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Effects of static and dynamic stretching on upper limb explosive, isometric and endurance strength, in male volleyball players

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Abstract

The purpose of this study was to investigate the acute effects of both static and dynamic stretching on upper limb strength and to assess whether a cross-over inhibitory effect occurred during the time in which this effect may appear. Eighteen male volleyball players (aged 21.50, standard deviation 3.12 years) underwent the experimental protocol organized in in two sessions, one of static and the other of dynamic stretching for upper body muscles. Participants performed three specific strength tests: Ball Throwing, Maximum Voluntary Isometric Contraction, and Push-Up, to assess explosive, isometric and endurance strength respectively, at baseline (T0) and 10, 20 and 60 minutes after the static stretching and dynamic stretching sessions. The Ball Throwing results showed significant differences between the two stretching protocols ($F_{1,14} = 4.967$; $p = 0.043$; $\eta p2 = 0.262$), among the 5 time measures ($F_{4,58} = 7.476$; $p < 0.001$; $\eta p2 = 0.348$), and for the interaction Protocol × Time (F4,58 = 8.258; $p < 0.001$; $\eta p2 = 0.371$). Maximum Voluntary Isometric Ccontraction scores showed significant differences among the time measures ($F_{4,58} = 4.015$; $p = 0.006$; $\eta p2 = 0.223$) and for the interaction Session × Time ($F_{4,58} = 2.625$; $p = 0.044$; $\eta p2 = 0.158$). At the Push-Up test significant differences were found only among the time measures ($F_{4,58} = 5.634$; $p = 0.001$; $\eta p2 = 0.287$). Static stretching may adversely affect upper limb endurance strength, whereas no changes in isometric and explosive strength were found. Dynamic stretching did not have a detrimental effect on upper limb endurance strength, whereas it may improve isometric and explosive strength.

Key words

Sport performance, shoulder, range of motion, resistance.

Introduction

Good shoulder flexibility and strength are essential components in volleyball performance, especially in the most explosive movements such as spike, stroke with jump and overhead movements. Shoulder range of motion positively affects the power and consequently the efficacy of these technical skills (Liu and Andersson, 2008).

Stretching is used by athletes and recommended to improve performance (Kay and Blazevich, 2009), to prevent injuries (Andersen, 2005), and to decrease soreness (Arampatzis et al., 2001).

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Several previous studies have established that acute static stretching (SS) has an adverse effect on maximal performances (Dallas et al., 2014; Leone et al, 2014), suggesting that neuromuscular inhibition may be the mechanism responsible for muscular impairment, rather than changes in muscle stiffness (Ryan et al., 2008). Viscoelastic stress relaxation after SS produces both mechanical and structural tissue alterations (passive muscle stiffness reduction), that affect muscle-tendon complex force transmission and consequently decreases the muscle force production (Moran et al., 2009). Moreover, a reduction in motoneuron pool excitability decreases the muscle performance (da Silva et al., 2015). Previous studies strongly recommended not performing SS immediately before a maximal strength performance (Behm et al., 2006). Impairment was estimated to persist for up to 60 minutes (Knudson et al., 2001). The duration of single SS exercise is also responsible for loss of strength performance: a duration of 30 sec or less, showed no detrimental effect on performances that required maximal strength and power (di Cagno et al., 2010). Several authors showed that dynamic stretching (DS) does not negatively affect performance and may improve some body physical skills (McMillian et al., 2006; Yamaguchi et al., 2007). Few studies have examined the effects of stretching on upper body muscles and found controversial findings. Evetovich et al. (2003) and Leone et al. (2014) provided evidence for a decrease in strength production and sport performance. Knudson et al. (2001) and Torres et al. (2008) did not find any negative effect following previous SS in the upper limb maximal force production and power tasks. Jelmini et al. (2018) demonstrated that acute SS negatively affects the rate of force generation more than peak force, due to a neural inhibitory mechanism.

The aim of the present investigation was to determine whether, in volleyball athletes, isometric, isotonic and explosive strength were negatively influenced by an acute bout of SS and DS. We hypothesised that an acute bout of SS would decrease the strength muscle performance, whereas DS would improve or would have no effect on the type of strength output tested in this study.

Material and methods

Participants

Eighteen adults male volleyball players (aged 21.50 ± 3.12 years old) underwent the study procedures. Participants were recruited in two different volleyball clubs competing in the national championships. In order to be enrolled in the study, participants had to meet the following inclusion criteria: (1) participation in at least 80% of the training sessions and in the competitions of their own club, (2) at least 5 years of volleyball practice, and (3) no injury occurred in the last year. The following exclusion criteria were applied: presence of injury or disease (temporary or not) influencing the experimental protocol execution and the testing session and use of medicine influencing neuromuscular functioning, resistance performance and/or muscular characteristics (e.g. elasticity, stiffness, or contractility). The study was designed and conducted in conformity with the Declaration of Helsinki. All participants gave their informed written consent.

Procedures

The procedures were designed in order to evaluate the respective effects of SS and DS on explosive, isometric, and endurance strength. The experimental protocol consisted of two sessions, performed in two non-consecutive days of the same week, two days apart each other. Pre and post intervention specific strength tests consisted in: Ball Throwing test (BT), Maximum Voluntary Isometric Contraction test (MCIV), and Push-Up test (PU), that assessed explosive, isometric and endurance strength respectively.

Three repetition of each strength test (BT, MVIC and PU) were performed at baseline (T0), immediately after the stretching protocols (T1), and at 10 (T10), 20 (T20) and 60 (T60) minutes after each stretching protocols. The tests and the stretching protocols used in the experimental sessions are described in detail in the following paragraphs.

Strength tests

The three strength tests (BT, MVIC and PU) were completed in 90 sec, with 10 sec rest between each test and the next. This procedure was used in both sessions (SS and DS) and in the repeated measures (T0, T1, T10, T20 and T60), to reduce the influence of each test on the next. In fact, the fatigue produced by each test could influence the result of the subsequent tests. However, the proper evaluation of the immediate acute effects of stretching did not allow longer rest periods or multiple attempts. The execution of the tests in the same order, instead of randomised order, was used to favour the homogenous overestimation or underestimation of the test scores. Authors tolerated the systematic error of measurements, due to the impossibility to eliminate the interferences among the tests.

Ball throwing

This text was performed to evaluate the upper limb explosive strength. The test consisted in throwing the heavy medicine ball (Dynamax Inc. Dallas, TX 3 kg, 65 cm in diameter), sitting on the floor, the back oriented vertically against a back support, with legs crossed, knees flexed at 90°. Participants were secured to a support with an elastic strapping, placed around the trunk at mid-chest level under the axillae. This position and mode of stabilization minimized trunk movements during the put. Tacking the ball with both hands from behind the head, participants threw the ball ahead, using an explosive forward movement. Participants completed 3 medicine ball puts, and the greater distance was considered for the analysis.

Maximum voluntary isometric contraction

This test was performed to evaluate the maximum isometric contraction of shoulder extensor muscles, assessed when participants were in the same position in which they usually impact the ball during the spike. In sitting position, the participants had to pull, with the outstretched arm, a dynamometer handle, keeping a shoulder abduction of ≈140° and a horizontal adduction of ≈30°. The core and the trunk of the participants were stabilized during the test.

Push-up

This test was used to evaluate the muscular endurance strength of the participants (Vossen et al., 2000; Battaglia et al., 2013). The PU was performed in a prone position. Each subject lifted the body, raising the arms and leaving the feet in touch with the ground, and, without pausing, changed direction to return in starting position. In this test, the participants had to perform the largest number of complete and correct push-up in 30 sec. The maximum number of correct lifts that each subject made in 30 second was considered for the analysis.

Stretching sessions

Static stretching session

Static stretching consisted of a slow passive manoeuvre until the maximum range of motion was attained, in a position in which subjects reported a feeling of maximal stretch but no discomfort or pain. The participants performed two sets of three stretch repetitions of 30 sec each (2 sets x 3 rep x 30 sec), with a 10 sec rest between repetitions and a 15-sec rest between sets (Behm et al., 2004). They did not warm-up prior to stretching. Participants performed three type exercises as showed in the following paragraphs. All stretches were performed in standing position. The investigator helped and controlled each stretch of the subjects to ensure consistency in stretching procedures. The total time under stretch was 180 sec for each exercise.

In the first exercise the subject extended the right arm across the upper chest with the forearm, roughly parallel with the floor, then he pressed the left hand against the outside of the right elbow (posterior deltoid and under scapular muscle stretching). In the second exercise the subject placed one arm behind the head and tried to touch the opposite shoulder blade with the hand. The investigator placed a hand on the elbow of the stretched arm and began the stretch, pushing the elbow across the subject's body toward the opposite shoulder (triceps muscle stretching). In the third exercise the subject, standing in front of the investigator with the investigator grasping the elbow joins, abducted the shoulder and extended the arms to a position that was below parallel to the ground. The investigator pushed the arms together to stretch the pectoralis major and anterior deltoid muscles.

Dynamic stretching session

Dynamic stretching consisted of moving the limbs actively with a controlled slow to moderate velocity until maximum range of motion. The participants performed 10 repetitions of 6 sec each (3 sec in the ascendant phase and 3 sec in the descendent phase) for each of the 6 different exercises. Dynamic stretching consists of function based exercises through a full range of motion, which use sport-specific movements to prepare the athletes for practice and competition. Dynamic shoulder stretch included external and internal arm rotation, abduction, adduction, flexion and extension movements.

Statistical analysis

The analysis of variance for repeated measures (RM-ANOVA) was performed on the scores obtained from each resistance test. The RM-ANOVA was performed assuming the two sessions for BETWEEN FACTORS analysis (Session: SS vs. DS) and the 5 repeated measures for WITHIN FACTORS analysis (Time: T0 vs. T1 vs. T10 vs. T20 vs. T60). The distance covered in the BT, the isometric strength, measured with the MVIC (in Newton), and the number of push-ups, performed in the PU test, were used as dependent variable for the analysis, and analysed separately. Due to the 5 repeated measures in the time factor, paired comparisons were performed when a significant F was observed, using Bonferroni post-hoc test.

The results are reported as mean ± standard deviation. The alpha test level for statistical significance was set at 0.05. The analysis was performed using SPSS statistical software package version 22 (IBM, Armonk, NY, USA).

Results

For BT, significant values were found for the differences between the two stretching protocols ($F_{1,14} = 4.967$; $p = 0.043$; $\eta_p^2 = 0.262$) and among the 5 time measures ($F_{4,58} = 7.476$; $p < 0.001$; $\eta_p^2 = 0.348$), and for the interaction Protocol × Time ($F_{4,58} = 8.258$; $p < 0.001$; $\eta_p^2 = 0.371$). Analysis performed on MVC scores showed significant differences among the time measures ($F_{4,58} = 4.015$; $p = 0.006$; $\eta_p^2 = 0.223$) and significant interaction Session × Time ($F_{4,58} = 2.625$; $p = 0.044$; $\eta_p^2 = 0.158$), but no differences between the two protocols ($F_{1,14} = 2.921$; $p = 0.109$; $\eta_p^2 = 0.173$). Concerning the PU, significant differences were found only among the time measures ($F_{4,58} = 5.634$; $p = 0.001$; $\eta_p^2 = 0.287$), whereas no differences were found between the two session ($F_{1,14} = 1.420$; $p =$

Table 1. Duration-dependent effects of acute static and dynamic stretching on explosive, isometric and endurance strength in volleyball players (mean ± standard deviation).

	T0	T1	T10	T20	T60	Significance (p<0.05)
Static Stretching						
BT (m)	4.43 ± 0.43	4.28 ± 0.44	4.38 ± 0.5	4.4 ± 0.5	4.54 ± 0.46	None
MVC (kg)	11.77 ± 1.92	10.44 ± 1.75	10.87 ± 2.79	11.12 ± 2.49	11.63 ± 2.51	None
PU (n)	21.88 ± 1.46	22.75 ± 2.82	22.5 ± 2.93	20 ± 2.98	18 ± 4.63	T1 vs. T60
Dynamic Stretching						
BT (m)	4.43 ± 0.43	4.92 ± 0.39	5.14 ± 0.5	5 ± 0.4	4.98 ± 0.64	T0 vs. T1, T10, T20 e T60
MVC (kg)	11.77 ± 1.92	12.41 ± 2.33	14.01 ± 1.88	13.22 ± 2.62	13.96 ± 3.12	T0 vs. T10
PU (n)	21.88 ± 1.46	22.13 ± 3.23	23.38 ± 3.81	22.5 ± 5.21	22.25 ± 5.28	None

BT= Ball Throwing; MCV=Maximum Voluntary Contraction; PU= Push-Up.
T0, T1, T10, T20 and T60= assessment of upper limb strength at baseline (T0), immediately after Static and Dynamic Stretching (T1) and after 10 (T10), 20 (T20) and 60 minutes (T60).

0.253; $\eta_p^2 = 0.092$) and no significance for the interaction Session × Time ($F_{4,58}$= 2.163; p = 0.085; $\eta_p^2 = 0.134$). The detailed scores and the post-doc analysis are showed in Table 1.

Discussion

The purpose of this study was to investigate the acute effects of both static and dynamic stretching (SS and DS) on upper limb strength and to assess whether a cross-over inhibitory effect occurred during the time in which this effect may appear. It was hypothesized that an acute bout of SS would adversely affect maximum voluntary isometric contraction, endurance and explosive strength in the stretched upper limbs.

The main findings were a significant difference between the effects of the SS and DS protocols on explosive strength (BT), as highlighted also by the significant interaction Protocol × Time. After SS no significant changes in BT test, used to assess explosive strength, were found. These results agree with other studies in which it was reported that there were no SS effects on upper limb muscular strength or power (Knudson et al., 2004; Torres et al., 2008; Molacek et al., 2010). In the present study DS improved BT performance within 20 minutes, in contrast with preview studies, in which no changes in upper limb explosive strength were found after DS. Torres et al. (2008) did not find any increase in upper body performance following DS, with the exception of the lateral throw. These conflicting results may depend by the different type of stretching protocols applied (Kay and Blazevich, 2012). Faigenbaum et al. (2005) and Yamaguchi and Ishii (2005) hypothesized that the improvements in strength after DS may be due to a post-activation potentiation effect on performance, increasing the rate of cross-bridge attachments, which allows a greater number of cross bridges to form. The BT improvement after DS is important for volleyball performance in which the players need to develop force rapidly and at high velocity (Leone et al., 2014; Piazza et al., 2014).

Regarding the duration dependent effects of stretching on muscle strength endurance, no significance changes after DS were found, whereas a significant decrease between T1 and T60 was found following SS in accordance with the results of Nelson et al. (2005). The impairment may be attributable to different mechanisms consequent to SS, as motor unit fatigue state prior to the initiation of endurance task, a decrease in the motor units available for activation (Fowles et al, 2000), and/or a decrease in blood flow during the time in which muscles are being stretched, with lower oxygen available. Moreover, the partial ischemia elevates the level of metabolites within the muscles (Poole, 1997). Finally, the altered Ca++ kinetics, due to SS, may determine a 63% decrease of twitch tension (Armstrong et al., 1999).

No changes in isometric strength were found as result of SS. The duration dependent effects showed a little decrease at T1-T20, reaching the baseline value at T60. Preview studies reported that, after 15 minutes of recovery from SS, the decrease in isometric strength was due to intrinsic mechanical properties of the stretched muscles, rather than neural factors (Fowles et al., 2000). The length-tension relationship and the plastic deformation of connective tissue, altered by muscle elongation, impaired the maximal force-producing capacity and decreased the stiffness of the complex muscle-tendon (Nelson et al., 2001). In the present study, the little decrease in isometric strength may be attributable also to the angle-torque relationship used during isometric shoulder muscle action, chosen at 30°. A preview study highlighted that the stretching induced force deficit was most evident at shorter muscle lengths (Mc Hugh and Johnson, 2006). The DS elicited a significant improvements in isometric strength until T10. This result may be due to an increase in electromyography activity after DS, that counteract a loss of force production related to the altered length-tension relationship. Moreover, an increase in temperature due to DS may have improved the compliance of both contractile and non-contractile tissues in the muscles (Taylor et al., 1995). In contrast with these findings, Evetovich et al. (2003) reported no changes electromyography but an increase in mechanomyography amplitude for the biceps brachii after stretching and suggested that neither SS no DS decreased muscle activation but both SS and DS increased muscle compliance.

Further investigations are needed to explain why upper and lower-body strength performances respond differently to an acute bout both of SS and DS. For example the stretching-induced effect increases the compliance but does not change the muscle activation in the biceps brachii, whereas in the vastus lateralis and rectus femoris muscles it decreases the muscle activation but causes no change in muscle compliance (Evetovich et al., 2003; Cramer et al., 2006; Kirialinis et al., 2015). Future studies may assess whether structural architectural differences among upper and lower limbs determine different acute responses to stretching. The difficulty in determining volume and intensity levels of each static and dynamic stretch regimen limits the application of the results of the present study on this topic. A limitation of this study is that the physical condition of the participants was not controlled, especially the stiffness of the tissues which regulates their flexibility profiles.

In conclusion, in the present study SS adversely affected the upper limb endurance strength, whereas no changes in isometric and explosive strength after an acute bout of SS were found. The DS did not have a detrimental effect on upper limb endurance strength, whereas it can improve isometric and explosive strength. Therefore, DS rather than SS should be proposed before volley performance to maintain or increased muscle strength and power performance of the upper limbs.

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