.

## METHODS

This systematic review and meta-analysis is reported in accordance with the recommendations and criteria outlined in the preferred reporting items for systematic reviews and meta-analysis (PRISMA) statement.[7]

### Experimental approach to the problem

A search for articles up to and including November 2016 was carried out using the following electronic databases: PubMed (http://www.ncbi.nlm.nih.gov/pubmed),

[1]Laboratory of Resistance Exercise and Health, Campus III, Department of Physical Education, University of State of Pará, Brazil; [2]Nove de Julho University (UNINOVE), São Paulo, Brazil; [3]Faculdade Metropolitana da Amazônia—FAMAZ, Belém, Brazil and [4]Brazilian Institute of Teaching and Research in Pulmonary and Exercise Immunology (IBEPIPE), Laboratory of Pulmonary and Exercise Immunology (LABPEI), School of Medical Sciences of São José dos Campos Humanitas and Universidade Brasil, São Paulo, Brazil.
Correspondence: Dr, Professor RP Vieira, Brazilian Institute of Teaching and Research in Pulmonary and Exercise Immunology (IBEPIPE), Laboratory of Pulmonary and Exercise Immunology (LABPEI), School of Medical Sciences of São José dos Campos Humanitas and Universidade Brasil, São José dos Campos-SP, 12245-520, Brazil.
E-mail: rodrelena@yahoo.com.br
Received 11 January 2017; revised 6 March 2017; accepted 14 April 2017; published online 3 August 2017

Cochrane Library (http://onlinelibrary.wiley.com/cochranelibrary/search), LILACS (http://www.lilacs.bvsalud.org), BIREME (http://www.bireme.br) and SciELO (http://www.scielo.org). The search strategy included a mix of medical subject headings and free text terms for the key concepts: 'hypertension', 'hypertensive', 'prehypertensive', 'resistance exercise', 'strength training' and 'weight-lifting'. These terms were combined with a sensitive search strategy to identify randomized controlled trials.

The titles and abstracts of retrieved articles were individually appraised by two reviewers to assess whether they were eligible for the present study. Reviewers were not blinded to authors, institutions or manuscript journals. After reviewing the studies and applying the inclusion criteria independently, the reviewers held a consensus meeting to compare results and to decide which articles should be included in the study. Disagreements were solved by consensus or, if necessary, by a third reviewer.

### Inclusion criteria

(1) Studies randomized controlled trials (RCTs).
(2) Studies that evaluated the chronic effects (⩾8 weeks) of RT in prehypertensive and/or hypertensive subjects.
(3) Articles written in English.

### Exclusion criteria

(1) Studies which combined RT with other types of exercise (for example, aerobic).
(2) Studies were duplicate publications.
(3) Abstracts and reviews were excluded.

### Data extraction

The two reviewers separately and independently evaluated full-text articles and conducted data extraction. Pertinent information regarding the details of population characteristics (number of subjects per group, age, sex and duration of the intervention), dropout and compliance to treatment percentage, study methods/design, RT (intensity, training volume, number of exercises, rest, velocity and weekly frequency), and outcomes was collected using a standardized, predefined form. When provided, details on the number of patients excluded and their compliance with treatment were also recorded. Shortly after extraction, the authors crosschecked the data to confirm their accuracy. Any discrepancies were discussed in order to reach a consensus decision.

The search strategy identified a total of 1608 articles: 644 articles from BIREME, 53 SciELO, 67 LILACS, 122 Cochrane Library and 722 PubMed. Of these, 1562 clearly did not fulfill the eligibility criteria and were excluded on the basis of titles and abstracts. Duplicates were excluded and resulted in the inclusion of 10 articles. Of these, five RCTs met the inclusion criteria and provided data on 229 subjects.[8–12] A flow diagram outlining search and selection parameters is shown in Figure 1.

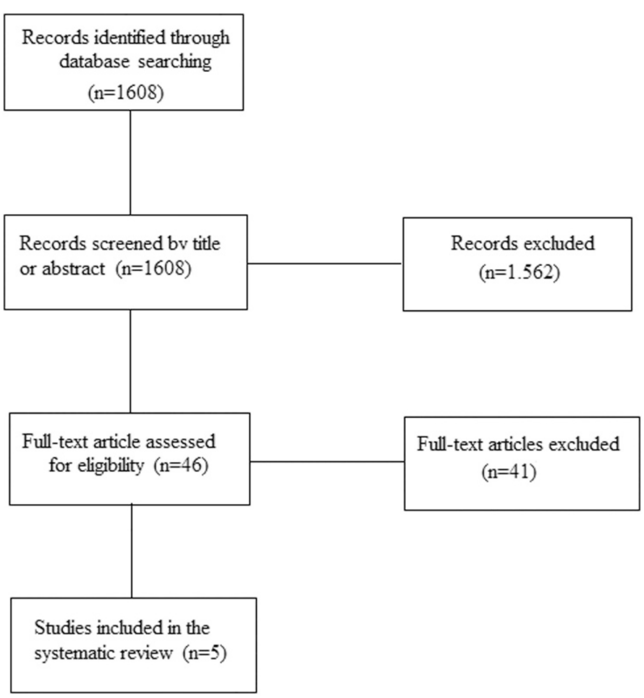


**Figure 1** Flow chart diagram of the study selection.

### Statistical analysis

Absolute changes in blood pressure (diastolic and systolic blood pressure) were extracted after interventions of the resistance intervention (training program) and control group. Heterogeneity refers to the existence of variation between studies for each main effect being evaluated. Statistical heterogeneity of the treatment effect among studies was assessed using Cochran Q test, a threshold $P$-value of 0.1 was considered statistically significant, and for the inconsistency $I^2$ test, values greater than 75% were considered indicative of high heterogeneity. This procedure quantifies the proportion of variability in the results that is due to a function of heterogeneity, rather than by chance. With this method, $I^2$ ranges from 0 to 100%, where 0% reflects low heterogeneity and 100% indicates substantial heterogeneity.

The analyzes of pooled data were conducted with an aleatory model to account for measurement variability among the included studies. For each outcome, a forest plot was generated to illustrate the study-specific effect sizes and their respective 95% confidence intervals (CIs). All analyzes were conducted using Stata software, version 12.0 (Stata, Inc., College Station, TX, USA).

## RESULTS

### Characteristics of the subjects and studies

All subjects included were sedentary. Among the included studies, 80% were elderly (older than 60 years). The mean duration of the intervention (resistance training) was 12 weeks (Table 1).

### Variables of resistance training

All studies used the progressive intensity and were performed three times per week. The number of total sets per session ranged from 14 to 30, and repetitions in each individual set varied from 8 to 25 (Table 2).

### Quantitative data synthesis

Figures 2 and 3 show the overall results for SBP and DBP. Statistically significant ($P<0.05$) reductions were found for SBP (−8.2 mm Hg CI −10.9 to −5.5; $I^2$: 22.5% $P$ valor for heterogeneity = 0.271 and effect size = −0.97) and DBP (−4.1 mm Hg CI −6.3 to −1.9; $I^2$: 46.5% $P$ valor for heterogeneity = 0.113 and effect size = −0.60) when compared with the control groups after RT in prehypertensive and hypertensive subjects.

## DISCUSSION

The main finding of this study demonstrated that RT is an effective physical training method in reducing the SBP and DBP in prehypertensive and hypertensive subjects. Furthermore, our results found only five studies that evaluated the effect of RT alone in prehypertensive and hypertensive subjects, which can be considered a limitation of the study. To the best of our knowledge, this was the first meta-analysis to evaluate the chronic effects only of RT in subjects clinically diagnosed with prehypertension or hypertension.

A meta-analysis by Cornelissen *et al.*[2] (only RCTs) reviewed the effect of RT on blood pressure and other cardiovascular risk factors in adults. The results suggested that both moderate-intensity dynamic RT and low-intensity isometric RT may cause reductions in SBP and DBP. In addition, dynamic RT significantly reduced other cardiovascular risk factors such as body fat and plasma triglycerides.

Other meta-analysis[3] (only RCTs) examined the effects of endurance, dynamic resistance, combined endurance and RT, and isometric RT on resting blood pressure in adults. The SBP was reduced after endurance (−3.5 mm Hg (CI −4.6 to −2.3)), dynamic resistance (−1.8 mm Hg (CI −3.7 to −0.011)), isometric resistance (−10.9 mm Hg (CI −14.5 to −7.4), and combined training (−1.4 mm Hg (CI −4.2 to +1.5). Reductions in DBP were observed after endurance (−2.5 mm Hg (CI −3.2 to −1.7)), dynamic resistance (−3.2 mm Hg (CI −4.5 to −2.0)), isometric resistance (−6.2 mm Hg (CI −10.3 to −2.0)) and combined training (−2.2 mm Hg (CI −3.9 to −0.48)). However, the two meta-analyzes cited previously[2,3] did not include only subjects clinically diagnosed with hypertension. Furthermore, all studies included in our meta-analyzes examined only the chronic effect of RT.

Traditionally, aerobic exercises are recommended for hypertensive subjects as potential non-pharmacological treatments for SAH. In 2003, aerobic exercise prescription for hypertension treatment included: 20–60 min, 3–5 days per week, at 40–70% of maximum oxygen uptake ($\dot{V}O_{2max}$).[13] A guideline published in 2013, by *Canadian Journal of Cardiology* prescribed the accumulation of 30–60 min of moderate-intensity dynamic exercise (for example, walking, jogging and cycling) 4–7 days per week, in addition to the routine activities of daily living for the prevention and treatment of hypertension.[1]

In our meta-analysis, all RT protocols (studies that did not include aerobic exercise) were performed three times per week and this frequency was effective in promoting the reduction of SBP and DBP. This frequency is associated with optimal adherence to training, while increased frequency is associated with a higher dropout rate. This is one advantage of RT compared to aerobic work, which is normally performed with a higher frequency weekly (four to seven times per week).

Current studies recommended the practice of RT for SAH patients, especially for both prehypertensive patients[1,3] and hypertensive subjects in stage 1. The Canadian Hypertension Education Program highlighted that resistance exercise does not adversely influence blood pressure among non-hypertensive or stage 1 hypertensive individuals.[1] However, the benefits promoted by RT depend of the adjustments of training variables (intensity, number of sets and repetitions, rest between sets and exercises, frequency and speed and order of exercises) to guarantee greater safety and efficiency for practitioners.

In this meta-analysis, all studies used progressive intensity training, as the biological/methodological principle of training. The number of total sets per session ranged from 14 to 30, and repetitions in each individual set varied from 8 to 25. The inter-set rest interval ranged from 60 to 180 s.

The exact physiological mechanisms responsible for the reduction of blood pressure is still unclear. The reduction in peripheral vascular

**Table 1 Characteristics of the included studies**

| *References* | *Subjects* | *Age (years)* | *Group (no. of subjects)* | *Duration of the intervention* |
|---|---|---|---|---|
| Beck *et al.*[8] | Prehypertensive subjects (M/F) | 18–35 | PHRT: 15<br>PHET: 13<br>PHCG: 15<br>NMCG: 15 | 8 weeks |
| Heffernan *et al.*[9] | Prehypertensive and hypertensive older adults (M/F) | 61 ± 1 | EG: 11<br>GC: 10 | 12 weeks |
| Mota *et al.*[10] | Hypertensive older adults (F) | 67.5 ± 7.0<br>66.8 ± 5.4 | EG: 32<br>GC: 32 | 16 weeks |
| Terra *et al.*[11] | Hypertensive older adults (F) | 65.9 ± 4.5 | EG: 20<br>GC: 26 | 12 weeks |
| Park *et al.*[12] | Hypertensive older adults (M/F) | 60–88 | EG: 45<br>CG: 47 | 12 weeks |

Abbreviations: CG, control group; EG, experimental group; F, female; M, male; NMCG, normotensive control group; PHRT, prehypertensive resistance exercise; PHET, prehypertensive endurance training; PHCG, prehypertensive control group.

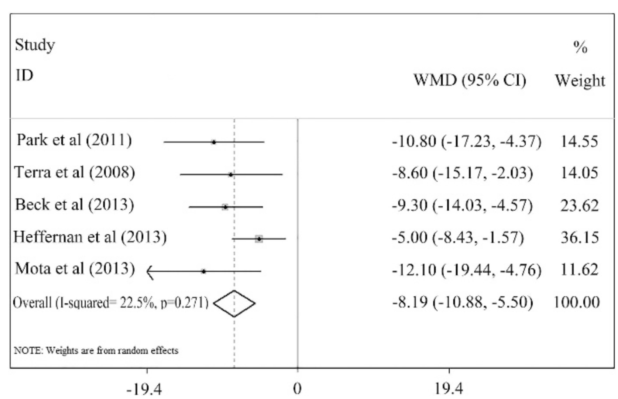


**Figure 2** Forest plot of the changes in systolic blood pressure after resistance training *vs.* control group.

**Table 2 Variables of resistance training of the included studies**

| *References* | *Intensity* | *Training volume* | *Exercises* | *Rest* | *Velocity* | *Frequency* |
|---|---|---|---|---|---|---|
| Beck *et al.*[8] | Progressive | 2 × 8–12 | 7 | 120–180 s | — | 3 d/w |
| Heffernan *et al.*[9] | Progressive 40–80% 1RM | 2 × 12–15 | 9 | — | — | 3 d/w |
| Mota *et al.*[10] | Progressive 60–80% 1RM | 3 × 8–12 | 10 | 60–90 s | 2:2 | 3 d/w |
| Terra *et al.*[11] | Progressive 60–80% 1RM | 3 × 8–12 | 10 | 60–90 s | 2:2 | 3 d/w |
| Park *et al.*[12] | Theraband ‘light’ red color band | 2–3 × 15–25 | 12–15 | — | — | 2 d/w |

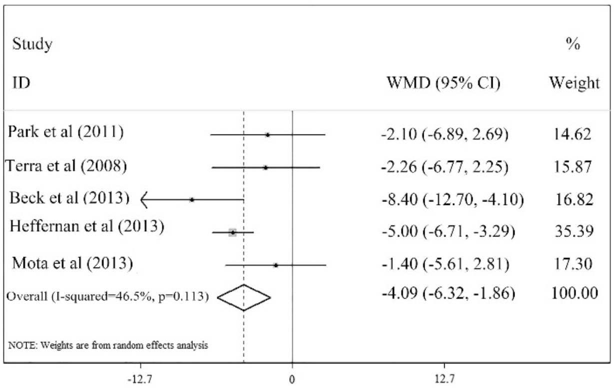


**Figure 3** Forest plot of the changes in diastolic blood pressure after resistance training *vs.* control group.

resistance,[14,15] resting heart rate, double product[11] and arterial stiffness[16] are factors influence post-exercise hypotension. The improvement in endothelial function induced by exercise helps in post-exercise hypotension.[15] Nevertheless, these effects have been found in hypertensive people who perform such as aerobic[1,4] and resistance exercise.[5,9,10]

Some studies have shown that RT improves biosynthesis and activity of endothelial nitric oxide synthase, leading to physiological levels of nitric oxide production, which has a key role in the control of vascular tone, mediating reduction in blood pressure.[8,17] However, for the safety of the hypertensive patient and improvement of endothelial function, the intensity of resistance training must be controlled (not allowing the movement until concentric failure).[18,19] Beck *et al.*[8] found improvements in endothelium function in prehypertensive patients submitted to aerobic exercise and RT (2 sets of 8–12 repetitions to volitional fatigue on seven variable resistance machines).

Possible beneficial effects of RT when compared to aerobic exercise in hypertensive subjects include neuromuscular adaptations such as: improved intra and intermuscular coordination, as well as joint stability that are associated with muscle strength gains. One cross-sectional prospective study followed 1506 hypertensive men 40 years or older for two decades. High levels of muscle strength decrease the risk of death from all causes.[20] Based on these results, muscle strength is a physical component that should also be encouraged in this population, justifying the inclusion of RT.

On the other hand, when specific high intensity RT is focused, controversial results on endothelial function have been demonstrated. Although some authors demonstrated that high intensity resistance training, particularly eccentric exercise impairs endothelial function in young men, as demonstrated by reduced endothelium-dependent vasodilation and not by endothelium-dependent vasoconstriction,[21] others have demonstrated that acute high intensity improves endothelial function[22,23] or even has no effect on endothelial function.[24]

Concernig the hemodynamic response to RT, Karlsdottir *et al.*[25] have demonstrated that moderate-intensity RT is safe for healthy individuals, patients with stable coronary artery disease and patients with congestive heart failure, considering that left ventricular function remained into the normal ranges when aerobic and RT were compared.

### Limitations

This review, as well as other similar ones, is limited by the relative lack of data specifically about the chronic effect of RT in prehypertensive and hypertensive subjects. Our meta-analyzes included only five RCTs. Based on this analysis, an RCT longitudinal study that exclusively investigates the effects of RT on SAH patients is recommended.

## CONCLUSIONS

The results of our study showed that resistance training alone reduces systolic and diastolic blood pressure in prehypertensive and hypertensive subjects, especially in elderly people, beyond to demonstrate the safety of this modality of physical training.

## CONFLICT OF INTEREST

The authors declare no conflict of interest.

1 Hackam DG, Quinn RR, Ravani P, Rabi DM, Dasgupta K, Daskalopoulou SS, Khan NA, Herman RJ, Bacon SL, Cloutier L, Dawes M, Rabkin SW, Gilbert RE, Ruzicka M, McKay DW, Campbell TS, Grover S, Honos G, Schiffrin EL, Bolli P, Wilson TW, Feldman RD, Lindsay P, Hill MD, Gelfer M, Burns KD, Vallée M, Prasad GV, Lebel M, McLean D, Arnold JM, Moe GW, Howlett JG, Boulanger JM, Larochelle P, Leiter LA, Jones C, Ogilvie RI, Woo V, Kaczorowski J, Trudeau L, Petrella RJ, Milot A, Stone JA, Drouin D, Lavoie KL, Lamarre-Cliche M, Godwin M, Tremblay G, Hamet P, Fodor G, Carruthers SG, Pylypchuk GB, Burgess E, Lewanczuk R, Dresser GK, Penner SB, Hegele RA, McFarlane PA, Sharma M, Reid DJ, Tobe SW, Poirier L, Padwal RS, Canadian Hypertension Education Program. The 2013 Canadian hypertension education program recommendations for blood pressure measurement, diagnosis, assessment of risk, prevention and treatment of hypertension. *Can J Cardiol* 2013; **29**: 528–542.
2 Cornelissen VA, Fagard RH, Coeckelberghs E, Vanhees L. Impact of resistance training on blood pressure and other cardiovascular risk factors: a meta-analysis of randomized, controlled trials. *Hypertension* 2011; **58**: 950–958.
3 Cornelissen VA, Smart NA. Exercise training for blood pressure: a systematic review and meta-analysis. *J Am Heart Assoc* 2013; **2**: e004473.
4 Pescatello LS, Franklin BA, Fagard R, Farquhar WB, Kelley GA, Ray CA. American College of Sports Medicine. American College of Sports Medicine position stand. Exercise and hypertension. *Med Sci Sports Exerc* 2004; **36**: 533–553.
5 Kim HS, Kim DG. Effect of long-term resistance exercise on body composition, blood lipid factors, and vascular compliance in the hypertensive elderly men. *J Exerc Rehabil* 2013; **9**: 271–277.
6 MacDonald HV, Johnson BT, Huedo-Medina TB, Livingston J, Forsyth KC, Kraemer WJ, Farinatti PTV, Pescatello LS. Dynamic resistance training as stand-alone antihypertensive lifestyle therapy: a meta-analysis. *J Am Heart Assoc* 2016; **5**: e003231.
7 Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PLoS Med* 2009; **6**: e1000097.
8 Beck DT, Casey DP, Martin JS, Emerson BD, Braith RW. Exercise training improves endothelial function in young prehypertensives. *Exp Biol Med* 2013; **238**: 433–441.
9 Heffernan KS, Yoon ES, Sharman JE, Davies JE, Shih Y-T, Chen C-H, Fernhall B, Jae SY. Resistance exercise training reduces arterial reservoir pressure in older adults with prehypertension and hypertension. *Hypertens Res* 2013; **36**: 422–427.
10 Mota MR, de Oliveira RJ, Dutra MT, Pardono E, Terra DF, Lima RM, Simões HG, da Silva FM. Acute and chronic effects of resistive exercise on blood pressure in hypertensive elderly women. *J Strength Cond Res* 2013; **27**: 3475–3480.
11 Terra DF, Mota MR, Rabelo HT, Bezerra LMA, Lima RM, Ribeiro AG, Vinhal PH, Dias RM, Silva FM. Reduction of arterial pressure and double product at rest after resistance exercise training in elderly hypertensive women. *Arq Bras Cardiol* 2008; **91**: 299–305.
12 Park YH, Song M, Cho BL, Lim JY, Song W, Kim SH. The effect of integrated health education and exercise program in community -dwelling older adults with hypertension. *Patient Educ Couns* 2011; **82**: 133–137.
13 Wallace JP. Exercise in hypertension. A clinical review. *Sports Med* 2003; **33**: 585–598.
14 Brito AF, de Oliveira CVC, Santos MS, Santos AC. High-intensity exercise promotes postexercise hypotension greater than moderate intensity in elderly hypertensive individuals. *Clin Physiol Funct Imaging* 2014; **34**: 126–132.
15 Ciolac EG. High-intensity interval training and hypertension: maximizing the benefits of exercise? *Am J Cardiovasc Dis* 2012; **2**: 102–110.
16 Li Y, Hanssen H, Cordes M, Rossmeissl A, Endes S, Schmidt-Trucksäss A. Aerobic, resistance and combined exercise training on arterial stiffness in normotensive and hypertensive adults: a review. *Eur J Sport Sci* 2015; **15**: 443–457.
17 Macedo FN, Mesquita TRR, Melo VU, Mota MM, Silva TL, Santana MN, Oliveira LR, Santos RV, Miguel Dos Santos R, Lauton-Santos S, Santos MR, Barreto AS, Santana-Filho VJ. Increased nitric oxide bioavailability and decreased sympathetic modulation are involved in vascular adjustments induced by low-intensity resistance training. *Front Physiol* 2016; **7**: 265.
18 Dekleva M, Lazic JS, Arandjelovic A, Mazic S. Beneficial and harmful effects of exercise in hypertensive patients: the role of oxidative stress. *Hypertens Res* 2017; **40**: 15–20.
19 Inder JD, Carlson DJ, Dieberg G, McFarlane JR, Hess NC, Smart NA. Isometric exercise training for blood pressure management: a systematic review and meta-analysis to optimize benefit. *Hypertens Res* 2016; **39**: 88–94.

20 Artero EG, Lee D, Ruiz JR, Sui X, Ortega FB, Church TS, Lavie CJ, Castillo MJ, Blair SN. A prospective study of muscular strength and all-cause mortality in men with hypertension. *J Am Coll Cardiol* 2011; **57**: 1831–1837.
21 Choi Y, Akazawa N, Zempo-Miyaki A, Ra SG, Shiraki H, Ajisaka R, Maeda S. Acute effect of high-intensity eccentric exercise on vascular endothelial function in young men. *J Strength Cond Res* 2016; **30**: 2279–2285.
22 Francois ME, Durrer C, Pistawka KJ, Halperin FA, Little JP. Resistance-based interval exercise acutely improves endothelial function in type 2 diabetes. *Am J Physiol Heart Circ Physiol* 2016; **311**: H1258–H1267.
23 Phillips SA, Das E, Wang J, Pritchard K, Gutterman DD. Resistance and aerobic exercise protects against acute endothelial impairment induced by a single exposure to hypertension during exertion. *J Appl Physiol* 2011; **110**: 1013–1020.
24 Varady KA, Bhutani S, Church EC, Phillips SA. Adipokine responses to acute resistance exercise in trained and untrained men. *Med Sci Sports Exerc* 2010; **42**: 456–462.
25 Karlsdottir AE, Foster C, Porcari JP, Palmer-McLean K, White-Kube R, Backes RC. Hemodynamic responses during aerobic and resistance exercise. *J Cardiopulm Rehabil* 2002; **22**: 170–177.