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Original Article

Effects of flexibility training with different volumes and intensities on the vertical jump performance of adult women

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Abstract
The prescription of stretching exercises prior to physical and sports activities should consider control of training volumes and intensities. Thus, the purpose of this study was to compare the acute effects of different volumes and intensities of flexibility training on the vertical jump performance of adult women. The vertical jump of twenty-five women (28.24 ± 3.54 years) was assessed using the countermovement jump (CMJ) test on a contact platform (Jump Test Pro, Ergojump - BRASIL). The flexibility training was randomly performed in four conditions, on four consecutive days: a) control (C), no flexibility training; b) submaximal stretching (A3), with 03 sets of 10 seconds; c) maximum stretching (F1), with 01 series of 10 seconds; and d) maximum stretching (F3), with 03 series of 10 seconds. ANOVA for repeated measures ($p = 0.05$) showed a significant difference between the jumps. Loss of ($\Delta\% = 2.7\%$, $p = 0.014$) occurred in the (F1) condition; ($\Delta\% = -3.6\%$, $p = 0.001$) in (A3) and ($\Delta\% = -6.5\%$, $p = 0.001$) in (F3). The reduction caused by (F1) was significantly lower ($p = 0.016$) than that caused by (F3) while (A3) showed a smaller reduction in jump capacity (-0.87cm) than (F3) (-1,66cm). These results suggest that the stretching at maximum intensities (one and three series) and submaximal (three series) reduced the performance of vertical jump, showing that the greater the volume of stretching exercises, the greater the deleterious effects on jump performance.
Keywords: **joint range of motion (ROM); muscle stretching exercises; physical education and training; muscle strength.**

Introduction

Flexibility training should integrate all physical fitness programs aiming to maintain and improve range of motion, using static or dynamic techniques and focusing on the larger muscle groups, with a minimum frequency of two to three days a week (American College of Sports Medicine, 2011; Dantas et al., 2011). According to Dantas and Conceição (2017), control of flexibility training intensities allows the differentiation between submaximal stretching and maximum stretching exercises, which is essential for good planning and physical preparation. These techniques can be performed with submaximal intensity within the normal motion range and forcing lightly for 4 to 6 seconds, or at maximum intensity with discomfort at the pain threshold for, at least 10 a 15 seconds (Galdino et al., 2010).

Kawamori and Haff (2004) emphasized that the ability of the neuromuscular system to produce high muscular power is one of the most important components of physical fitness in sports, thus, any negative effect is not favorable, especially on performance. Paulo et al. (2001) discussed that in the prescription of physical-sports training is normal to use training sessions that combine strength and flexibility exercises. Therefore, understanding the influence of a motor capacity on another is important for planning the training and prescribing exercises in order to avoid possible deleterious effects that may influence the performance of the subsequent

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activity. Neto and Manffra (2009) concluded that the maximum capacity of the hamstring muscles to generate power depends on the stretching volume, and undergoes reduction at peak torque and maximum work. Galdino et al. (2010) reported changes in the performance of the explosive force in non-athletes when performing different intensities of maximum and submaximal stretching exercises. Currently, studies have pointed out that the inclusion of stretching prior to strength and power activities has no negative effects on performance (Ferreira et al., 2015; Nodari Júnior et al., 2012; Nogueira et al., 2010; Oliveira Júnior et al., 2018; Silveira et al., 2011 & Souza et al., 2017). However, other studies reported an acute decrease in strength due to several factors (Paulo et al., 2012; Cramer et al., 2004; Ribeiro et al., 2016). These results have led a number of researchers to question the inclusion of stretching exercises, especially a warm-up, before muscle-strengthening and power activities (Kirmizigil et al., 2014; Ribeiro et al., 2016).

Therefore, the present study will approach the need to understand the acute effects of flexibility training when applied prior to strength training at different volumes and intensities. This information is fundamental to assist health professionals to plan strategies for prescription of exercises and training correctly.

We hypothesize that vertical jump performance should be reduced after flexibility training in high intensity and large volume. Thus, the objective of this study was to compare the acute effects of two flexibility training intensities (submaximal and maximum stretching) and two exercise volumes (one and three series) on vertical jump performance of adult women.

Material and Methods

Participants

This is a non-randomized cross-sectional study with 25 adult women (mean and standard deviation of age: 28.24 ± 3.54 years; weight: 56.88 ± 1.88 kg; and height: 162.24 ± 1.41 m) from a Vidativa Fitness Center, of Santos Dumont, Minas Gerais - Brazil, who registered as volunteers for the research.

The study included physically active participants (regular physical exercise for at least six months), without a recent history of musculoskeletal or ligament injury in the lower limbs and able to perform vertical jumps and flexibility exercises. All participants were instructed to avoid intense physical activity for 48 hours prior to the training sessions. The volunteers have signed a Free Informed Consent Form for participation in the study.

The present study followed the recommendations of Resolution 466/12, II.4, of the National Health Council (CNS), and of the Helsinki Convention (2013) and was approved with protocol no. 0004/2008 by the Research Ethics Committee of the Castelo Branco University.

Procedure

After negatively responding to the physical activity readiness questionnaire (PAR-Q), the participants performed three vertical jumps to familiarize themselves with the test, practising the technique used in the experiment. The anthropometric measures body mass and height were obtained using a digital scale with a stadiometer (Filizola Digital Scale, São Paulo, Brazil, 2002). The degree of flexibility of the volunteers was assessed by the LABIFIE protocol of goniometry (Dantas et al., 1997) using a 360° steel goniometer (Cardiomed - Brazil) to verify if all fit the healthy patterns of range of motion in the hip joint extension (EQ) and hip flexion (CF) movements as presented in Table 1.

The participants performed, prior to the test routine, a 10-min systemic warm-up in a stationary cycle ergometer (Movement Summer G2 - Brazil) with submaximal intensity, i.e., 60 to 70% of a person's maximum age-related heart rate (Nogueira et al., 2010). The visits occurred between 7:00 and 10:00 am in order to avoid to the maximum the cumulative effects of the day on the participants' circadian cycle.

Countermovement Vertical Jump

The Vertical jump was assessed by the Countermovement Jump (CMJ) test on a contact platform (Jump Test Pro, Ergojump - BRASIL). This technique is described as a vertical jump with a preparation movement (counter-movement) in which the performer is allowed to perform the eccentric phase to then perform the concentric phase. The subject begins in an upright standing position and, with hands placed on the hips, feet parallel and approximately shoulder-width apart, squats down, bending the hip, knees, and ankles. The transition from the descending to the ascending phase takes place in a continuous movement in which the joints are extended and is made as fast as possible (Galdino et al., 2005; Nodari Júnior et al., 2012).

Stretching Protocols

The experiment consisted of four treatments, on four consecutive days, in a randomized design, as shown in Figure 1.

- Condition without flexibility training (C): participants performed the initial vertical jump and repeated the jump after 10 minutes, which was the approximate duration time of the subsequent stretching routines, without flexibility training.

- Condition of submaximal stretching with three series (A3): after the initial vertical jump, a static stretching session was performed involving three series of 10 seconds of submaximal insistence with a 10-second interval between series. After stretching, the vertical jump was performed to assess the influence on the explosive force.
- Condition of maximum stretching with one series (F1): participants performed the same methodological sequence as in A3, but subjected to a series of 10 seconds of maximum static insistence (greater intensity than A3).
- Condition of maximum stretching with three series (F3): same procedure as F1, but two more series of 10 seconds of maximum stretching were added with an interval of 10 seconds between them.

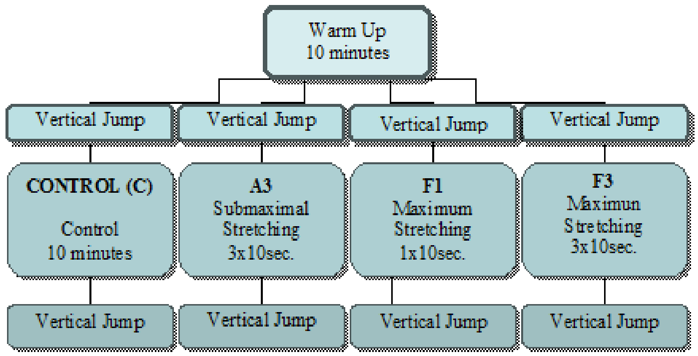

Figure. 1. Study Design.

The movements performed were: flexion of the hip joint with the knee extended in dorsal decubitus; dorsal flexion of the ankle joint with the individual in dorsal decubitus; and flexion of the knee joint with the individual in the ventral decubitus position. During the flexibility routines, the muscle groups were stimulated to reach the controlled limit of the articular arch. The difference in intensity applied (submaximal or maximum) was measured with a handheld dynamometer (Muscle Test System - Model 01163, Lafayette, USA, 2006), which was used to quantify the force applied on the flexed body segment. The device was held on the distal end of the limb tested and the reading was performed on the 10^{th} second of posture holding (Galdino et al., 2010).

Statistical analysis

The statistical analysis was carried out with the program SPSS 20.0 for Windows. Descriptive statistics were used and homogeneity was tested by the Shapiro-Wilk test. The Student's t-test ($p < 0.05$) was used to analyze the percentage difference of the force intensity applied in the flexibility exercise routines. Analysis of variance (ANOVA) for repeated measures ($p = 0.05$) was applied to verify the differences between jumps.

Results

Table 1 shows the anthropometric measurements and range of motion measurements using a goniometer.

Table 1: Characteristics of the sample and range of motion by goniometry.

Variable	Mean	SD
Age (years)	28.24	3.54
Mass (kg)	56.88	1.13
Height (cm)	162.24	1.41
Hip Flexion (º)	102.52	38.89
Hip Extension (º)	44.52	9.90

Values expressed as mean and standard deviation (SD)

Table 2 shows the force values recorded during the two flexibility routines.

Table 2: Strength applied to flexibility exercise routines

Movement	Submaximal stretching **(Kgf)**		Maximum stretching **(Kgf)**		**Δ%**
	Mean	**SD**	**Mean**	**SD**	
Hip flexion	4.28	1.33	7.25	1.24	69*
Dorsal flexion of ankle	7.01	3.17	14.77	4.56	110*
Knee flexion	9.56	3.94	15.19	4.34	59*

Values expressed as mean and standard deviation (SD), Δ%: Percentage difference between submaximal and maximum stretching groups (flexibility), * p <0.05 - t-student test

The ANOVA (p = 0.00002) showed a significant difference between the jumps and between the pre-test and the test when any flexibility work was applied (Figure 2).

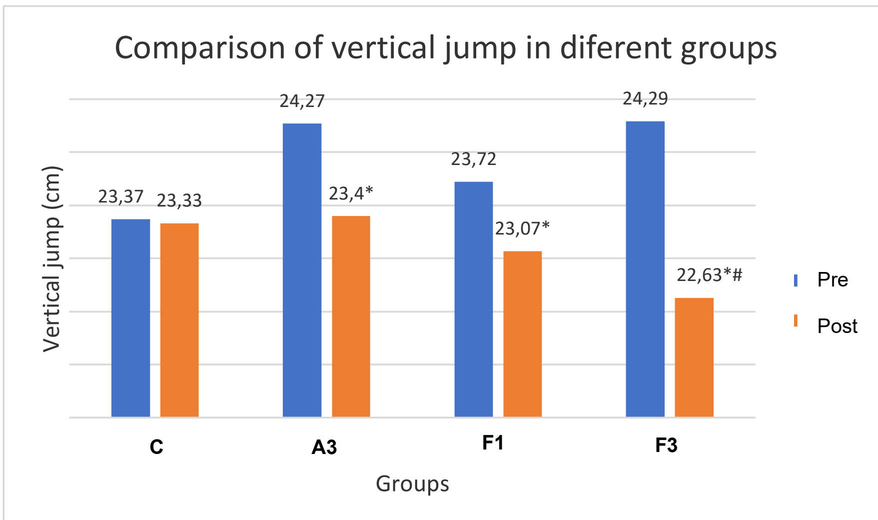

Figure 2: Comparison of vertical jump in different groups.
* p <0.05 for intragroup comparison; #p <0.05 for intergroup comparison F1 and F3.C = control group; A3 = submaximal stretching 3 series group; F1 = maximum stretching 1 series group; F3 = maximum stretching 3 series group.

The jump capacity had a significant reduction (Δ%= - 3,6%, p = 0.001) in the three series of submaximal stretching. The same occurred in one and three series of maximum stretching (Δ%= - 2,7%, p = 0.014) and (Δ%= - 6,5%, p = 0.001), respectively. No significant difference was found between the pre-test and the test on the day of the control evaluation. The ANOVA showed that the flexibility exercise routines were significantly different (p = 0.004).

Discussion

The present study aimed to investigate the acute effects of flexibility on jump capacity of adult women with different volumes and intensities of training. There was a significant decrease in the vertical jump performance, with reduction in the height achieved by the participants in the countermovement jump after the stretching routines (submaximal and maximal).

Cornwell et al. (2002) found a significant reduction in the countermovement jump, after applying maximum stretching, with 3 sets of 30 seconds of insistence to the point of discomfort, but no pain. The present study corroborates these authors' results and reaffirm the assumption of reduction in the explosive force after applying a greater volume of maximum stretching, as well as the questioning about the inclusion of stretching prior to strength and power activities, even in smaller volumes of application (insistence time) (Kirmizigil et al., 2014; Ribeiro et al., 2016). Similarly, Marek et al. (2005) reported a deficit of 3.2% in lower limb power when they applied 4 series of 30 seconds of static stretching with maximum intensity and proprioceptive neuromuscular facilitation (PNF). In another study, Bradley and Colleagues (2007) found a decrease of 4.0% in vertical jump performance after 04 series of 30 seconds of maximum static stretching. It is noteworthy that in the case of a higher volume (04 series of 30 seconds) and maximum intensity, the results of both studies were very close to ours. However, Endlich et al. (2009) reported reduction of 4.8% and 14.3% in the dynamic force with submaximal stretching with different times (8 minutes with 03 series of 30 seconds and 16 minutes with 04 series of 30 seconds), respectively, to the performance of the lower limbs in young males compared with the treatment without stretching (control). On the other hand, César et al. (2013) found no reduction in height of vertical jumps of physically active individuals after the application of 02 series of 30 seconds of submaximal static stretching, same as Nogueira et al. (2010) who applied 03 series of 06 seconds of sustained submaximal static before the vertical jump in military participants and found no damage to the performance of the vertical jump. It is noted that despite the submaximal stretching intensity, the reduction in performance after the vertical jump seems to be related to the volume of the stretching routines, in which prolonged stretching times acutely affect strength performance, even at submaximal intensity. However, the present study did not use the Scale of Perceived Effort in the Flexibility – PERFLEX (Dantas et al., 2008), which characterizes a pedagogical limitation of the experiment.

Ferreira et al. (2013) reported that 01 series of 10 seconds of static stretching, with submaximal intensity, was not enough to produce mechanical or neural alterations capable of compromising vertical impulsion in professional male soccer players. In this way, we believe that, unlike the maximum stretching, the smaller the volume of static stretching applied, as submaximal, the smaller the interference in the vertical jump performance. The findings of the present study show that the variation in the volume of application of flexibility affected differently the reduction in jump capacity, demonstrating that the decrease caused by 01 series of maximum stretching was significantly lower than that caused by 03 series. Winchester et al. (2009) observed that 01 series of maximum static stretching was sufficient to promote a reduction in maximal limb strength performance in 18 students after applying 01, 02, 03, 04, 05, and 06 series of 30 seconds of maximum static stretching. These results showed a decrease of 5.4% in the performance of force with a single 01 series, up to a reduction of 12.4% with the application of 06 series of 30 seconds of maximum stretching, corroborating with the findings of the present study and from which we can infer that the greater the volume of stretching, the greater the decrease in performance of force.

Segundo Carvalho et al. (2012), the submaximal static stretching caused muscle power losses in young tennis players, even though no significant difference was found in relation to the control group (without stretching) in the performance of the vertical countermovement jump. The authors pointed out that, although the flexibility routine with 01 series was more intense and showed lower value, it cannot be stated statistically that it caused greater decreases in jump capacity than submaximal static stretching, since PERFLEX (Dantas et al., 2008) was not used. On the other hand, Behm and Kibele (2007) observed that the performance in the execution of the jumps decreased significantly after applying flexibility in 03 different intensities (50%, 75%, and 100% of the point of muscle discomfort), that is, submaximal and maximum, prior to different vertical jumps, and the main reason can be attributed to changes in muscle compliance. The results of the present study showed that the performance of 01 and 03 maximum stretching series caused a decrease of -2.7% and 6.5%, respectively, while three stretching series caused a decrease of - 3.6%. However, it cannot be said that the reduction caused by submaximal stretching differs significantly from the decrease caused by 01 series of maximal intensity ($p = 0.550$), nor by 03 series of maximal stretching ($p = 0.157$). However, as already mentioned, there is a significant difference between the losses caused by 01 and by 03 maximum stretching series ($p = 0.016$). This finding suggests that the loss caused by 03 series of submaximal intensity stretching is in an intermediate position between the other two routines of maximum flexibility, where both the intensity and the volume seem to cause variations.

Conclusion

This study has shown that both the maximal and submaximal stretching negatively changed the vertical jump performance of the women evaluated. It is also concluded that the greater the volume of flexibility exercises, the greater the deleterious effects on the jumping capacity, suggesting that the application of flexibility training, even at submaximal intensity, for prolonged periods, acutely affects the explosive strength and power.

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