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original article

Effect of the number of sets on acute cardiovascular responses during stretching exercise

Efeito do número de séries nas respostas cardiovasculares agudas durante exercício de alongamento

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Abstract – Few studies have investigated the effects of manipulating variables of stretching exercise prescription on acute cardiovascular responses. The objective of this study was to compare the acute responses of heart rate, blood pressure and double product before, during and after four sets of passive static stretching during unilateral hip flexion. The sample consisted of 16 adult men aged 18 to 27 years (22±2.8 years) with no experience in flexibility training. The cardiovascular variables were measured by photoplethysmography with continuous recording for 5 minutes at rest, during exercise and 10 minutes after stretching. A difference was observed in all variables ($p<0.05$) when resting and post-exercise values were compared to exercise values. There was only an increase in blood pressure values between sets. Systolic blood pressure was increased in the third set compared to the first [set 1 = 136 mmHg (±9.4); set 3 = 145 mmHg (±9.7)] and diastolic blood pressure was increased in the second set compared to the first [set 1 = 79 mmHg (±6.7); set 2 = 84 mmHg (±9.1)]. Hypotension was not observed post-exercise. It was concluded that the stretching sets have a cumulative effect on systolic and diastolic blood pressure responses, but not on heart rate. However, the stretching protocol produced no hypotensive effect after exercise.

Key words: Blood pressure; Muscle stretching exercise; Physical education and training.

Resumo – *Poucos estudos investigaram os efeitos da manipulação das variáveis de prescrição do exercício de alongamento nas respostas cardiovasculares agudas. O objetivo do estudo foi comparar as respostas agudas de frequência cardíaca, pressão arterial e duplo produto, antes, durante e após quatro séries de alongamento estático passivo no movimento de flexão unilateral do quadril. A amostra foi composta por 16 homens com idades entre 18 e 27 anos (22±2,8 anos), sem experiência no treinamento de flexibilidade. Mediu-se as variáveis estudadas por meio de fotopletismografia com registro contínuo cinco minutos em repouso, durante os exercícios e dez minutos após os alongamentos. Todas as variáveis investigadas diferenciaram-se (p<0,05) na situação de repouso e pós-esforço em comparação ao exercício. Somente houve aumento dos valores de pressão arterial entre as séries, sendo a sistólica aumentada da terceira em relação à primeira [série 1= 136 mmHg (±9,4); série 3= 145 mmHg (±9,7)] e a diastólica aumentada da segunda para a primeira [série 1= 79 mmHg (±6,7); série 2= 84 mmHg (±9,1)]. Na situação pós-esforço, não foi verificada hipotensão. Pode-se concluir que as séries de alongamento exibiram efeito cumulativo sobre as respostas de pressão sistólica e diastólica, mas não de frequência cardíaca. No entanto, o protocolo de alongamento não produziu efeito hipotensivo pós-exercício.*

Palavras-chave: *Educação física e treinamento; Exercícios de alongamento muscular; Pressão sanguínea.*

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INTRODUCTION

Flexibility is one of the components of health-related physical fitness[1,2]. The American College of Sports Medicine (ACSM)[1] recommends two or three weekly sessions of flexibility training which should consist of at least four sets involving the main muscle groups. Furthermore, it is recommended that stretching is performed to the point of discomfort in order to obtain gains in range of motion.

Although the variables of flexibility training prescription for healthy adults are well established, knowledge of the cardiovascular responses resulting from the manipulation of these variables is still insufficient. Within this context, heart rate (HR) and blood pressure (BP) can be used to control exercise-associated cardiovascular stress[3]. However, in contrast to strength[4-6], aerobic[7,8] or even concurrent exercise[9,10], few studies have investigated the cardiovascular responses associated with the manipulation of variables of flexibility training prescription[11-13].

Studies on the influence of methodological aspects of flexibility exercise prescription on cardiovascular responses are sparse. Many factors can affect acute cardiovascular responses to stretching exercise, including the number of sets, interval between stimuli or stimulus duration[11-14]. In this respect, some studies have investigated cardiovascular responses manipulating these variables[11-13], but important methodological limitations restrict the extrapolation of the results. Cornelius et al.[11], for example, did not report the degree of joint range of motion of the subjects. There was also no mentioning of aspects of breathing control during exercise. The sum of these factors may exert different effects on cardiovascular responses due to the different levels of exercise-related stress[14]. Holt et al.[13] used an oscillometric method and did not control the angle of movement during exercise, which may have caused a loss of tension during exercise, minimizing cardiovascular responses. The fact that the subjects performed and controlled their own stretching exercises may have affected the accuracy of the BP measurements since oscillometry is sensitive to movement and the arm should be held completely still during measurement[15].

More recently, Farinatti et al.[12] examined cardiovascular responses in a successive series of stretching exercise, controlling the level of flexibility and breathing pattern of the subjects. However, BP was measured manually, a fact that could reduce accuracy of the measurement due to possible artifacts caused by movement of the subject[16]. Therefore, even when the measurements were made by an experienced examiner, the BP values may have been underestimated when compared to more accurate noninvasive methods such as photoplethysmography[17].

In view of the small number of studies evaluating the effect of manipulating variables of flexibility exercise prescription on cardiovascular responses and of the limitations of the studies cited, further investigation on this topic is needed. Therefore, the objective of the present study was to compare the acute responses of systolic blood pressure (SBP), diastolic blood pressure (DBP), HR and double product (DP) before, during and after four sets of passive static stretching during unilateral hip flexion.

METHODOLOGICAL PROCEDURES

Sample

Post hoc statistical power analysis was performed with the GPower 3.1 software considering an alpha value of 0.05, a sample of 16 subjects and an effect size of 0.25. A β value of 0.8 was obtained for F-statistics. Therefore, 16 asymptomatic men without experience in flexibility training were studied. The following exclusion criteria were adopted: use of medications interfering with cardiovascular responses; osteomyoarticular problems limiting participation in the exercise sessions; consumption of substances that could alter cardiovascular responses on the day of data collection; a high flexibility level tested by unilateral flexion of the hip with the knee extended, considering a cut-off value higher than 90° for this movement[18]; a positive Physical Activity Readiness Questionnaire (PAR-Q). Prior to study entry, the volunteers signed the informed consent form and the study was approved by the institutional Ethics Committee.

Experimental procedures

Data were collected during two visits. In the first visit, the PAR-Q was applied, anthropometric measures were obtained, and flexibility was evaluated. The last assessment was necessary to verify homogeneity of the sample in terms of the range of motion observed because of the possible relationship between flexibility levels and HR and BP responses for the same joint range of motion[14]. The pre-test range of motion was measured with a Fleximeter® (Instituto Code de Pesquisa, Campinas, São Paulo, Brazil). In the second visit, HR, SBP and DBP were measured at rest and during and after exercise using the Finometer Pro® (Finapres Medical Systems, Amsterdam, The Netherlands).

Stretching protocol

The stretching protocol was applied in a single visit. The subjects were asked not to perform any physical activity during the 24 hours prior to evaluation. During the stretching exercises, the examiner manipulated the segment of the subject until the maximum range of motion, which is characterized by the point of mechanical restriction to movement or symptoms of pain reported by the subject. The subjects were asked to breathe continuously during the stretching exercise in order to avoid the Valsalva maneuver. The acute cardiovascular variables were measured continuously from passive static stretching of the hamstring muscles during unilateral hip flexion with the knee extended. Four sets of 30 seconds each were applied, with a 30-second interval between sets.

The stretching exercise was standardized as follows (Figure 1): position for rest and post-exercise measurements: the subject remained in the supine position lying on the mat (A); intermediate position: the subject performed mild unilateral hip flexion in order to reduce the time between the beginning of the movement and achievement of the final angle (B); position of maximum range: the movement was conducted with the knee extended until the occurrence of pain or mechanical restriction to movement (C). During the exercise, the ankle remained free to avoid the transmission of tension by the triceps surae.

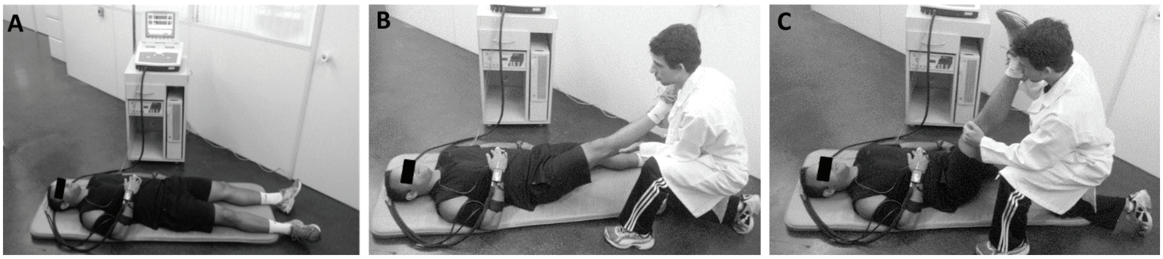

Figure 1. Position adopted for rest and post-exercise measurements (A), intermediate position (B), and final exercise position (C).

Although only one examiner manipulated the segment for application of the stretching protocol, three examiners were necessary. The first had the task to control the time during stretching and the respective intervals, passing this information to the second examiner who applied the protocol. Finally, the third examiner held the contralateral hip in order to stabilize the movement, preventing movements in this joint. These examiners are not shown in the figures in order to permit a better understanding of the movement phases.

Cardiovascular assessment

The cardiovascular variables were measured at three time points (rest, exercise and post-exercise). The subjects were placed in the supine position on a mat in a silent room with controlled temperature and humidity (23.5 ± 2.12 °C and 62.5 ± 10.6 g/m^3, respectively). The right arm was used for the measurements in all subjects. For this purpose, the Finometer sensor was placed on the middle phalanx of the right middle finger and the forearm was maintained flexed at 90° and supported on the trunk. Resting data were monitored over a period of 10 minutes. The first 5 minutes were used to calibrate the equipment, while the subsequent 5 minutes were used to calculate the mean of each cardiovascular variable. In the post-exercise situation, the mean value of each variable was calculated every 5 minutes, for a total of 10 minutes.

For the data obtained during the stretching sets, first, the mean value of each variable obtained at intervals of 5 seconds was calculated. Next, the highest value of the variables in each set was identified and this value was used to test differences in the responses obtained between sets. The first five seconds of measurement in each set were excluded to avoid possible overestimation of the cardiovascular variables due to increased muscle stiffness caused by the stretch reflex at the beginning of the stretching exercise[19].

Statistical analysis

Normality of the data was confirmed by the Kolmogorov-Smirnov test and the results are expressed as the mean ± standard deviation. One-way ANOVA for repeated measures followed by Fisher's post-hoc test was used to verify differences in the responses obtained between the different situations. A level of significance of $p \leq 0.05$ was adopted. The data were analyzed using the Statistica 6.0 software (Tulsa, USA) and the graphs were prepared using the GraphPad Prism 5 program (San Diego, USA).

RESULTS

The age, anthropometric characteristics, cardiovascular variables at rest and flexibility level of the sample are shown in Table 1.

Table 1. Age, anthropometric measures, cardiovascular variables at rest, and flexibility level of the volunteers.

Variable	Mean±standard deviation
Age (years)	22.0±2.8
Height (m)	1.75±0.10
Body weight (kg)	78.3±13.2
Body mass index (kg/m^2)	25.5±4.4
Heart rate (bpm)	66.0±10.0
Systolic blood pressure (mmHg)	124.0±9.0
Diastolic blood pressure (mmHg)	70.0±4.0
Flexibility (degrees)	84.9±10.4

Flexibility: unilateral hip flexion with the dominant limb.

Figure 2 and 3 illustrate the SBP, DBP, HR and DP responses at rest, during exercise and post-exercise. Differences were observed in all variables at the end of each set compared to resting and post-exercise values ($p<0.05$). With respect to SBP and DBP at the end of the sets, significant differences ($p<0.05$) were found from the first to the third and fourth sets. In contrast, no differences in HR or DP were observed between sets.

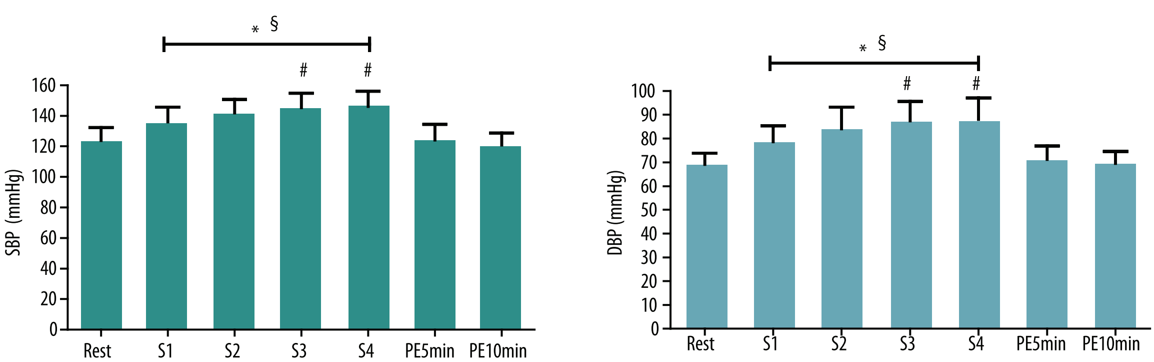

Figure 2. Responses of systolic blood pressure (SBP) (A) and diastolic blood pressure (DBP) (B) at rest, during exercise and post-exercise. S1 = first set; S2 = second set; S3 = third set; S4 = fourth set; PE5min = 5 minutes post-exercise; PE10min = 10 minutes post-exercise. * significant difference in values obtained at the end of all sets compared to resting values ($p<0.001$); # significant difference in SBP ($p=0.006$) and DBP ($p=0.03$) obtained in the respective sets compared to the first set; § significant difference in SBP ($p<0.001$) and DBP ($p=0.003$) obtained in the respective sets compared to those at 5 and 10 minutes of post-exercise recovery.

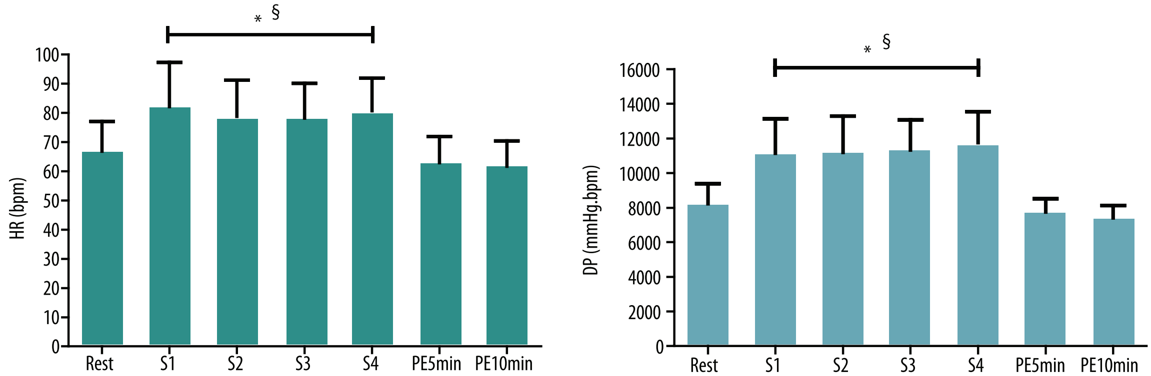

Figure 3. Responses of heart rate (HR) (A) and double product (DP) (B) at rest, during exercise and post-exercise. S1 = first set; S2 = second set; S3 = third set; S4 = fourth set; PE5min = 5 minutes post-exercise; PE10min = 10 minutes post-exercise. * significant difference in HR ($p=0.005$) and DP ($p<0.001$) obtained at the end of all sets compared to resting values; [§] significant difference in the values obtained in the respective sets compared to those at 5 and 10 minutes of post-exercise recovery ($p<0.001$).

DISCUSSION

The present study investigated the cardiovascular responses to multiple sets of stretching exercise involving a large muscle group. The first finding was that all cardiovascular variables studied were higher at the end of the sets when compared to resting and post-exercise values. SBP and DBP differed from the first to the third and fourth sets of stretching exercise. Furthermore, no hypotensive effect was detected after the stretching protocol.

Few studies have investigated methodological aspects of stretching exercise prescription and their repercussions on acute cardiovascular responses. Cornelius et al.[11] evaluated SBP and DBP responses to different proprioceptive neuromuscular facilitation (PNF) stretching techniques. Both SBP and DBP varied less than 15 mmHg compared to pre-exercise levels. This finding was probably due to the fact that the time of tension was less than 10 seconds during the isometric contraction phase of the protocol. In the present study, the application of passive static stretching resulted in a variation of 22 mmHg for SBP and of 19 mmHg for DBP compared to resting values. A possible explanation for this divergence is the difference in the duration of the stretch stimulus. Continuous stimuli lasting 30 seconds were applied in the present study, while in the study of Cornelius et al.[11] the three stimuli of each set of PNF exercise were shorter.

Also using PNF techniques, Gültekin et al.[20] investigated the effect of 10 sets of stretching of the upper limb in adult men. SBP, DBP, HR and DP were measured before, immediately after the stimulus, and at the first, third and fifth minute of recovery. The protocol affected all variables studied at the end of the sets. A reduction in SBP and DP was only observed at the fifth minute of recovery. It should be noted that the SBP and DBP values obtained in that study were lower than those observed here (125±10.8 versus 146±10.8 mmHg and 75±7.7 versus 88±8.3 mmHg, respectively). The same was not observed for HR and DP (108±15 versus 84±9.5 bpm and 13,500±238 versus 11,751±278 mmHg.bpm, respectively). Some factors may have influenced these differences. Although 10 sets were performed in the study of Gültekin et al.[20], the stretch stimuli were reduced and intermingled with periods of relaxation as recommended by the PNF method. Furthermore, different muscle groups were studied (hip in the present study and shoulder in the study of Gültekin et al.[20]).

Holt et al.[13], also using the PNF method, investigated SBP, DBP and HR responses of two muscle groups, erector spinae (trunk flexion performed in the sitting position) and hamstrings (unilateral hip flexion performed in the supine position). The subjects performed four sets per muscle, which was exercised at two intensities (100% and 50% of maximum voluntary isometric contraction). At the higher intensity, SBP values resulting from stretching of the erector spinae muscle differed from the second set onwards when compared to resting and post-exercise values, with a peak of 163±37.1 mmHg. However, for hamstring stretching performed at the same intensity, a significant difference was only observed between the last set and resting and post-exercise values, with a peak of 159±24 mmHg. Differences in SPB between sets were found until the fourth set. In the present study, stabilization of SBP was observed after the third set, showing similarity between experiments. With respect to DBP, Holt et al.[13] obtained similar values for the two muscle groups at the higher intensity (erector spinae: 91±25.8 mmHg; hamstrings: 88±22.4 mmHg). In the present experiment, a similar increase in DBP was observed for hamstring stretching (88±8.3 mmHg). Furthermore, the highest values were also found in the last sets, demonstrating a cumulative effect of the number of sets.

The size of the muscle group exercised, together with the characteristic of the movement, plays an important role when the effect of exercise on acute BP responses is analyzed. In this case, Holt et al.[13] showed higher BP values for trunk flexion compared to unilateral hip flexion. Furthermore, the erector spinae muscles, which are basically postural muscles, are very stiff[21], a fact that can reduce mobility of the segment. This additional stiffness may lead to different cardiovascular responses due to higher exercise-associated stress[14]. Moreover, abdominal compression resulting from trunk flexion can increase intra-abdominal pressure and consequently reduce venous return, decreasing filling of the cardiac chamber, with consequent loss of contractile efficiency of the myocardium (Frank-Starling Law). With the reduction in cardiac output, BP also decreases. To restore cardiac contraction strength, the organism makes use of systemic arteriolar vasoconstriction, increasing BP levels through the discharge of catecholamines[22].

Still comparing the data of Holt et al.[13] with the findings of the present study, HR values were lower for both types of exercise when performed at maximum range (101±33 bpm for erector spinae, 94±25 bpm for hamstrings versus 84±10 bpm in the present study). Furthermore, in the present study the highest value was observed in the second set, while in the study of Holt et al.[13] peak HR was found in the fourth set. These results suggest that HR may not be influenced by the sum of sets such as BP, but higher values are observed when stretching involves larger muscle groups[12,14].

Perhaps the study by Farinatti et al.[12] is the one methodologically closest to ours. SBP, HR and DP responses were investigated during four sets of passive static stretching (duration of 30 seconds and interval of 15 seconds) of the hamstring and gastrocnemius muscles performed in the presence and absence of the Valsalva maneuver. The highest SBP values were observed in the fourth set (about 160 mmHg) in the presence of the Valsalva maneuver. However, SBP values for the same muscle group also increased significantly in the absence of the Valsalva maneuver (about 150 mmHg). This was also observed in the last set. In contrast to the present study, the SBP values across sets were sufficient to trigger a significant increase in DP during unilateral hip flexion in the absence of the Valsalva maneuver[12]. These values were even higher (about 16,000 mmHg.bmp) when stretching was performed in the presence of the maneuver.

There are several explanations for these differences in the responses between experiments. One explanation is related to the different methods used for BP measurement. Farinatti et al.[12] performed manual BP measurements, while in the present study BP was measured by photoplethysmography. Moreover, the intervals between sets used here were twice as long as those adopted in the experiment of Farinatti et al.[12] (30 versus 15 seconds, respectively). Finally, although both studies used the same cut-off value for the definition of reduced flexibility, it is unknown to which extent the minimum values of the two groups were similar. In the case of less flexible subjects, a greater intensity needs to be imposed to overcome muscle stiffness in an attempt to maintain the maximum range of motion[14].

Although the volunteers were instructed to relax the quadriceps muscle during unilateral hip flexion, reflex static contraction of the antagonistic musculature cannot be ruled out. However, the examiner paid careful attention to the occurrence of any involuntary contraction of the quadriceps muscle. Furthermore, during execution of the movement, the examiner called the subject's attention regarding the importance of maintaining this musculature relaxed. It should be noted that there was no case of involuntary contraction perceived by the examiner or reported by the subject.

CONCLUSIONS

In the protocol of stretching exercise prescription studied, a difference was observed in all cardiovascular variables during exercise compared to resting and post-exercise values. However, only the SBP and DBP responses exhibited a cumulative effect related to the number of sets. Furthermore, the stretching protocol produced no hypotensive effect. Further studies are needed to better elucidate the cardiovascular responses to stretching exercise. Such studies should consider different respiratory maneuvers, as well as the effects of stretching sessions with higher training volumes (number of sets and stimulus duration).

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