Acute Effects of an Active Static Stretching Class on Arterial Stiffness and Blood Pressure in Young Men

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¹Laboratory of Physiology and Human Performance / Federal Rural University of Rio de Janeiro / Seropédica, RJ, Brazil; ²Department of Physiological Sciences / Federal Rural University of Rio de Janeiro / Seropédica, RJ, Brazil; ³Department of Physiology / Faculdade de Medicina do ABC, ABC Fundation, Santo André, SP, Brazil

ABSTRACT

Silveira ALB, Rocha AL, Costa CRM, Magalhães KS, Laureano-Melo R, de Paula WV, Ribeiro WMV, Costa e Silva G. Acute Effects of an Active Static Stretching Class on Arterial Stiffness and Blood Pressure in Young Men. JEPonline. 2016;19(4):1-11. The purpose of this study was to investigate the effects of a low intensity active static stretching class on blood pressure and arterial stiffness in young healthy men. Twenty-six young untrained men were randomly assigned to one of two groups: Control (CTRL) with no stretching; and active static stretching routine (STCH-CLASS) during which the subjects were submitted to 4 sets of an active static stretching routine. Brachial pulse pressure (BPP), systolic blood pressure (SBP), diastolic blood pressure (DBP), and mean arterial pressure (MAP) were assessed before and immediately after each condition in both groups. Prior to the treatment, there were no significant differences in blood pressure between the two groups (P>0.05). However, after the STCH-CLASS, BPP, SBP, and MAP increased in comparison to the CTRL (P<0.05). The active static stretching routine resulted in an increase in blood pressure and pulse pressure, which indirectly reflects an increase in arterial stiffness. These findings indicate that active static stretching should be conducted cautiously since an increase in pulse pressure is related to a greater risk of adverse cardiovascular events (even in young healthy adults).

Keywords: Vascular stiffness, Arterial pressure, Stretching exercises
INTRODUCTION

The cardiovascular system adapts to physical activity, and blood pressure (BP) is the main circulatory factor to evaluate this system during exercise (17). The precise measurement of this variable is essential for scientific studies (16,30). Nevertheless, despite BP values being reliable when obtained through direct (16,30) or automatic indirect methods (16), this reliability is questionable during exercise (2). The auscultatory technique, which is also an indirect method, shows high reliability at low intensity exercises (30), but only when BP measurement guidelines are applied (24).

Two components characterize BP: pulsatile and static. The former may be estimated by pulse pressure (PP), which represents blood pressure variation. The latter is assessed by mean arterial pressure (MAP) (27). Some authors (3,18) have demonstrated that the shifts in BP’s pulsatile component are associated with the stiffness of large arteries. This factor in turn reflects the total opposition of the large arteries to the pulsatile effects of ventricular ejection. Any elevation of arterial stiffness (AS) directly affects PP. As a result, the measurement of brachial pulse pressure (BPP) is used as an indicator of AS (3,18,27).

Stretching classes have been widely used as a comfortable, relaxing, and low-impact exercise that provides a better quality of life (1). However, the literature regarding the acute effects (23) and the long term (21,31) effects of active static stretching on AS and BP is scarce and mainly related to yoga practice.

Due to the lack of information about the effects of muscle stretching on the cardiovascular system, it is necessary to get a better understanding of the possible interference of stretching exercises on BP and peripheral artery elasticity. Since an acute increase of AS seems to be related to a decrease in coronary perfusion (22) and the risk of adverse cardiovascular events in young healthy adults (18,7,11,13), the purpose of this study was to investigate the acute effects of active static stretching (similar to those used in stretching classes at gyms) on BP and BPP in healthy young men.

MATERIAL AND METHODS

Subjects

Twenty-six normotensive (BP <140/90 mmHg at rest) young untrained men participated in this study (Table 1). All subjects were free from osteomyoarticular injury. The number of subjects participating in this study provided a high statistical power calculated by G*Power (10). The institutional research ethics committee approved this study. Each subject signed a Consent Form to participate. This study was designed in accordance with the Resolution 466/2012 of the National Health Council.

Procedure

The subjects visited the Laboratory of Exercise Physiology for two consecutive occasions. During the first visit, the subjects performed a familiarization session identical to the methodological procedures used in the experimental protocol in order to avoid learning influence on the results.

All subjects were instructed to refrain from strenuous physical activities, caffeine-based products, smoking, alcoholic beverages, or any substance that might interfere with the cardiovascular system for at least 48 hrs prior to experimental procedure.
Initially, the subjects were randomly assigned to one of two groups: the Control Group (CTRL, n=15) of which the subjects engaged in no exercises and the Active Static Stretching Group (STCH-CLASS Group, n=11). Four subjects in the CTRL failed to attend on the experimental day and were excluded from analysis. Both groups performed the tasks in a room with controlled temperature and humidity (22 to 24 °C and 65 to 75 %, respectively).

<table>
<thead>
<tr>
<th>Variables</th>
<th>CTRL (n = 11)</th>
<th>STCH-CLASS (n = 11)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yrs)</td>
<td>20.7 ± 2.16</td>
<td>19.0 ± 1.08</td>
<td>0.13</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>83.0 ± 12.83</td>
<td>71.7 ± 14.36</td>
<td>0.14</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>172.5 ± 4.62</td>
<td>177.2 ± 10.31</td>
<td>0.31</td>
</tr>
<tr>
<td>BF (%)</td>
<td>19.4 ± 11.69</td>
<td>11.2 ± 6.5</td>
<td>0.08</td>
</tr>
</tbody>
</table>

Abbreviations: CTRL = Control Group; STCH-Class = Active Static Stretching Group; BF = Body Fat; P = Significance after CTR Group and STCH Group comparison

### Stretching Routine

The subjects in the STCH-CLASS group performed 4 sets of an active static stretching routine. The stretching routine recruited the major muscle groups of the: (a) neck (trapezius, sternocleidomastoid, and scalene); (b) upper limbs and trunk (pectoralis major and minor, latissimus dorsi, biceps brachii, triceps brachii, deltoids, flexor carpi radialis, extensor carpi radialis, rectus abdominis, abdominal oblique, multifidus, and erector spinae); and (c) lower limbs (iliopsoas, gluteus maximus, quadriceps femoris, hamstring, lower limb adductors, tibialis anterior, gastrocnemius, and soleus). A licensed Physical Education teacher led the stretching classes.

The muscle stretching order that was followed in the STCH-CLASS group was the: (a) neck (Figure 1: A, B, C); (b) upper limbs and trunk (Figure 1: D, E, F, G, H, I, J, K); and (c) lower limbs (Figure 1: L, M, N, O, P, Q, R, S, T). The subjects held the stretched position for 20 sec at the point of maximal discomfort with no interval between sets. For unilateral movements both hemi-bodies were stretched identically. In addition, both the number of sets and the hold-time for each stretching movement were similar to those applied at gym active static stretching class to preserve internal validity and enhance external validity of the study. The total active static stretching class time was 45 min. The CTRL group rested in a seated position during the same period of time. The subjects in the CTRL group were instructed to maintain normal respiratory pattern during the stretching class to avoid the Valsava maneuver.
Blood Pressure and Pulse Pressure Assessment

The measurements of BP were taken in sitting position by the auscultatory technique using a conventional aneroid sphygmomanometer (Tycos, Skaneateles Falls, NY, USA) in order to determine systolic blood pressure (SBP) and diastolic blood pressure (DBP). An expert evaluator assessed BP three times consecutively, before and immediately after each protocol. The mean values of the three before measures and three immediately after measures were used for statistical analysis. All BP evaluation procedures followed the current guidelines (4). The following mean blood pressure (MAP) equation was used: $MAP = DBP + \frac{1}{3} (SBP - DBP)$ (20). Lastly, BPP was determined as the difference between SBP and DBP (8).

Statistical Analysis

The results are expressed as means ± standard deviation. Normality was assessed through the Shapiro–Wilk test. The SBP, DBP, MBP, and BPP variables were compared within and between groups using two-way ANOVA with repeated measures followed by the Bonferroni’s post hoc test, when F was significant. Graphpad Prism version 6.01 was the software used to perform all statistical analysis (GraphPad Software Inc., La Jolla, CA, USA). Complementarily to the P-value, Cohen’s (4)
A measure of effect size was used and the same cutoff values adopted to categorize the magnitude treatment effect, as follows: $0.41 \leq$ small; $0.41-0.70 =$ moderate; $0.70 \geq$ large.

**RESULTS**

Anthropometric variables did not differ significantly between groups ($P>0.05$). This finding demonstrated the homogeneity of the sample (Table I). SBP ($F(1,20) = 30.28; P=0.0001$), in basal conditions, was similar between groups ($\text{CTRL}_{\text{basal}} = 117.2 \pm 4.99$ vs. $\text{STCH-CLASS}_{\text{basal}} = 117.2 \pm 6.49 \text{ mmHg}; P>0.05$). However, SBP response was significantly higher in STCH-CLASS group after 45 min of static stretching compared to CTRL ($\text{CTRL}_{\text{post}} = 115.8 \pm 7.45$ vs. $\text{STCH-CLASS}_{\text{post}} = 135.8 \pm 10.15 \text{ mmHg}; P>0.0001$). Likewise, within the STCH-CLASS group, SBP was higher after 45 min of static stretching compared to the baseline conditions ($\text{STCH-CLASS}_{\text{basal}} = 117.2 \pm 6.49$ vs. $\text{STCH-CLASS}_{\text{post}} = 135.8 \pm 10.15 \text{ mmHg}; P>0.0001$) (Figure IIA). The CTRL group did not demonstrate differences between the two periods.

Analyzing DBP ($F(1,20) = 0.18; P = .68$), we found no differences within each group ($P>0.05$), and between groups for both basal ($P>0.05$) and after stretching class ($P>0.05$) conditions (Figure IIB). The MAP ($F(1,20) = 4.98; P=0.037$) was similar to SBP and DBP in basal level ($\text{CTRL}_{\text{basal}} = 84.2 \pm 6.49$ mmHg).
7.91 vs. STCH-CLASS\textsubscript{basal} = 88.1 ± 4.53 mmHg; P>0.05). However, after the stretching class, MAP for the STCH-CLASS increased significantly both between groups (CTRL\textsubscript{post} = 85.3 ± 4.92 vs. STCH-CLASS\textsubscript{post} = 99.9 ± 11.31 mmHg; P>0.0001) and intra-groups (STCH-CLASS\textsubscript{basal} = 88.1 ± 4.53 vs. STCH-CLASS\textsubscript{post} = 99.9 ± 11.31 mmHg; P<0.005). Possibly, this response is directly associated with the increase in arterial resistance, total peripheral vascular elasticity, and/or the reduction of local blood flow caused by stretching routine (Figure IIC).

Similar to the SBP and MAP variables, BPP showed a significant interaction (F (1,20) = 16.07; P = .0007). At basal level, there was no difference between groups (P>0.05). But, after the active static stretching class, BPP was significantly increased in comparison to the CTRL (CTRL\textsubscript{post} = 45.5 ± 8.06 vs. STCH-CLASS\textsubscript{post} = 57.6 ± 10.98 mmHg; P = .005). Likewise, in the STCH-CLASS group, the BPP was higher after 45 min of static stretching class than at rest (STCH-CLASS\textsubscript{basal} = 43.4 ± 6.86 vs. STCH-CLASS\textsubscript{post} = 57.6 ± 10.98 mmHg; P<0.0004) (Figure IID).

The effect size analysis between CTRL and STCH-CLASS showed a large magnitude treatment effect for SBP (1.13), MAP (1.02), PP (1.84), and small magnitude for DBP (0.39).

**DISCUSSION**

There are several stretching methods that are commonly used as part of sports and recreational activities. However, given the physiological responses during these methods, it is reasonable to conclude that these stretching methods require clarification and further elucidation (29). Hence, the purpose of this study was to assessed the subjects’ acute BP and AS responses after an active static stretching class. According to our data, which indicates that a low-intensity active static stretching class does in fact increase SBP when compared within or between groups.

A key point in explaining these results is that the arterial system progressively branches into smaller and smaller vessels, which influences the blood pressure due to its variation at different points of these vessels. Thus, a propagating wave into a branching and elastic system created after systolic contraction tends to have a reflection. In normal arteries, the reflection tends to arrive during diastole, which increases the diastolic pressure (32). Accordingly, we hypothesized that both the initial pulse wave and the reflected wave travel faster after our model of stretching class. As the velocity of the waves increase, an earlier return of the reflected pulse wave occurs during the systolic phase, which raises SBP and left ventricular afterload (18,19).

It is clear that some studies have attempted to understand the effects of muscle stretching on the cardiovascular system using an inappropriate methodological design, such as: (a) to base the muscle stretching on yoga classes (21,23); (b) to apply the stretching on isolated muscle groups (9); and to allow for unsupervised volume and intensity of the stretching exercises (5). To address these points, the present study used an active static stretching routine that was designed to match the features of those offered at the gym stretching classes. This consideration allows for a translational application of the data. Additionally, the present study used the auscultatory technique for both the BP and the BPP evaluation due to its high reliability at low intensity exercises (30) and its strong relationship to compliance and arterial elasticity (2,18). In this regard, the recommendations of the American Heart Association Council (24) pertaining to the BP assessment were followed very carefully to improve the reliability of both measures and results.

Previous studies (15,20) have indicated that changes in the subject’s breathing pattern are able to promote synergic and contraction-independent interferences in the BP response during exercise. While exercising during moments of greater mechanical effort, people usually contract abdominal
muscles and close their glottis, which is known as the Valsalva maneuver (20). Both responses result in an increase in oxygen consumption and breath-holding during muscle stretching, which may increase BP (9,15). But, since the evaluators carefully controlled this variable by continuously instructing the subjects to maintain the same breathing pattern during the entire stretching class, the subjects’ BP responses were not affected by the respiratory pattern. In fact, the BP changes shown in the current study were similar to those found in Farinatti’s (9) in which the valsalva maneuver during stretching exercise was also controlled.

Pulse pressure is widely used as an indirect measure of arterial stiffness and, consequently, an important prognostic marker for coronary artery disease (18,19,27) and perfusion (22), and the risk of adverse cardiovascular events (7,11,13,18). In this context, recent research (26) showed that dynamic exercises chronically promote decreases of AS and PP in young men. On the other hand, acute (23) or chronic (21) static stretching seems to promote opposite responses on vascular stiffness and arterial pressure. Additionally, during muscle stretching (14) or dynamic exercises (18), peripheral vascular resistance increases due to compressive muscle-generated external forces, which could also induce an increase in PP. Surprisingly, only in dynamic exercises is it evident that an acute BPP rise does not occur (19,28). These findings reinforce the hypothesis that stretching-induced BPP rise is not related to mechanical compression of the vasculature but rather to an increase in AS, which means a decrease in peripheral artery compliance.

In this context, Miles et al. (23) showed the acute effects of a Yoga stretching routine on cardiovascular system in which SBP and MAP were significantly higher than basal conditions, possibly indicating an increased BPP. Madanmohan and colleagues (21) observed similar results in young healthy men who were submitted to a chronic Yoga-based stretching program. Likewise, the current study found similar results to both the acute (23) and chronic (21) studies on BP, BPP, and indirectly to AS after a non-yoga based active static-stretching class in healthy young men.

It is likely that the active static stretching class increased the subjects’ initial pulse wave and the reflected wave velocity, which occurs earlier during systole and impacts both waves causing a higher BPP (3). Other researches have shown conflicting results, possibly due to some methodological problems (perhaps, due to both gender in the same experimental group of subjects) (5) or specific to post-menopausal women subjects (31). Likely, these sample features may have caused those differences between results, especially because PP is significantly different between healthy men and women (2,8). Thus, it would be reasonable to avoid comparisons of these studies (5,31) with ours or others previously described (21,23).

In addition to the arterial pulse wave responses, changes in muscle length may increase type III afferent fibers (mechanoreceptors) responsivity on the nucleus lraclus solilarii (NTS). Thus, inhibiting the cardiac vagal tone and activating the sympathetic tone, which results in tachycardia and increases in BP (9,12,20,24). However, a recent study from our group showed that low intensity static stretching session, even promoting muscle length changes, did not produce direct interference on autonomic modulation in young healthy men (6). The current study also used a low intensity active static stretching protocol and likewise autonomic modulation did not influence the BP results. Bearing in mind that any extrapolation between the protocol of Costa e Silva (6) and ours should be made with caution due to our use of high volume stretching exercise. More research is needed to assess autonomic modulation responses after low-intensity and high volume muscle stretching, such as was used in the present investigation.

Other results also showed that after the active static stretching class, there were no significant differences in DBP within or between groups. This finding seems to support the notion that stretching
acutely increases PP due to higher AS. Also, given that the reflected pulse wave of less compliant vessels is faster than normal and tends to arrive early and during systole, there is only an increase in SBP with no change in DBP (27). Lydakis and colleagues (19) found the same result in DBP using an acute static and isometric exercise, which has analogous features with our exercise model. On the other hand, Miles et al. (23) observed an acute increase on DBP immediately after each of the hatha-yoga postures that consist of systemic isometric contractions and stretching of the skeletal muscles. However, Miles et al. (23) did not evaluate DBP immediately after completing the yoga routine. This makes it hard to compare to our result.

Also, the present study found that the low-intensity active static stretching class increased MAP. Presumably, the increase in MAP is a function of the active static stretching and its role in increasing cardiac output and peripheral vascular resistance (23). However, the changes in MAP were not likely due to an increase in muscle blood flow since the stretched muscles often change the tortuosity of the capillary network with resultant increase in compression and narrowing of the vessels that ultimately alters vascular resistance and reduces local blood flow (14,18,25).

The magnitude of the results was also evaluated in the present study. For example, according to Cohen (4) the lack of a statistically significant P-value between different research variables does not predict the magnitude of physiological effects. Statistical significance per se only assesses the study’s reproducibility. Therefore, the physiological relevance of the treatment cannot be ruled out by its mathematical greatness. The present study used the effect size to understand the acute physiological effects of the active static stretching class on the subjects’ arterial pressure and stiffness. The effect size-based results showed that active static stretching class caused a high magnitude effect for SBP, MAP, and PP, but only a small effect size for DBP.

The results of the present study collectively describe that a low-intensity active static stretching class resulted in an acute increase in BP and AS. Based on recent findings, these data deserve further attention since the acute increase in AS may decrease coronary perfusion (22) and a greater risk of adverse cardiovascular events during physiological stress (even in young healthy adults) (7,11,13,18).

**CONCLUSIONS**

Our major finding was that a low-intensity active static stretching routine similar to what is commonly used in gym stretching classes, resulted in an increase in blood pressure and pulse pressure, which indirectly reflects an increase in arterial stiffness in young healthy men. Thus, despite being classified as relaxing, low impact, and low-intensity exercise, gym-stretching classes should be conducted cautiously, especially for people with previous cardiovascular disease or cardiovascular risk factors.

**ACKNOWLEDGMENTS**

We would like to thank Yan Vilela for the drawings in Figure 1.

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REFERENCES


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