Acute Effects of a Warm-Up Including Active, Passive, and Dynamic Stretching on Vertical Jump Performance

Felipe L.P. Carvalho,[1] Mauro C.G.A. Carvalho,[1] Roberto Simão,[3] Thiago M. Gomes,[3] Pablo B. Costa,[4] Ludgero B. Neto,[5] Rodrigo L.P. Carvalho,[6] and Estélio H.M. Dantas[1,2]

[1]*Laboratory of Human Motricity Biosciences (LABIMH), Federal University of State of Rio de Janeiro, Rio de Janeiro, Brazil;* [2]*Doctorate in Nursing and Bioscience (PPgEnfBio), Federal University of State of Rio de Janeiro, Rio de Janeiro, Brazil;* [3]*Federal University of Rio de Janeiro, Physical Education Post-Graduation Program, Rio de Janeiro, Brazil;* [4]*Department of Kinesiology, California State University - San Bernardino, San Bernardino, California;* [5]*University of São Paulo, São Paulo, Brazil; and* [6]*Department of Physical Therapy, Speech, and Occupational Therapy, School of Medicine, University of São Paulo, São Paulo, Brazil*

Abstract

Carvalho, FLP, Carvalho, MCGA, Simão, R, Gomes, TM, Costa, PB, Neto, LB, Carvalho, RLP, and Dantas, EHM. Acute effects of a warm-up including active, passive, and dynamic stretching on vertical jump performance. *J Strength Cond Res* 26(9): 2447–2452, 2012—The purpose of this study was to examine the acute effects of 3 different stretching methods combined with a warm-up protocol on vertical jump performance. Sixteen young tennis players (14.5 ± 2.8 years; 175 ± 5.6 cm; 64.0 ± 11.1 kg) were randomly assigned to 4 different experimental conditions on 4 successive days. Each session consisted of a general and specific warm-up, with 5 minutes of running followed by 10 jumps, accompanied by one of the subsequent conditions: (a) Control Condition (CC)—5 minutes of passive rest; (b) Passive Stretching Condition (PSC)—5 minutes of passive static stretching; (c) Active Stretching Condition (ASC)—5 minutes of active static stretching; and (d) Dynamic Stretching Condition (DC)—5 minutes of dynamic stretching. After each intervention, the subjects performed 3 squat jumps (SJs) and 3 countermovement jumps (CMJs), which were measured electronically. For the SJ, 1-way repeated measures analysis of variance (CC × PSC × ASC × DC) revealed significant decreases for ASC (28.7 ± 4.7 cm; $p = 0.01$) and PSC (28.7 ± 4.3 cm; $p = 0.02$) conditions when compared with CC (29.9 ± 5.0 cm). For CMJs, there were no significant decreases ($p > 0.05$) when all stretching conditions were compared with the CC. Significant increases in SJ performance were observed when comparing the DC (29.6 ± 4.9 cm; $p = 0.02$) with PSC (28.7 ± 4.3 cm). Significant increases in CMJ performance were observed when comparing the conditions ASC (34.0 ± 6.0 cm; $p = 0.04$) and DC (33.7 ± 5.5 cm; $p = 0.03$) with PSC (32.6 ± 5.5 cm). A dynamic stretching intervention appears to be more suitable for use as part of a warm-up in young athletes.

Key Words flexibility, power, strength, athlete

Introduction

Power is an essential determinant of many types of athletic performance, and its optimization during training and competition can be enhanced with an appropriate active warm-up (12,23). It is believed that the use of stretching exercises as part of a warm-up routine may enhance performance (28) and reduce the risk of injuries and delayed onset muscle soreness (27,20). However, recent studies have found decreases in different strength and power output tests when they are preceded by stretching exercises (4,11,15,22,24,25,35,39). Thus, some authors have recommended not using stretching exercises before activities that depend of high levels of strength and power (4,15).

In an extensive review, Behm and Chaouachi (6) reported that dynamic stretching routines are more helpful than static stretching to improve explosive performance. Performance reductions after static stretching have been explained by a combination of mechanical and neural factors. Mechanically, static stretching results in a longer and more compliant musculotendinous unit, resulting in reduced peak torque and a slower rate of force development (13). Neurologically, static stretching may cause a decrease in motor unit activation (1,5,15). Dynamic stretching has been reported to either facilitate power (36) and jump performance (17) or have no adverse effects (9,10). Thus, the use of dynamic stretching rather than static stretching for the warm-up would tend to be a more judicious choice (6). The improvement in neuromuscular performance after dynamic stretching warm-up has been associated with

Address correspondence to Felipe L.P. Carvalho, flpcarvalho@gmail.com.

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enhanced motor unit excitability (16), increased motor unit recruitment and synchronization, decreased presynaptic inhibition, or greater central activation of the motor neuron (1).

Studies that analyzed vertical jump (VJ) performance after stretching exercises have shown conflicting results. Christensen et al. (8), Church et al. (9), Dalrymple et al. (10), and Unick et al. (31) reported no significant decreases ($p > 0.05$) in VJ performance after static and ballistic stretching. In contrast Bradley et al. (7) reported a significant decrease in VJ height after static and PNF stretching (4.0 and 5.1%, respectively) and a smaller decrease after ballistic stretching (2.7%). However, jumping performance had fully recovered 15 minutes after all stretching conditions. Wallman et al. (32) and Young and Elliot (38) also found significant ($p < 0.05$) decreases in VJ performance after static stretching exercises. Conversely, Holt and Lambourne (17) reported significant increases in VJ performance when using ballistic and dynamic stretching combined with a warm-up.

In summary, the acute effects of stretching exercises on VJ performance show conflicting results in the literature. It appears that an important gap is yet to be filled by sport scientists: determine the response of VJ performance after different stretching methods. Thus, the purpose of this study was to examine the acute effects of warm-up including active, passive, and dynamic stretching methods on VJ performance. Based on previous studies suggesting a decrease in VJ height after static stretching (7,32,38), it is hypothesized that there will be an acute decrease in VJ after passive static stretching, whereas performing dynamic stretching will increase the VJ performance.

Methods

Experimental Approach to the Problem

The purpose of this study was to examine the acute effects of active, passive, and dynamic stretching used in a warm-up routine setting. Several studies have shown static stretching to be detrimental for strength and power. However, most of these studies have used stretching in isolation, which does not occur in real-world sports settings. Common warm-up settings use stretching along with a dynamic activity.

To compare the acute effects of 3 different stretching methods on the VJ performance, the participants' performance in the SJ and CMJ was measured electronically after each 1 of 4 experimental conditions. This study was performed during 5 visits on consecutive days, always at 3 PM, 2 hours after the subjects had lunch. The same time was used to start their training session during the entire study. On the first day, the subjects read and signed an informed consent form, underwent anthropometric measurements, and all the explanations about the experimental procedure were provided. From the second to the fifth days, the subjects were randomly ordered to the following experimental conditions (Figure 1): (a) Control Condition (CC)–VJ without stretching exercises; (b) Passive Stretching Condition (PSC)–VJ preceded by passive static stretching; (c) Active Stretching Condition (ASC)–VJ preceded by active static stretching; and (d) Dynamic Stretching Condition (DC)–VJ preceded by dynamic stretching.

The same warm-up protocol was used during all the visits and consisted of 5 minutes of running around a tennis court with the heart rate standardized at approximately 140 $b \cdot min^{-1}$ and 10 jumps performed after the running. The jumps consisted of 5 squat jumps (SJs) and 5 countermovement

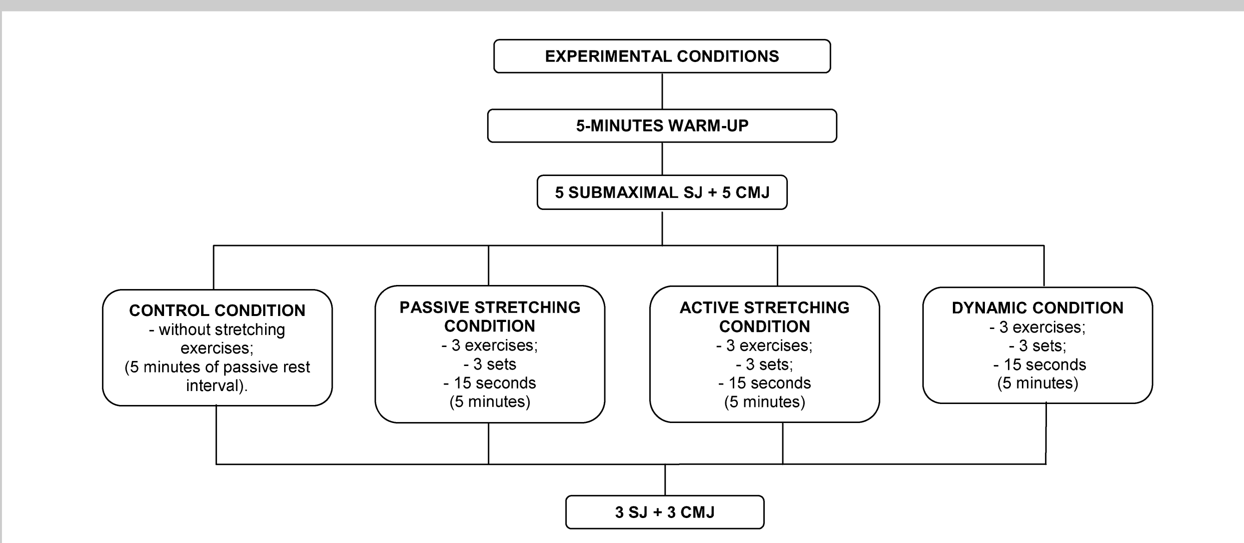

Figure 1. Experimental design.

jumps (CMJs) that aimed to reproduce the test but with a lower intensity. For the CC, after the warm-up, the subjects remained seated for 5 minutes before the VJ tests, which was the approximate time used in the procedures with stretching exercises. Both SJs and CMJs were performed on the same day.

Subjects

Sixteen physically active young men, who were tennis athletes, volunteered to participate in the study (14.5 ± 2.8 years; 175 ± 5.6 cm; 64.0 ± 11.1 kg). All the athletes had >2 years of experience in training and competition and practiced the specific sport at least 8 $h \cdot wk^{-1}$. To be included in the study, the participants should have had the following characteristics: (a) been physically active and had at least 2 years of experience in the sport; (b) not have any functional limitation that could interfere in the tests performance; (c) not presented any medical condition that could influence the tests; (d) maintained their regular physical activity during the course of the study. All the participants signed and read an assent form. Informed consent was granted by the parents or legal guardians after they were thoroughly explained the testing procedures that would be performed during the study. The study was approved by the Research Ethics Committee of the institution.

Vertical Jump Test

To test the jump height, 2 different types of VJs were performed: the SJ and the CMJ. Given below is a detailed description of the movement of each type of jump:

The SJ–only the concentric phase of the movement was used. The jump was started from a static position at 90° of knee flexion. The subjects were instructed to keep their hands on their hips and were encouraged to jump as high as possible.

The CMJ–uses the eccentric phase of movement to achieve the jump. The jump was initiated from an eccentric action of the knee and hip extensors. The subject was instructed to keep their hands on the waist and jump as high as possible.

To measure the height of the jumps, the jump mat Axon Jump (Axon Bioengenaria Desportiva, Buenos Aires, Argentina) and the software Axon Jump 4.0 were used (18). To achieve the SJ and CMJ, the subjects stepped on the mat and with the investigator's signal, jumped as high as they could. Each type of jump was tested 3 times.

Stretching Protocol

Stretching exercises were designed for the hamstrings, quadriceps, and triceps surae muscles. These exercises were chosen with the intention of reproducing the stretching routine of athletes before sports activities (31). Each stretching method, with the exception of the dynamic stretching intervention, consisted of 3 sets of exercises with 15 seconds maintained in the stretch position. For the static stretching method, the stretches were held at a point of mild discomfort (2). The stretching methods used for each exercise were as follows: active static–each subject made the movement without external assistance to the position of mild discomfort; passive static–every movement was led by an experienced investigator in conducting stretching exercises to the point of mild discomfort; and dynamic. For the dynamic stretching protocol, the same procedures were followed, but instead of holding the stretching positions for 15 seconds, the subjects had to bob in 1:1-second cycles for 30 seconds trying to reach a greater stretch in each repetition (4). For all the methods and exercises, an investigator demonstrated the correct stretching techniques before each routine and monitored each subject to ensure that the activity was being conducted properly. Below, is a detailed description of the stretching exercises.

Hamstrings–with the subject seated and the knees fully extended, a full flexion of the hips was made bringing the hands toward the feet such that the head stayed between the knees.

Quadriceps–with the subject in the lateral position, complete flexion of the knee was performed. This exercise was carried out with 1 leg at a time.

Triceps Surae–with the subject standing in a position to push the wall, with both feet on the floor, 1 foot placed behind, at a distance of 1 foot from the heel of the front. The subject flexed the knee forward, keeping the back leg extended and the heel of the foot placed behind always positioned on the floor.

Statistical Analyses

The statistical analysis was initially performed by the Kolmogorov-Smirnov normality test and by the homoscedasticity test. All the variables presented normal distribution and homoscedasticity. The 1-way repeated measures analyses of variance (CC × PSC × ASC × DC) were used to

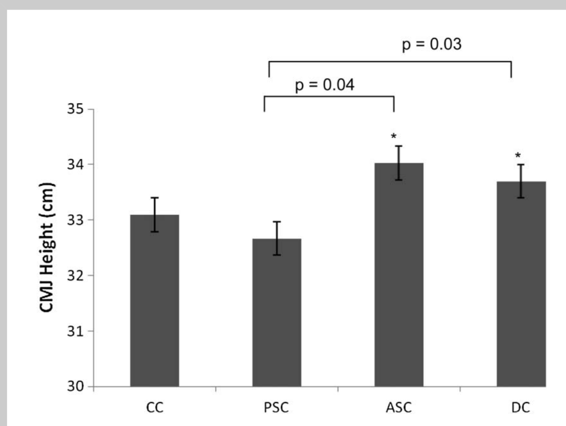

Figure 2. Mean (bars) and *SD* for the CMJ height in all the experimental conditions. CMJ = countermovement jump; CC = CMJ without stretching exercises; PSC = CMJ with passive static stretching exercises; ASC = CMJ with active static stretching exercises; DC = CMJ with dynamic stretching exercises. (*) Significant difference when compared with the PSC ($p < 0.05$).

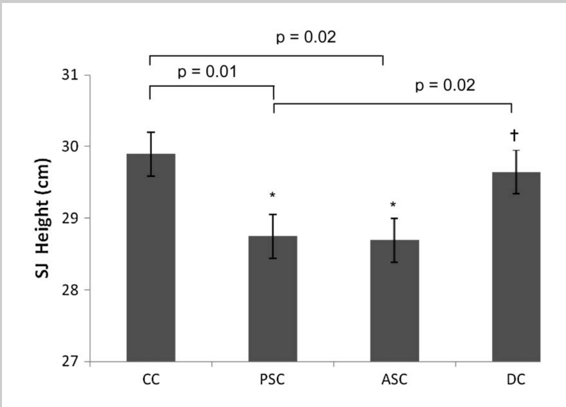

Figure 3. Mean (bars) and *SD* for the SJ height in all the experimental conditions. SJ = squat jump; CC = SJ without stretching exercises; PSC = SJ with passive static stretching exercises; ASC = SJ with active static stretching exercises; DC = SJ with dynamic stretching exercises. (*) Significant difference when compared with the CC ($p < 0.05$); (†) significant difference when compared with the PSC ($p < 0.05$).

determine the effects of the different experimental conditions on VJ performance. When appropriate, Tuckey post hoc tests were used to determine the specific differences. An alpha level of $p < 0.05$ was considered statistically significant for all analyses. Effect sizes were calculated and classified to determine the magnitude of changes among experimental conditions as proposed by Rhea (26) (difference between the average pretest and posttest divided by the *SD* of the pretest).

Results

For the CMJ (Figure 2), there were no significant differences ($p > 0.05$) when comparing all stretching conditions to the CC. However, there was a significantly greater VJ performance when comparing the conditions ASC (34.0 ± 6.0 cm) and DC (33.7 ± 5.5 cm) with the PSC condition (32.6 ± 5.5 cm). The effect size magnitude was classified as trivial and small, respectively (ASC × PSC; DC × PSC).

For the SJ (Figure 3), there was a significantly lower ($p < 0.05$) VJ performance when comparing the stretching interventions of PSC (28.7 ± 4.3 cm) and ASC (28.7 ± 4.7 cm) with CC (29.9 ± 5.0 cm). A significantly greater VJ performance was observed when comparing the conditions of DC (29.6 ± 4.9 cm) with PSC (28.7 ± 4.3 cm). The effect size magnitude was classified as trivial for comparisons with CC and small in the DC vs. PSC comparison.

Discussion

In this study, the subjects practiced their warm-up with specific activities, using jumps, which may have influenced the outcome. These findings are in agreement with the findings of Woolstenhulme et al. (33) who had their subjects perform a specific warm-up for basketball and found no significant differences in jump height immediately after static stretching. Stewart et al. (29) examined 14 rugby athletes on 40-m sprint using a specific warm-up with and without static stretching or just static stretching and found a better time for the protocols of specific warm-up with and without stretching in detriment to the protocol that only used the stretching. Thus, it seems likely that the performance of a specific warm-up with dynamic stretching is not detrimental for strength and power activities.

Despite using in their methodologies a different number of exercises and time to maintain the position of stretch, several studies (7,31,32) corroborate to the findings of the present investigation. The results of this study also demonstrated no increase or decreases in the CMJ performance after any of the stretching conditions when compared with the CC. However, a significant increase of 3.0 and 2.1% was observed in the VJ performance when performed after active static stretching and dynamic stretching, respectively, when compared with the PSC. For the SJ, the performance was significantly decreased by 3.5 and 3.7% when performed after passive and active static stretching, respectively, when compared with CC. One reason that can explain the fact that no decrease in CMJ performance was observed after the static stretching exercises was the total volume of stretching exercises used. Perhaps the volume of the static stretching used in our study may not have been sufficient to cause a significant change in musculotendinous stiffness, thus, not altering the rate of muscle activation and reflex sensitivity (3). Corroborating with this hypothesis, the study by Yamaguchi and Ishii (34) showed that static stretching of the lower body divided into 30 seconds per muscle group before a power test of lower body showed no statistically significant change. In addition, Unick et al. (31) demonstrated that a lower volume of stretching showed no decreased ability to generate power in the lower body.

Knudson et al. (19) showed that there were no significant changes in vertical speed of the jump or in the durations of the eccentric and concentric phases as a result of static stretching. Although, 55% of the subjects obtained lower vertical velocities and 45% of the subjects showed no changes after the intervention. Otherwise, the maximum passive stretching protocol used in this study showed significantly decreased in the jump height performance for SJ when compared with the CC and for the CMJ when compared with ASC or DC. Yamaguchi and Ishi (34) also demonstrated that passive stretching during a warm-up resulted in a reduction of peak power, peak velocity, and increased time of peak torque achieved under different loading conditions, at 5, 30, and 60% of maximal voluntary isometric contractions attributing that their findings may be because of the high volume of stretching used, which resulted in changes in neuromuscular and mechanical properties of muscles. One possibility for this might be the high intensity applied in this intervention, resulting in a decrease of neuromuscular coordination capacity. Avela et al. (3) reported that changes in the aponeurosis–tendon complex after passive stretches occurred because of a phenomenon known as stress relaxation or plastic deformation, which affects the proprioceptive response thereby decreasing motor unit activation, which can lead to deterioration in intramuscular and intermuscular coordination (14).

For the dynamic stretching condition, this study revealed no significant differences when comparing to CC. This corroborates with recent studies such as Bradley et al. (7) who examined 18 college students and found no significant differences in the CMJ height after dynamic stretching. Likewise, Unick et al. (31) investigated trained women and reported no significant differences in VJ performance after a warm-up with dynamic stretching. In contrast, Fletcher and Jones (14) examined 97 rugby players on the 20-m sprint performance and reported improvements in speed after dynamic stretching. Nelson et al. (24) observed a decrease in performance after dynamic stretching; a 20-minute flexibility training protocol was used for 2 muscle groups, thus using a high volume, which is not commonly used for warm-up in athletes. Therefore, the findings of this study contribute to the literature by adding more evidence that dynamic stretching has no detrimental effects in muscle power performance. This effect appears to be irrespective of gender, as Unick et al. (31) found a similar result with women.

Another important point to consider is the group of subjects used in our research: trained adolescents. In agreement with this work, Unick et al. (31) in a study with 16 trained women demonstrated no decrease in performance after treatment with static and ballistic stretching and cites the use of female athletes with extensive experience in jumps as the probable cause of the results found, because it is unclear in the literature which influence flexibility training has on the jump power in people with extensive training experience. In another study with trained subjects, Young et al. (37) examined 16 Australian football athletes to study the influence of stretching on kick performance. They concluded that there were no differences in the speed of the kick between a warm-up with and without stretching and suggested that the probable cause of this finding was the complexity of the technique of kicking. It is reasonable to believe then, that as few studies investigated young individuals with high training experience, the neural and mechanical responses such as maximal voluntary activation and stiffness in the musculotendionous unit may exhibit different behaviors in this population.

According to Magnusson et al. (21), flexibility exercises held at the same angle for 45 seconds results in a reduction in passive tension (muscle stiffness). For Taylor et al. (30), the intensity imposed repeatedly for flexibility work increases the muscle length resulting in the decrease of generated power. Thus, it appears likely that the variation in intensity and volume of flexibility work during the warm-up interfere differently on the manifestation of muscle strength as power or as the maximum strength. Therefore, the high intensity and volume are detrimental, whereas the low intensity and volume apparently cause no significant acute effects. However, the real causes of strength loss by the practice of intense stretching exercises still needs further studies to identify the key factor for this decrease, whether acute or transient.

Practical Applications

According to our findings, it seems probable that passive and active static stretching is detrimental to power development in well-trained younger's tennis players. Additionally, our results provide evidence that dynamic stretching appears to cause no significant acute effect for this population when used in conjunction with a specific warm-up. Practitioners and coaches should avoid static stretching when designing warm-up routines. More studies using low and high volumes, and intensity should be conducted for a better understanding in how these can interfere in power development for trained individuals.

More studies using low and high volumes and intensity should be conducted for a better understanding in how these can interfere in power production for trained people.

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