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Exercise order in resistance training – a brief review of the acute effects on cardiovascular response in the post-exercise period

Ordem dos exercícios no treinamento resistido – uma breve revisão dos efeitos agudos sobre as respostas cardiovasculares no período pós-exercício

Orden de ejercicios en el entrenamiento de fuerza: una breve revisión de los efectos agudos en las respuestas cardiovasculares en el período posterior al ejercicio

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Abstract
This study aims to review the main effects of the performance order of resistance exercises on cardiovascular response in strength training (ST) sessions. To do so, a search was carried out in PubMed, BIREME, and Google Scholar databases using as descriptors: 'order', 'resistance training order', 'resistance exercise order', 'blood pressure' 'hypotension', 'effect hypotensive', 'post-exercise hypotension' and 'cardiovascular responses'. After applying the inclusion/exclusion criteria, six studies were considered in this review. The results suggest that ST can be considered as a non-pharmacological therapeutic option against arterial hypertension. Although the alternate exercise sequence and the sequence that progresses from multi-joint exercises towards single-joint ones present a longer duration of the hypotensive effect in hypertensive individuals, literature needs more studies that investigate the influence of different exercise orders in the hypertensive audience for further conclusions on the subject.
Keywords: Resistance training; Hypertension; Post-exercise hipotension.

Resumo
O objetivo deste estudo foi revisar os principais efeitos da ordem de execução dos exercícios resistidos sobre as respostas cardiovasculares após sessões de treinamento de força (TF). Para isso, foi realizada uma busca nas bases de dados PubMed, BIREME, e Google Scholar utilizando como descritores: ‘order’, ‘resistance training order’, ‘resistance exercise order’ ‘blood pressure’ ‘hypotension’, ‘effect hypotensive’, ‘post-exercise hypotension’ and ‘cardiovascular responses’. Após aplicar os critérios de inclusão/exclusão, seis estudos foram considerados nesta revisão. Os resultados sugerem que o TF pode ser considerado como uma opção terapêutica não farmacológica contra a hipertensão arterial. Embora a sequência de exercício alternada por seguimento e a sequência que progride dos exercícios multiarticulares em direção aos uniarticulares apresentarem maior duração do efeito hipotensivo em indivíduos hipertensos, a literatura precisa de mais estudos que investiguem a influência de diferentes ordens de exercícios no público hipertenso para maiores conclusões sobre o assunto.
Palavras-chave: Treinamento de força; Hipertensão; Hipotensão pós-exercício.

Resumen
El objetivo de este estudio fue hacer la revisión de los principales efectos del orden de ejecución de los ejercicios de fuerza sobre el comportamiento cardiovascular en sesiones de entrenamiento de fuerza (EF). Para ello, se realizó una búsqueda en las bases de datos PubMed, BIREME y Google Scholar utilizando como descriptores: 'orden', 'orden de entrenamiento de resistencia', 'orden de ejercicio de resistencia', 'presión arterial', 'hipotensión', 'efecto hipotensor', ' hipotensión post-ejercicio' y 'respuestas cardiovasculares'. Después de aplicar los criterios de inclusión/exclusión, se consideraron seis estudios en esta revisión. Los resultados sugieren que la EF puede ser considerada como una opción terapéutica no farmacológica contra la hipertensión arterial. Aunque la secuencia de ejercicio alternada por seguimiento y la secuencia que progresa de ejercicios multiarticulares hacia ejercicios uniarticulares presentan una mayor duración del efecto hipotensor en hipertensos, la literatura necesita más estudios que investiguen la influencia de diferentes órdenes de ejercicio en el público hipertenso para mayores conclusiones al respecto.
Palabras clave: Entrenamiento de fuerza; Hipertensión; Hipotensión posejercicio.

1. Introduction

In recent years, the number of studies about strength training (ST) has increased, primarily because of the findings on the impact this modality of physical exercise has on health promotion and sports performance (ACSM, 2002; ACSM 2009; Williams et al., 2007; Rhea et al., 2016).

In their exercise prescription guides, important health organizations, such as the American College of Sports Medicine and the American Heart Association (Pescatelo et al., 2004; Williams et al., 2007), have been helping to publicize the importance of this type of physical exercise for the academic, medical and coaches communities.

When manipulating a strength training program, the trainer has to think about many prescription variables, such as the rest interval between sets and exercises, the number of sets and repetitions, the speed of execution, the order of exercises, the weekly frequency, the state of training, among others (ACSM, 2002, ACSM 2009). All these must be precisely organized to achieve the desired objectives in ST programs. However, it is noted that much of the literature focuses on the effects of load intensity, manipulation of different rest intervals and training volume. As for other training variables, such as the order of exercises, there is still a need to clarify some specific questions, such as cardiovascular responses, for example. For this reason, the objective of this review was to present/summarize the main effects of the performance order of resistance exercises on cardiovascular response after ST sessions.

2. Methodology

Research Methodology

This study is a literature review with a narrative characteristic (Simão et al., 2012). The search was conducted in the PubMed, BIREME, and Google Scholar databases using the search words: ‘order’ [Title/Abstract], ‘resistance training order' [Title/Abstract], 'resistance exercise order' [Title/Abstract], 'blood pressure' [Title/Abstract], 'hypotension' [Title/Abstract], 'effect hypotensive' [Title/Abstract], 'post-exercise hypotension' [Title/Abstract] and 'cardiovascular response' [Title/Abstract] in different combinations, with the help of the Boolean operators 'AND' and 'OR'. The terms were also searched in Portuguese. No time limits were applied to the research period.

Criteria for inclusion and exclusion

Studies were included in this review if they met the following inclusion criteria: a) studies published in Portuguese and English; b) who compared the acute effects of different exercise orders on post-exercise cardiovascular responses; c) analyzes lasting at least 60 minutes after the training sessions. Studies that used other types of methodologies (i.e., aerobic, flexibility, isometric training) and that was not available for free access were excluded.

3. Results and Discussion

The search identified 2153 studies in the selected databases (Google Scholar=2030; PubMed=79 and BIREME=44). After excluding the articles based on the title/abstract, with the removal of duplicates, in the inclusion and exclusion criteria, six studies were analyzed. Table 1 presents a summary of the main information from the selected studies. The temporal distribution of the articles included in this study was as follows: 1 article from 2009, 1 from 2013, 1 from 2014, 1 from 2018, 1 from 2019 and 1 from 2020. Of these, 2 articles investigated the hypertensive audience, 4 studies analyzed normotensives, 3 were conducted on older people, 2 articles analyzed trained young men and 1 study examined young trained women.

Table 1. Description of the selected studies.

Authors	Population	Training protocol	Main effects
Jannig et al. (2009)	Older people of both sexes (61.1 ± 3.1 years), hypertensive, inexperienced in ST.	**TP1:** lower limbs towards the upper limbs; **TP2:** inverse order to TP1; **TP3:** sequence alternating lower and upper limbs; 3 sets, 12RM, 2-3 minutes rest between sets and exercises.	TP3 was more effective in the duration of the hypotensive effect compared to the other two training protocols.
Figueiredo et al. (2013)	Young men (26.6 ± 4.5 years), normotensive, trained	**SEQ1:** upper limbs towards the lower limbs; **SEQ2:** inverse order to SEQ1; 3 sets, 10-12 reps, 80% 1RM, 3-minute rest.	No statistical differences were observed for the hypotensive effect. However, the sequence that progressed from upper to lower limbs presented greater cardiac stress.
Bentes et al. (2014)	Young women (29.8 ± 11.0 years), normotensive, trained (5 years)	**SEQA (60 and 80% of 1RM):** alternated lower and upper limbs; **SEQB (60 and 80% of 1RM):** upper limbs towards the lower limbs; 3 sets, 60 and 80% of 1RM, 2-minutes rest.	SEQA (60 and 80%) and SEQB (80%) were more effective in the duration of the hypotensive effect.
Lemos et al. (2018)	Young men (25.0 ± 4.5 years), normotensive, trained (12 months)	**SEQA (40 and 90):** large muscle groups towards small muscle groups; **SEQB (40 and 90):** inverse order; 3 sets, 15RM, 40 or 90 seconds rest	The 90-second interval was more effective in the hypotensive effect, regardless of the exercise order. While sessions with 40 seconds interval promoted greater cardiac stress in the post-exercise period.
Cardozo et al (2019b)	Hypertensive older women, Group 1 (69.9 ± 5.6 years), Group 2 (69.7 ± 5.9 years), inexperienced in ST	**G1 (upper limbs group)** **SEQ1:** multi-joint exercises towards single-joint exercises; **SEQ2:** inverse order; **G2 (lower limbs group)** **SEQ1:** multi-joint exercises towards single-joint exercises; **SEQ2:** inverse order; 3 sets, 15RM, 2-minute rest.	The exercise sequences that progressed from multi-joint to single-joint promoted a longer duration of the hypotensive effect.
Tomereli et al. (2020)	Older women (68.3 ± 3.3 years), normotensive, trained (24 weeks)	**SEQMS:** multi to single-joing exercises; **SEQSM**: inverse order; 8 exercises, 3 sets, 8-12 reps, 2 minutes rest between sets and 3 minutes rest between exercises.	Both exercise sessions were effective in lowering blood pressure. The order of the exercises did not influence the duration and magnitude of the results.

ST= strength traning; G= group; SEQMS= multi-joint to single-joint sequence; SEQSM= single-joint to multi-joint sequence.
Source: Authors.

Acute effect of exercise order on post-exercise blood pressure

Basically, the exercise order is defined as the sequence of exercises performed in an ST session. The choice of this sequence is considered of great importance for adequate planning because it targets to meet the desired needs and objectives. Literature demonstrates that the exercises starting the training sessions present better strength performance, regardless of whether they involve a large or small muscle group (Simão *et al*., 2005; Spreuwenberg *et al*., 2006; Simão *et al*., 2007; Beleza *et al*., 2009; Simão *et al*., 2010; Figueiredo *et al*., 2011; Simão *et al*., 2013; Lemos et al., 2016; Cardozo et al., 2019a; Cardozo et al., 2021). However, these analyses are directed towards repetition performance and strength gains.

Regarding cardiovascular responses, literature demonstrates that only a single ST session can reduce blood pressure after its practice (there are reports of 10-hour length), a phenomenon known as post-exercise hypotension (Pescatello et al.,

2004; Melo et al., 2006). These responses are extremely important for hypertensive individuals who need to control blood pressure.

Regarding the exercise order variable, one of the first studies that investigated the influence of this training variable on post-exercise hypotension in hypertensive older people was by Jannig et al. (2009). In this study, training protocol 1 was organized in the sequence from lower limbs to upper limbs, in training protocol 2 the exercise sequence was inverted (starting from the upper limbs towards the lower limbs) and training protocol 3 was organized in an alternate sequence. All exercises were performed with 3 sets and 12 repetitions. The results of this study demonstrated that the alternate order was more efficient in the duration of the hypotensive response when compared to the other exercise sequences.

After a few years, Figueiredo et al. (2013) investigated the effect of two different exercise sequences on the hypotensive effect: sequence 1 started with upper limb exercises and progressed to the lower limbs, in sequence 2 the order was inverted (starting with the lower limbs towards the upper limbs). In this study, no hypotensive effect was observed after the training protocols. However, there was greater cardiac stress, measured by heart rate variability, in the post-exercise period when the exercises started with the upper limbs and progressed to the lower limbs.

Bentes et al (2015) verified the effect of two different exercise sequences (SEQA and SEQB) and training intensities (60% and 80% of 1RM) on the hypotensive response. In this study, 13 trained young women were submitted to four experimental sessions. Sequence A alternated upper and lower limb exercises and sequence B progressed upper limb exercises towards the lower limbs. All volunteers were also submitted to two different training intensities (60% and 80% of 1RM). Thus, the sessions consisted of SEQA60%, SEQA80%, SEQB60% and SEQB80%. All training sessions were conducted in three maximum sets with a two-minute rest between sets and exercises. The results demonstrated significant decreases in systolic blood pressure after the training protocols. However, for the duration of the hypotensive effect, the two sessions of SEQA (60 and 80% of 1RM) were effective, while SEQB only with the protocol of larger intensity (80% of 1RM).

Lemos et al (2018) investigated the effect of different exercise sequences for upper limbs (A and B) and different rest intervals (40 and 90 seconds) on blood pressure alongside heart rate variability in young people experienced in ST. The training order A followed a sequence of multi-joint exercises towards single-joint exercises: chest press (CH), front lat pulldown (FLP), seated row (SR), upright row (UR) triceps curl (TC) and biceps curl (BC). Order B was inverted progressing single-joint exercises towards multi-joint exercises: BC, TC, UR, SR, FLP and CH. The results showed that the 90-second rest interval provided a longer duration of the hypotensive effect regardless of the exercise order. The training sessions with 40-second intervals provided larger cardiac stress in the post-exercise period.

The study by Cardozo et al (2019b) verified the effect of different sequences of exercises aimed at strength resistance in hypertensive older women. Group 1 (G1) performed two different sequences for upper limbs: sequence 1 consisted of bench press (BP), machine seated row (MSR), triceps curl (TC) and biceps curl (BC). Sequence 2 was inverted: BC, TC, MSR and BP. Group 2 (G2) performed two different exercise sequences for the lower limbs. The sequence 1 of G2 consisted of leg press (LP), leg extension (LE) and plantar flexion (PF). The sequence 2 of G2 was also inverted: PF, LE and LP. In this study, G1 performed three submaximal sets of 15 repetitions in four exercises, while G2 performed four submaximal sets of 15 repetitions in three exercises. Both groups had two-minute rest intervals between sets and exercises. The results showed that the exercise sequences starting with multi-joint exercises and progressing to single-joint exercises provided a longer duration of the hypotensive effect, regardless of whether the muscle groups were upper or lower limbs. On the other hand, Tomeleri et al. (2020) found no differences between exercise sequences in the hypotensive effect in normotensive older women. Both protocols were equally effective. Thus, we can verify different responses in studies that analyzed the effect of different exercise orders on the hypotensive effect.

Therefore, we can attribute these different findings to factors such as age, sample composition and health conditions. For example, in the studies by Jannig et al. (2009) and Cardozo et al. (2019b), the analyzes were aimed at the hypertensive older audience, while the study by Tomeleri et al. (2020) investigated trained normotensive older women. The study by Figueiredo et al (2013) was aimed at men, while Bentes et al. (2015) investigated the female audience. In the study by Lemos et al. (2018), analyzes were associated with different rest intervals in trained young men. An issue that deserves to be highlighted is that the training protocols induced a reduction in systolic blood pressure and had little or no impact on diastolic blood pressure (DBP). Possibly these responses can be attributed to values close to or even below normality for the DBP of the sample in the studies, a hypothesis known as the law of initial values (Pescatello and Kulikowich 2001), and also because ST can induce an increase in DBP during its practice. Therefore, the ST impact on DBP reduction will be smaller.

4. Conclusion

Resistance training can be considered a non-pharmacological option against arterial hypertension, as the training protocols provided a significant reduction in blood pressure in the post-exercise period. From a clinical point of view, we can consider the alternate sequence and the sequence progressing from multi-joint exercises towards single-joint ones more effective to extend the duration of the hypotensive effect in hypertensive individuals inexperienced in resistance training. However, literature needs more studies that investigate the influence of different exercise orders on the hypertensive audiences for further conclusions on the subject. Future studies could explore other exercise sequences, as well as associate them with other training variables so that we have more information about the manipulation of methodological variables and their effects on blood pressure.

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