Acute cardiovascular responses on knee extension at different performance modes

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ABSTRACT

The objective of this study was to verify the systolic arterial blood pressure (PAS) and diastolic arterial blood pressure (PAD), heart rate (FC) and double-product (DP) during and after the knee extension performed unilaterally and bilaterally until exhaustion. Eighteen healthy volunteers – six men and 12 women (33 ± 11 years old; 63.5 ± 11.4 kg; 168.6 ± 7.1 cm), experienced on strength training, performed three series of 12 maximal repetitions of knee extension unilaterally (UN) and bilaterally (BI). The arterial blood pressure was measured through the auscultatory method at the end of each series and during 20 minutes after the exercise, with 5-minute intervals. The two-way ANOVA with repeated measures showed that the percentile variation in relation to the rest situation (Δ%) of the PAS was significantly higher at the 3rd series (UN = 31.7 ± 11.9%; BI = 38.5 ± 10.9%) than at the 1st (UN = 19.5 ± 12.5%; BI = 26.0 ± 10.2%). With regard to the PAD, the Δ% was higher at the 3rd series (UN = 48.5 ± 13.9%; BI = 51.4 ± 13.3%) than at the 1st (UN = 30.5 ± 13.0%; BI = 34.9 ± 16.0%) and 2nd (UN = 40.9 ± 15.4%; BI = 47.3 ± 12.9%). No differences for FC and DP were observed as well as between the performance modes. After the exercise, no differences between all variables observed were identified. Apparently, the performance mode of the knee unilateral extension would not reflect on the acute cardiovascular responses, during or after the exercise. However, the bilateral performance showed tendency to elevate the values of PAS and DP in relation to the unilateral performance, what should be considered in prescriptions for people who need special cares.

Key words: Strength. Training. Cardiovascular physiology. Health.

INTRODUCTION

The strength training is currently presented as a basic part of an exercise program aimed at healthy people[1]. Even subjects that need attention with regard to the cardiovascular safety are able to perform the strength exercise[2]. In this purpose, some training variables must be controlled, such as the load to be moved[3], number of repetitions[4] and series[5], in order for the cardiovascular responses during the exercise not to elevate excessively to present risks to the health.

An interesting strategy to minimize the possibility of cardiovascular risks during the strength exercise is the requesting of few and small muscular groups, even with high loads, in order for a small vascular occlusion to occur and consequently smaller response of the arterial blood pressure[6]. However, this strategy loses power when it is intended to train, for instance, the knee extensor muscles, once they are relatively large. The choice for unilateral works, in other words, to train each member separately, is made to solve this problem[3].

Most studies that investigated the relationship between the performance mode (unilateral or bilateral) of the strength exercise and the acute cardiovascular responses used submaximal repetitions[7] or the exercise until exhaustion[3,6,8], but with loads determined from percentages of a maximal repetition (1 RM). Thus, the number of repetitions reached on the bilateral performance may not be equal to the unilateral performance (in the case of repetitions until exhaustion) or the stimulus may be insufficient to maximize the cardiovascular responses in order to enable the identification of differences between the performance modes (in the case of submaximal repetitions).

With regard to the cardiovascular responses after the strength exercises, information is still scarce in literature. Recent data suggest that the arterial blood pressure, especially the systolic, would decrease in relation to values in rest situation for up to 60 minutes after a strength training session, regardless the intensity[9]. However, there are no available data on the arterial blood pressure after the isolated strength exercise or on the muscular mass involved.

In this context, the objective of this study was to verify the cardiovascular variables: systolic arterial blood pressure (PAS) and diastolic arterial blood pressure (PAD), heart rate (FC) and double-product (DP) during and after two sequences of knee extension performed unilaterally and bilaterally with loads corresponding to 12 RM.

MATERIAL AND METHODS

Selection of subjects

Eighteen healthy volunteers – six men and 12 women (33 ± 11 years old; 63.5 ± 11.4 kg; 168.6 ± 7.1 cm), experienced on strength training for at least three months. All volunteers signed up the consent form, according to the resolution 196/96 of the National Health Council for researches involving human beings after the approval by the Ethics Committee of the respective institution. The use of substances that could affect the cardiovascular responses of rest or effort, physical activities in days of data collecting, ingestion of alcohol or coffee 12 hours before tests and any other fact, of any nature that could make the performance of the proposed exercise impossible, were considered as criteria for exclusion.

Data collecting

The data collecting was performed within four non-consecutive days. Firstly, the 12 RM test was performed for the bilateral knee extension in the extensor chair equipment. The initial position was established by the knee angulation corresponding to 90º (established by the equipment) and the final position was established by the total knee extension. Two seconds were established as contraction time for each one of the concentric and eccentric phases, adjusted through a metronome (*Yamaha*®, model QT-1). At the second day, the same procedure was performed for the unilateral test

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of the same exercise on the dominant member. At the third day, as the subjects arrived at the tests place, they remained sit and calm on the own extensor chair for approximately five minutes, in order to stabilize the values of the arterial blood pressure (PA) and FC for the measure in rest situation. After this phase, three series of 12 RM of the knee bilateral extension were performed, with two minutes of interval between series, being the PA and FC recorded at the end of each series. After the end of the last series, the individuals remained in the own extensor chair for 20 minutes. During this period, the PA and FC were measured with intervals of five minutes, performing a total of four post-exercise measures. Finally, at the last day, the same procedure was used, but the exercise was performed unilaterally.

Arterial blood pressure and heart rate measures

The measure of the arterial blood pressure was indirectly performed through the auscultatory method, using a sphygmomanometer of mercury column (*Missouri*®) and a stethoscope (*Rappaport*®). The cardiac frequency was recorded by telemetry though a frequency meter (*Polar*®, model A1). The PA measure standard followed the recommendations of the American Heart Association[10]. An experienced appraiser performed the measures in rest situation during and after the exercise in all subjects. For the measure in rest situation, the subject positioned his relaxed left arm on a plane surface at the shoulder height. The fastening of the cuff to the arm occurred with approximately 2.5 cm of distance between its lower extremity and the antecubital cavity. After the cuff had been inflated, the emptying process was started at a ratio of 2 mm Hg per second until the 1st and 5th Korotkoff noises were distinguished, corresponding to the systolic and diastolic values, respectively. Once the measure in rest situation was performed, the subject started the exercise with the empty cuff fastened to the adequate position and the arm positioned on the surface. During the exercise, the beginning of the cuff emptying was coincident to the beginning of the last but two repetition. This enabled sufficient time for the determination of the PAS simultaneously to the end of the last repetition. The PAD was checked until four seconds after the end of the established repetitions. This procedure was adopted due to two main criterions. Firstly, the highest PAS value is required when one desires to estimate the DP. For this, the measure should occur the later as possible especially when one sequence is performed until exhaustion. Secondly, in case the PAD measure was coincident to the end of the exercise, it would not be possible to identify the exact moment of the PAS recording, what would influence directly on the DP calculation. For this reason, the observation of the FC value was simultaneous to the PAS measure. After the exercise, the PA measure followed the procedures adopted in the rest situation.

During all tests, the subjects were instructed not to perform the Valsalva maneuver and to move or to contract the left arm, for the PA measure to be performed with no alterations.

Statistical treatment

The two-way ANOVA was used with repeated measures at the second factor, followed by Tukey *post-hoc* verification, in order to compare the influence of the exercise performance mode and the number of series on the responses of the cardiovascular variables. As the auscultatory method may underestimate the PA value, the percentile variation in relation to the rest situation (Δ%) of the PAS, PAD, FC and DP was considered for statistical treatment purposes. In order to compare the values of the cardiovascular variables after the exercise, the two-way ANOVA was used with repeated measures, followed by Tukey *post-hoc* verification. In this case, both the absolute values and the Δ% were considered. In all cases, the level of significance of $p < 0.05$ was adopted. The data treatment was performed in the *Statistica*® 5.5 (*Statsoft*©, USA) software.

RESULTS

During the exercise

The table 1 presents the values corresponding to the Δ% for the variables observed. The PAS presented non-combined isolated association, to the variables performance mode and number of series. In both the unilateral and bilateral performances, significant differences were observed between the first and third series, however, no significant differences were verified between series when the performance modes were compared. The PAD was significantly associated only to the number of series, and for both performance modes, the third series was significantly higher than the first and the second. With regard to the FC and DP, although being significantly associated to the performance mode, no differences between the unilateral and bilateral series were identified.

TABLE 1
Percentile variation in relation to the rest situation (Δ%) in each series of the unilateral and bilateral performance modes for the systolic arterial blood pressure (PAS), diastolic arterial blood pressure (PAD), cardiac frequency (FC) and double-product (DP) (average ± standard deviation)

	PAS (%)	PAD (%)	FC (%)	DP (%)
Bilateral				
Δ% 1st series	26.0 ± 10.2	34.9 ± 16.0	56.6 ± 21.6	97.7 ± 34.0
Δ% 2nd series	33.2 ± 11.2	47.3 ± 12.9	53.5 ± 26.2	105.2 ± 42.6
Δ% 3rd series	38.5 ± 10.9*	51.4 ± 13.3*†	54.9 ± 27.2	115.7 ± 47.4
Unilateral				
Δ% 1st series	19.5 ± 12.5	30.5 ± 13.0	38.1 ± 30.2	68.9 ± 40.9
Δ% 2nd series	26.4 ± 13.7	40.9 ± 15.4	37.6 ± 31.4	78.0 ± 46.1
Δ% 3rd series	31.7 ± 11.9*	48.5 ± 13.9*†	41.5 ± 37.7	90.9 ± 55.3

* significant difference ($p < 0.05$) for the first series of the same execution mode;
† significant difference ($p < 0.05$) for the second series of the same performance mode.

After the exercise

The analysis of the absolute values identified no differences for all variables in relation to the rest situation during the post-exercise period as well as differences between the performance modes. However, the last two PAS and PAD measures at the bilateral performance were significantly different for the corresponding values observed at the fifth minute (table 2). Now, the analysis of the Δ% for the PAS and PAD indicated no differences between the performance modes (figures 1 and 2).

TABLE 2
Absolute values in rest situation in the unilateral and bilateral performance modes for the systolic arterial blood pressure (PAS), diastolic arterial blood pressure (PAD), cardiac frequency (FC) and double-product (DP) (average ± standard deviation)

	PAS (mmHg)	PAD (mmHg)	FC (bpm)	DP (mm Hg.bpm)
Bilateral				
Rest	120.9 ± 12.5	80.2 ± 6.9	72.8 ± 9.5	8767.9 ± 1198.2
5 min	122.9 ± 15.3	77.7 ± 7.6	74.6 ± 9.7	9131.1 ± 1403.4
10 min	120.8 ± 14.8	80.9 ± 9.5	74.7 ± 11.0	9029.1 ± 1861.9
15 min	118.1 ± 13.4*	83.3 ± 8.9†	73.5 ± 8.1	8663.8 ± 1271.4
20 min	117.6 ± 12.3*	83.6 ± 9.0†	74.7 ± 9.1	8764.2 ± 1338.4
Unilateral				
Rest	119.6 ± 11.2	79.4 ± 9.6	74.5 ± 11.4	8660.3 ± 1361.9
5 min	119.8 ± 12.1	77.8 ± 9.7	72.6 ± 11.6	8676.7 ± 1477.8
10 min	117.9 ± 11.9	80.6 ± 9.6	72.3 ± 10.4	8511.7 ± 1356.4
15 min	116.9 ± 11.0	81.0 ± 9.1	72.4 ± 11.1	8445.0 ± 1399.1
20 min	116.1 ± 8.5	81.9 ± 9.1	73.9 ± 11.1	8558.0 ± 1309.8

* significant difference ($p < 0.05$) in relation to the measure obtained at the 5th minute for PAS in the bilateral performance mode;
† significant difference ($p < 0.05$) in relation to the measure obtained at the 5th minute for PAS in the bilateral performance mode.

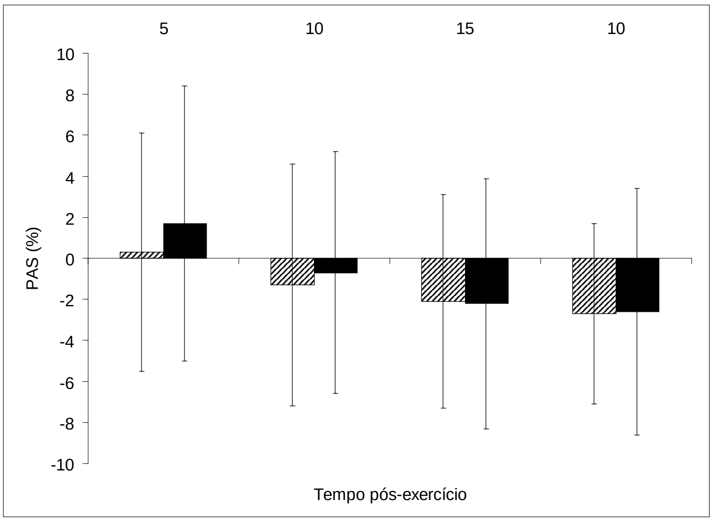

***Fig. 1** – Percentile variation of the systolic arterial blood pressure (PAS) after unilateral performance (diagonal bar) and bilateral performance (black bar)*

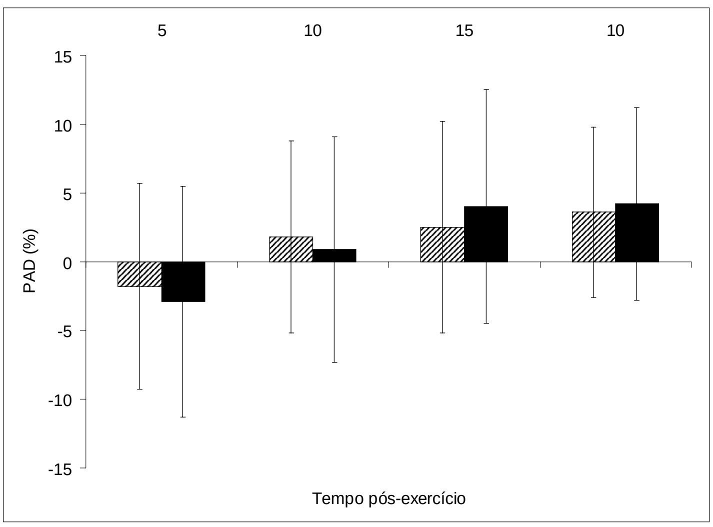

***Fig. 2** – Percentile variation of the diastolic arterial blood pressure (PAD) after unilateral performance (diagonal bar) and bilateral performance (black bar)*

DISCUSSION

The accuracy of the PA measure in high intensity and short duration activities, such as the strength exercise, depends on the method of measure used. The gold standard, through the intra-arterial catheter, became infeasible for applications in large scale or in non-laboratorial environments[11]. An interesting alternative would be the non-invasive equipments, which provide continuous PA reading, such as the *Finapres*®[5]. However, its application is limited due to the high costs of attainment and maintenance. Thus, strategies may be adopted for the auscultatory method to be used on the PA measure in strength exercises[12]. It is known that the auscultatory method may underestimate the PA actual value during the strength exercise, due to its checking intermittent nature[7]. However, when different performance modes of the same strength exercise are compared, this method may estimate the cardiovascular stress. This was verified in an experiment in which the significant correlation for PAS and PAD between the auscultatory muscle and the *Finapres*® was observed during the knee unilateral extension performed at 6 RM (PAS = 0.85; PAD = 0.84) and 15 RM (PAS = 0.88; PAD = 0.74), even with significant differences in the absolute values[13]. Thus, in the present study, one has chosen to use the PAS and PAD percentile variation in relation to the rest situation, once the objective was to investigate whether the performance mode would reflect on the cardiovascular stress.

The results of the present study indicate that the performance mode would not influence the acute cardiovascular responses, once no differences between exercises performed unilaterally and bilaterally were verified. However, as we observe data from table 1, it is verified that the PAS, FC and DP during the bilateral performance assume the inclination to elevate in relation to the unilateral performance, once they are significantly associated to the performance mode. Some explanations about this fact may be given. Firstly, the muscular mass or the amount of muscles requested in a strength exercise is directly proportional to the PA response, due to the higher vascular occlusion by the muscles in activity[6]. However, this relation seems to be more relevant when different muscular groups are requested. For example, in a study by MacDougall *et al.*[6], the PAS, PAD and FC responses were significantly higher in the unilateral leg-press than in the unilateral elbow flexion, when performed until exhaustion with 80, 90, 95 and 100% of maximal load. Now, when different exercises for similar muscular groups are performed, significant differences may not be identified. Bermon *et al.*[14] verified that the bilateral leg-press presented average responses of PAS (223.6 mm Hg), PAD (139.6 mm Hg) and FC (107.5 bpm) higher, but not significant, than the knee bilateral extension (PAS = 200.6 mm Hg; PAD = 127.4 mm Hg; FC = 105.5 bpm), when performed at 12 RM. Our results corroborate these suppositions, in other words, the highest quantity of muscles involved in the bilateral performance caused the highest PAS response, but not statistically significant as the exercise performed unilaterally. With regard to the FC, it is possible that this variable has been associated to the performance mode due to the vascular occlusion more pronounced in the bilateral performance, once with such reduced venous return, the FC should be increased in order not to impair the cardiac debt[6]. With regard to the DP, once depending on the PAS and FC, it demonstrated behavior similar to these variables.

Regardless the performance mode, no differences were observed in the course of the series for PAS, FC and DP. The behavior of the FC during an isolated series of strength exercise is associated to the duration time of the stimulus[15]. Now, in successive series, the increase in relation to the FC preceding series seems to be associated to the recovery interval[16]. In our study, the recovery interval between series was fixed as well as the stimulus duration, what may have been sufficient for differences not to have been observed from series to series. On the other hand, the PAS presented differences between the 1st and the 3rd series for both performance modes. These results are in agreement with reports from Gotshall *et al.*[5], who verified successive increase on the PAS in each one of the three series of 10 RM in the leg-press. However, in our study, besides the exercise, we used different stimulus duration. The sample of Gotshall *et al.*[5] performed each one of the concentric and eccentric phases in three seconds, performing a total of one minute of contraction. As the participants of our study performed each complete movement in four seconds, the total duration of each series was of 48 seconds, what may have been the differentiation factor for the results obtained. However, the PAD assumed behavior similar to what was reported by Gotshall *et al.*[5] for the PAS; in other words, the 3rd series was significantly higher than the 1st and 2nd. In this case, the fatigue accumulated after the preceding series seems to have exercised a somatic effect for this variable, once the utilization of accessory muscles in the final series would contribute for the elevation of the PAS[17]. However, it is worthy emphasizing that the PAD was checked a few seconds after the end of each series, not necessarily representing the exercise value.

After both aerobic and strength exercises, the PA may reduce in relation to the values of the rest situation. This condition, called as post-exercise hypotension, is particularly welcome to hypertensive individuals, once it consists of non-pharmacological intervention procedure[18]. The post-exercise hypotension occurs through the reduction on the vascular resistance, although the mechanisms responsible for the furtherance of such condition are not yet known[18]. With regard to the cardiovascular responses after the strength exercise, the few studies that investigated this behavior report incompatible results such as increase[20], no alteration[20] or reduction[9,21,22]. The inconsistency of information may be associated to the different interaction modes between volume and intensity of the strength training during the post-exercise measure period and other intervenient variables such as anxiety state. Roltsch *et al.*[20], for example, did not identify differences in the PAS after 24 hours from the performance of a sequence of strength exercises. Probably, the period used to follow the PA was excessively long to record any alteration. Recently, Polito *et al.*[9] verified the significant reduction on the PA, especially the PAS, until 60 minutes after two sessions of strength exercises with different intensities. Thus, in the present study, it was chosen to verify the PA during 20 minutes after exercise, sufficient time for any pressure alteration to show up. For both absolute and relative terms, no post-exercise measure was different from that recorded in the rest situation. It is possible that the exercise volume has contributed for these results. Considering that each series was performed in 48 seconds, the total time of contraction in the three series was approximately of three minutes. Since the literature presents no data on the relation between strength training volume and PA post-exercise, further speculations would be compromising. Furthermore, our sample was composed of normotensive subjects, who present some limitation on the reduction of the PA post-exercise in order not to imperil the orthostatic tolerance[18]. In this context, the results may be different for non-medicated hypertensive people in both during and especially after the exercise.

Finally, the performance mode of the knee unilateral extension seems not to reflect on the cardiovascular responses during or after the exercise. However, subjects who need special cares, such as people with cardiovascular diseases, would be provided more safety with the unilateral exercise, once the tendency to elevation is lower when compared to the bilateral exercise.

By the fact that the present study does not provide data about different muscular groups, intensities and training volumes, the results may not be reproduced in exercises involving other performance conditions. Thus, additional investigations are welcome.

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