SYNERGIST AND ANTAGONIST MUSCLES STATIC STRETCHING ACUTE EFFECT DURING A V-SIT POSITION ON PARALLEL BARS

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Original article

Abstract

The aim of this study was to examine the acute effect of synergist and antagonist muscles static stretching (SS) on the body segmental angles, during a strength element on parallel bars (V-sit). Fourteen male recreational gymnasts (20.9 ± 2.2 years) were asked to follow three different protocols with the following order: a) general warm-up without stretching (WU), b) synergist muscles static stretching (SSS) and c) antagonist muscles static stretching (ASS). Right after each condition, the gymnasts were photographed in the sagittal plane, executing a V-sit position on parallel bars with legs extended and stabilized at the highest possible level. The leg-horizontal, trunk-vertical and arm-vertical angles were measured using image-pro software. Pairwise comparisons revealed a significant decrease for legs-horizontal angle, after the SS exercise of synergist muscles (SSS<WU, p<.01). The antagonist muscles SS resulted in significant increase for legs-horizontal angle, compared with synergist muscles SS condition (ASS>SSS, p<.001). Consequently, synergist muscles SS may not be recommended before gymnastics exercises that require maximal strength production. Nevertheless, the beneficial acute effect of antagonist muscles SS can act as a counterbalance to diminish or inhibit the SS detrimental acute effect on synergist' muscles.

***Keywords**:* Static Stretching, Force Element, Digital Photography, Goniometry, Gymnastics.

INTRODUCTION

Stretching is crucial to enhance gymnasts' articular mobility (Sands, 2011). However, McNeal and Sands (2001, 2003) showed that static stretching (SS) had a negative acute effect, reducing the power of lower extremity muscles in competitive gymnasts. Authors' views about the acute effect of SS on subsequent performance varied in the last decades. In a systemic review by Behm and Chaouachi (2011), it was illustrated the far greater preponderance of measures reporting significant impairments (>50) as compared to no significant change (<20) or significant improvement (>10) of strength and power performance.

In college-aged subjects, studies showed the detrimental acute effect of SS on maximal isometric and isokinetic muscle strength performance (Bacurau et al., 2009; Behm et al., 2001; Cramer et al., 2004; Evetovich et al., 2003; Kokkonen et al., 1998; Nelson et al., 2001; Power et al., 2004; Rubini et al., 2007; Siatras et al., 2008). The impaired muscle strength production (peak torque) has occurred with just 30 to 60 seconds of quadriceps muscles acute SS (Siatras et al., 2008). Ogura et al. (2007), also, found a decrease in maximal voluntary contraction with 60 seconds of SS in hamstring muscles. In addition, Knudson and Noffal (2005) reported significant differences in mean normalized grip strength between the control and stretching group after 40 seconds of SS. Contradictory studies demonstrated no effect on peak torque after 6 to 20 minutes of acute SS (Cramer et al., 2007; Egan et al., 2006). Similarly, no significant difference was found between stretching and control conditions in leg extensors' maximal voluntary contraction, after a quadriceps, hamstrings, and plantar flexors SS for a duration of 45 seconds (Behm et al., 2004).

Nevertheless, the possible negative effect of SS may have impact in numerous athletic events, such as gymnastics, which includes many SS exercises, that is the most used technique in warm-up routines of this sport's daily workout. Gymnastics' routines also include a lot of strength holds in many apparatus (especially on still rings and parallel bars), requiring maximal isometric strength generation of several muscles. In order to avoid deductions in the final score during competitions, these static elements require prescribed time of hold and angular positions (International Gymnastics Federation, 2009).

However, it is not yet clear whether there is a SS acute effect on the synergist and antagonist muscle groups, which participate in performing strength elements in gymnastics. In the present study, the 60-seconds SS acute effect on a common strength hold element, that is a V-sit position performed on parallel bars, will be examined a) after SS of synergist muscles, and b) after SS of antagonist muscles. We hypothesized that strength performance during the V-sit position may be decreased by an acute bout of synergist muscles SS, leading to a drop down of the legs. In contrast, SS of the antagonists may decrease muscle stiffness (increased compliance) and the athletes' performance is expected to be increased (legs' ascent).

Therefore, the purpose of this study was to evaluate the acute effects of SS exercises of synergist (quadriceps, iliopsoas and abs) and antagonist (lumbar and hamstrings) muscles on the body segmental angles, during a gymnastics static strength element. The V-sit position was chosen as a representative static exercise in gymnastics, requiring a maximal strength production by the athletes. This exercise was performed on parallel bars, due to the steadiness of this apparatus and the adjustable height of the bars depending on the testing settings.

METHODS

Participants

Fourteen male recreational gymnasts (20.9 ± 2.2 years; 176 ± .5 cm; 68.7 ± 5.3 kg), having a minimum of six years experience in gymnastics (range 6-8 yrs), participated voluntarily in this study. They were all free from injury and any musculoskeletal problem. The subjects were selected having the ability to perform a good support on the parallel bars (elbows and knees extended) and maintain it as steady as possible for three seconds, with the lower limbs over the horizontal plane of the hips. The subjects were informed about the procedures and gave their consent to participate in this investigation.

Procedures and stretching protocols

The participants were asked to follow three different protocols, before the V-sit execution on parallel bars, in the following order: a) general warm-up (WU), b) synergist muscles static stretching (SSS) and c) antagonist muscles static stretching (ASS) exercises.

Muscle SS was performed for 60 seconds, as this duration was considered adequate to provoke a negative acute effect. According to Siatras et al. (2008) and Ogura et al. (2007) this 60-seconds SS was sufficient enough to impair maximal strength production in quadriceps and hamstring muscles, respectively. Any changes in flexibility as a result of SS were not determined, as Church et al. (2001) indicated a non-significant difference in flexibility comparing the pre-treatment and post-treatment sit-and-reach values.

The WU (control protocol) consisted of 5 minutes general exercises (jogging, jumping and general exercises without stretching) in order to raise muscles' temperature and prepare the body for vigorous exercises. Five swings and three L-supports followed as a specific WU on the parallel bars. The SSS protocol comprised a static stretching exercise, focusing on major synergist thigh and trunk muscles. The participants were lying on their low back on a vaulting horse (lumbar region), with the legs slightly bent and stabilized low on wall bars and the hands straight up aligned to the body. The subjects were asked to make a back hyper-extension of the body, in order to stretch simultaneously the synergist quadriceps, iliopsoas and abdominal muscles (figure 1). The stretching exercise of ASS protocol was performed in a sitting position on the floor with the legs extended together (pike position). The subjects flexed their trunk forward to the fullest extend, pulling their soles with their hands and encouraged to touch their thighs with their belly, in order to stretch the antagonist hamstring and lumbar muscles (figure 2). Each position of SSS and ASS protocols was developed slowly and gradually, with a controlled elongation of the muscles involved. The end range of motion was held passively for 60 seconds (one repetition) to a point of limitation before pain would develop (Siatras et al. 2008).

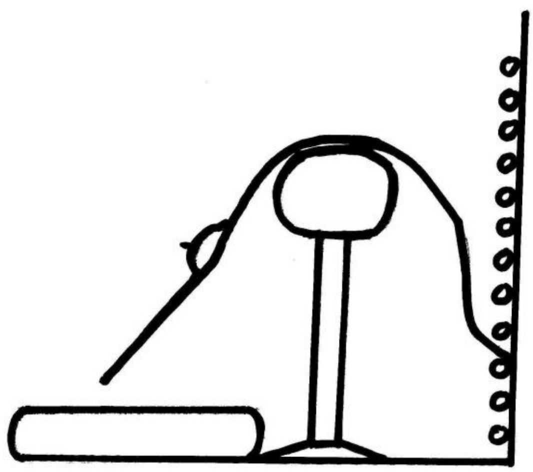

Figure 1. *Static stretching exercise included in SSS protocol, to statically stretch synergist quadriceps, iliopsoas and abdominal muscles. (SSS: Synergist muscles static stretching).*

Figure 2. *Static stretching exercise included in ASS protocol, to statically stretch antagonist hamstring and lumbar muscles. (ASS: Antagonist muscles static stretching).*

All subjects were not aware of the purpose of the study and executed the SS exercises unaided. The experimenter supervised so that all exercises were appropriately performed. The study of the SS acute effect on upper limb muscles was not in the purpose of the present investigation.

Immediately (max 30 sec) after each condition (WU, SSS and ASS), the V-sit exercise was executed on parallel bars. The subjects were instructed to lift slowly their legs to a maximal height, in which they could maintain them extended for 3 seconds. This static exercise is a strength element requiring steadiness and balance. The maximal isometric contraction of the synergist quadriceps, iliopsoas and abdominal muscles was also required. Two trials of V-sit were photographed and the best trial (>legs to horizontal angle) was selected for further analysis.

No familiarisation session with this specific position was imposed to the athletes, because they were familiar with this common gymnastics' element. SSS and ASS exercises were performed after WU session in the same order for all subjects (WU→SSS→ASS). This sequence was used in order to examine the possible SS negative effect on synergist muscles, as well as the minimization or elimination of this effect after the antagonist muscle groups SS. Besides, such stretching exercises in different orders are routinely performed by gymnasts in their daily training. A 5-min rest period was preserved between different conditions, in order to avoid any fatigue effect. All conditions were performed in the same day, in order to examine the hypothesis that the antagonist muscles SS could inhibit the synergist muscles SS negative acute effect.

Goniometric technique

The measurement of the angles formed by the different body segments during the V-sit position was achieved using a digital camera (Sony® 8.1 MP DSC-W90) and a software for image analysis (Image-pro plus v. 6.3, Media Cybernetics Inc., USA).

For the purpose of this study, each subject was photographed in the sagittal plane performing the strength hold element, having self-adhesives skin markers over the lateral malleolus, the greater trochanter, the acromion process and the midpoint between ulnar and radial styloid apophysis. These markers, positioned on the right side of the body, delimited the different body segments. The angles formed by the body segment and the horizontal or vertical planes were determined (legs to horizontal, trunk to vertical and arms to vertical angles), using the image analysis software. Additional details of this goniometric technique were reported in Siatras' study (2011). Afterwards, the percentages of the differences in legs to horizontal angle in the different protocols were computed [(WU - SSS) • 100 / WU, (ASS - SSS) • 100 / ASS, (ASS - WU) • 100 / ASS].

This photographic technique has the advantage to instantaneously capture an image from a distance and later quantify the different segmental angles using the image analysis software. In contrast to conventional goniometric techniques for range of motion assessment (universal goniometer, myrin goniometer, electrogoniometer, inclinometer, radiographic goniometry…), the examinee neither depends on the examiner, nor is restricted by the instrument during photographic testing and, therefore, he can perform difficult and specialized movements and postures.

Reliability of measurements

The intra-rater reliability of the legs to horizontal, trunk to vertical and arms to vertical angles measurements was, already, ascertained by Siatras (2011), showing that these measurements using digital photography and computer-assisted image analysis were precise enough (*ICC*: .945 to .971; *SEM*: 1° to 3°; *CV*: 5% to 7%) to be used for quantifying segmental angles during a V-sit position on parallel bars.

Statistical analysis

Means and standard deviations (± SDs) were calculated for all parameters. The effect of WU, SSS and ASS protocols (independent variables) on legs to horizontal, trunk to vertical and arms to vertical angles (dependent variables) during the V-sit position on parallel bars was determined using one-way analysis of variance (ANOVA) for repeated measures (within-subjects design). Pairwise comparisons were processed to determine any significant difference between the independent variables for each segmental angle. Statistical significance was set at a $p < .05$ level.

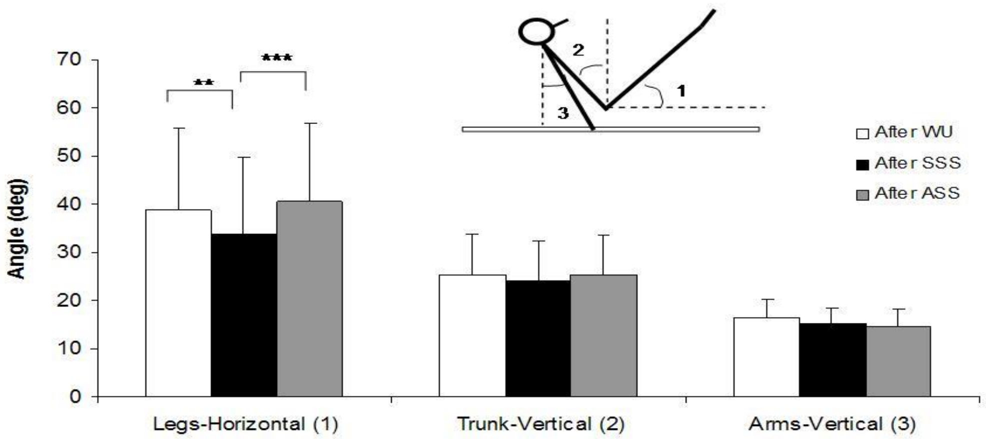

Figure 3. *Synergist and antagonist muscles static stretching acute effect on legs to horizontal, trunk to vertical and arms to vertical angles, during a V-sit hold element on parallel bars.*
*(WU: Warm-up; SSS: Synergist muscles static stretching; ASS: Antagonist muscles static stretching; **: p < .01; ***: p < .001)*

RESULTS

One-way repeated measures ANOVA revealed significant interaction of three conditions (WU, SSS, ASS) on legs to horizontal angle' size ($F_{2,41} = 24.520$, $p < .001$), during the V-sit position performed on parallel bars.

Concerning the acute effect of SS, pairwise comparisons revealed a significant decrease for legs to horizontal angle after the SS exercise of synergist muscles (SSS < WU, $p < .01$). The antagonist muscles SS resulted in significant increase for legs to horizontal angle, compared with synergist muscles SS condition (ASS > SSS, $p < .001$). No significant difference was observed between WU and ASS conditions ($p > .05$) (figure 3).

No significant interaction of three conditions was observed on the rest of trunk to vertical ($F_{2,41} = .561$, $p > .05$) and arms to vertical angles ($F_{2,41} = 1.557$, $p > .05$) (figure 3).

DISCUSSION

Given that SS is the most common form of pre-exercise stretching in athletic populations, the aim of the present study was to examine the acute effect of synergist and antagonist muscles SS exercises on the body segmental angles, during a static strength element in gymnastics (V-sit position on parallel bars). We hypothesized that SS of the antagonistic musculature could inhibit the precedent synergist muscles SS acute effect, allowing for a better V-sit performance (legs' ascent).

The main finding of this study was that there were significant differences among the three conditions (WU, SSS, ASS), only for legs to horizontal angle. These differences were focused on the decrease of legs to horizontal angle after SSS, obviously due to the synergists' maximal strength deficit. Specifically, after SSS treatment this angle was reduced by an average of -11.6% (SSS < WU). Moreover, ASS resulted in increased legs to horizontal angle. The ASS treatment had a beneficial effect on legs to horizontal angle of the order of +18.6% (ASS > SSS). This effect was also present between ASS and WU conditions, with a no significant difference of 5.7% (ASS > WU).

To date there is no literature sources that concern the effects of muscle SS on gymnastics' hold elements requiring maximal strength production. Furthermore, no findings exist concerning SS acute effects on hip and trunk flexor muscles, particularly for antagonist muscles SS effect on synergist muscles performance. Nevertheless, in a recent study, Costa and colleagues (2013) found no differences in isokinetic peak torque of hamstring muscles, when statically stretched the antagonist quadriceps muscles. No changes in the maximal strength of the knee flexor and extensor muscles were also observed by Jemni and colleagues (2014), when comparing the effects of an acute vibration-enhanced SS on the strength of hamstrings and quadriceps muscles. However, Costa and colleagues (2013) found reduced post-SS values in quadriceps isokinetic peak torque (60°/s), after SS of antagonist hamstring muscles. On the contrary, Sandberg and colleagues (2012), in a high-speed isokinetic testing (300°/s), showed that after antagonist hamstrings SS, the torque production of knee extensors was increased. Furthermore, they observed that stretching the hip flexors and dorsiflexors - the antagonists of the hip extensors and plantarflexors- may enhance jump height. Both vertical jump height and power were higher after the antagonists SS protocol. The findings of the present study are consistent with those of Sandberg and colleagues (2012), though the type of muscular contraction was different (isokinetic and power testing vs isometric).

In the literature, few investigations reported no negative effects on performance after SS of muscles involved in movements, such as vertical jump (Chaouachi et al., 2010; Church et al., 2001; Handrakis et al., 2010; Knudson et al., 2001; Power et al., 2004; Unick et al., 2005; Young and Elliot, 2001) and short sprint (Fortier et al., 2013; Little & Williams, 2006). This was probably due to the fact that jumps and sprints are movements that mobilize the intermuscular coordination, thus inhibiting the negative effect of SS. On the contrary, McNeal and Sands (2001) reported that, there was a reduction in drop jump performance after a SS protocol for ankle plantar flexors, in young female competitive gymnasts. This detrimental effect of SS exercises may be avoided by using short duration stretch of 20 - 30 seconds (Fortier et al., 2013; Little & Williams, 2006). Data of Winke et al. (2010) also suggested that a moderate SS of knee flexors before maximal isokinetic testing does not impair the muscle performance. No significant reductions were, also, reported after a SS duration of 30 – 45 seconds for bench press (Torres et al., 2008), or leg extension power (Yamaguchi & Ishii, 2005). These findings are important because the performance tasks examined are applicable to athletic activities. Similarly, no significant effects were reported on concentric knee extensor strength (Beedle et al., 2008; Zakas et al., 2006) and isometric knee flexor MVC (Ogura et al., 2007), following similar durations of stretch. Thus, it seems that SS duration up to 45 seconds has no detrimental effect on strength performance. When SS lasted approximately 60 seconds, the muscle strength was significantly decreased (Kay & Blazevich, 2008; Knudson & Noffal, 2005; Ogura et al., 2007; Siatras et al., 2008).

Most studies in college-aged subjects focused on the acute effect of SS, demonstrating loss of force production for plantar flexor (Fowles et al., 2000) and knee flexor and extensor muscles (Kokkonen et al., 1998). Other investigations also showed the detrimental effect of SS on isokinetic peak torque of knee extensors that requires high level of force (Costa et al., 2013; Nelson et al., 2001; Sekir et al., 2010; Papadopoulos et al., 2005). Moreover, McNeal and Sands (2003) found that, even in young competitive gymnasts -who are accustomed to perform static stretches in strength/power type training sessions- the acute SS reduced the power of lower extremity muscles during drop jumps. Likewise, in a systematic review by Kay and Blazevich (2012), it was suggested that all lower limb muscle groups are affected by SS, with the knee flexor muscles being more influenced (82%), compared with the knee extensors (64%) and plantar flexors (62%).

The decrease of strength-generating capacity of the statically stretched muscles was attributed to the changes in musculotendinous unit length (increased muscle compliance, decreased stiffness, less optimal length of cross-bridges) (Behm et al., 2004; Behm et al., 2001; Cramer et al., 2004; Cramer et al., 2007; Egan et al., 2006). The affected passive or active musculotendinous stiffness was also regarded as responsible for stretch-induced force production decrease (Magnusson et al., 1996, Rosenbaum & Hennig, 1995). Wilson et al. (1994) maintained that a stiff musculotendinous system allows for improved isometric and concentric force production, because the contractile elements of the muscle are in a more favorable position on the length/force curve. On the other hand, Knudson et al. (2001) suggested that neuromuscular inhibition may be the mechanism responsible for muscular impairment, rather than changes in muscle stiffness. The force decrement, after an acute bout of muscle SS, was related to the Golgi tendon organs, which responded by producing a reflexive inhibition of both muscle and its synergists (Moore, 1984). The limited activity of H-reflex immediately after stretching exercises was also attributed to the reduced sensitivity of muscular spindles (Avela et al., 1999; Thigpen et al., 1985). Limited muscle spindles sensitivity (Beaulieu, 1981) or reduced motoneuron excitability (Guissard et al., 1988) are implicated to the stretch-induced force deficit.

Static stretching of the synergist muscles results in a commonly accepted reduction of their strength. Power and colleagues (2004) investigated whether acute static stretching affects isometric force, muscle activation and jump power. They found that static stretches had reduced the maximal voluntary contraction torque of the quadriceps by 9.5%. They also showed that torque remained statistically decreased by 10.4% over the 120 min following the trial. Furthermore, Fowles and colleagues (2000) found that the negative effect persists for up to 60 minutes. In the present study, the SS of antagonists, though last in the order of static stretching conditions, inhibited this negative effect due to the synergist muscles stretching. Thus, the gymnasts were able to redevelop maximal strength, leading to an improved V-sit position (legs' ascent). Sandberg and colleagues (2012) suggested that stretching the antagonist musculature would result in an increased performance by increasing the neural drive to the agonist muscles. As pointed out by Hutton (1992), static stretching exercises allowed to a "softer" musculotendinous system, with an increased muscle length. Thereby, the reduced antagonist muscles' stiffness may explain the gymnasts' ability to perform larger movements.

It is worth asking whether the static stretching detrimental acute effect on synergist muscles is reduced or even suspended, thanks to antagonist muscles stretching. Perhaps this sequence of static stretching treatment (antagonist after agonist muscles stretching) is an effective "antidote" to diminish or inhibit the static stretching deleterious effect on synergist muscles.

Future research is needed to clarify the neuromuscular mechanisms responsible for the beneficial effect of antagonists' static stretching in agonist muscles performance.

Further, it must be clarified how these results on the maximal strength of hip and trunk flexors are applicable to other muscle groups or athletic populations.

CONCLUSION

Static stretching of the trunk and hip synergist and antagonist muscles resulted in significant legs to horizontal angle fluctuation, during the V-sit strength hold element on parallel bars in recreational gymnasts. After 60-seconds static stretching of synergist muscles there was a negative acute effect of static stretching exercises (decreased legs to horizontal angle). Reversely, a beneficial acute effect was observed after static stretching of antagonistic muscle groups (increased legs to horizontal angle). However, a limitation of the current study was that the experimental protocol assessed the three conditions successively in the same order (WU→SSS→ASS) and not separately. This sequence was used in order to examine the possible SS negative effect on synergist muscles, as well as the minimization or elimination of this effect after the antagonist muscle groups SS.

In conclusion, static stretching exclusively for synergist muscles may not be recommended right before gymnastics' strength hold elements, because it produces a deleterious effect on maximal force. On the other hand, antagonist muscles static stretching could be used as a counterbalance to diminish or inhibit the static stretching harmful effects on synergist muscles. However, the findings of the current study could have been different if the assessment was made in other order and/or on separate days.

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