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Research article

Sport-Specific Warm-Up Attenuates Static Stretching- Induced Negative Effects on Vertical Jump But Not Neuromuscular Excitability in Basketball Players

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Abstract
The purpose of this study was to examine the acute effects of static stretching (SS) and dynamic stretching (DS), alone and in combination with specific basketball warm-up (SBWU), on the neuromuscular excitability and vertical jump height in basketball players. Twelve healthy young male basketball players participated in the study (18 ± 0.42 years; 17.4 – 18.6 age range; 188 ± 9 cm; 76.5 ± 9 kg). All participants completed two different stretching treatments (static and dynamic), performed on different days at least seven days apart, in the same period of training microcycle, in a counterbalanced order. Each session consisted of a self-paced jogging warm-up, followed by a 10-minute testing period (T0), which involved eliciting H reflex and M waves, followed by three trials of a vertical jump test. Participants then performed one of the treatment protocols. After another test (T1), participants conducted 8-minute specific basketball warm-up and then one more test (T2). Combined 3 (time) x 2 (stretching protocol) analysis of variance with repeated measures on both factors revealed that SS significantly decreased spinal excitability (H/M ratio) ($p = 0.015$, $d = -0.38$, percentage of change = -20.55%) and vertical jump height ($p = 0.007$, $d = -1.91$, percentage of change = -2.6%), but after SBWU, vertical jump height increased ($p = 0.006$, $d = 1.13$, percentage of change = 3.01%), while H/M ratio continued decreasing ($p = 0.019$, $d = -0.45$, percentage of change = -30.23%). Acute effects of DS, alone and in combination with SBWU were not significant. It seems that SBWU attenuates negative acute effects of SS on vertical jump performance in young basketball players, while DS appears to cause no significant acute effect for this population.

Key words: Exercise, males, excitability, H- reflex, M- wave.

Introduction

Warm-up is common activity in basketball, used to increase muscle temperature, muscular blood flow and several other physiological/psychological responses, directed toward performance improvement and injury prevention (Behm and Chaouachi, 2011; Bishop, 2003). Routine traditionally involves different stretching exercises after light aerobic activity (Bishop, 2003), with static (SS) and dynamic stretching (DS) being most common (Behm et al., 2016; Behm and Chaouachi, 2011).

In past 15 years or so there were claims that acute SS may decrease performance in many explosive activities (Kokkonen et al., 1998), through both mechanical and neural alterations. It was found that SS decreases stiffness of the muscle-tendon unit (MTU) and/or increase in tendon slack (Mizuno et al, 2013), leading to a lower rate of force production and a delay in muscle activation (Kokkonen et al., 1998; Avela et al., 1999), and finally to a less effective transfer of force from muscle to lever (Ross et al., 2001). In addition, SS may induce reduction of the H-reflex amplitude, decreasing spinal reflex excitability and reducing stretch reflex activation in MTU (Avela et al., 199). Several factors may contribute to discrepancy in the findings of SS effects, but the most prominent are duration and intensity of stretching and subjects' characteristics (Behm et al., 2016). Consequently, dynamic stretching (DS) has been advised as more functional and physiologically applicable to sport activity preparation. DS increase muscle temperature, power output and aerobic power, lead to reduction in blood and muscle lactate accumulation and increase muscle glycogenolysis, glycolysis, and high-energy phosphate degradation during exercise (Guissard andDuchateau, 2006).

In the recent meta-study, Behm et al.(2016) showed that negative acute effects of static stretching were seen when stretching lasted more than 60sec, which is longer than what is common in basketball practice. In contrast, Reid et al. (2018), Behmet al. (2016) and Simic et al. (2013) concluded that SS lasting 15-30sec, tends to have less or no detrimental effects on performance. Blazevich et al. (2018) even concluded that incorporation of static stretching into a warm-up routine allowed for individuals to have more confidence of high performance in sport-related tests, there was a psychological effect. Additionally, it was shown that using sport-specific warm-up (SSWU) after SS, negative effects of the SS seemed to be reduced (Reid et al., 2018; Annino et al., 2017; Samson et al., 2012; Taylor et al., 2009). The additional SSWU may increase muscle temperature, nerve conduction velocity, along with a decrease in muscle viscosity (Clark et al., 2014). Behm and Chaouachi (2011) and Turki et al. (2011), hypothesized that increases in both cross-bridge cycling (peripheral factors) and neural potentiation (central factors) may be induced with lower intensity dynamic movements (post activation potentiation-PAP), like in SSWU, with consequent increase rate of force development. Recently, however, Trajano et al. (2017) concluded that evidence for peripheral factors are quite weak and propose a new hypothesis that a disfacilitation, occurring at the motoneuronal level after passive muscle stretch, is a major factor affecting the neural efferent drive to the muscle and subsequent deficits in performance.

The neuromuscular acute effects of both stretching methods along with effects on performance parameters,

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could provide insight how changes in neurological aspects of stretched muscles affects the functional changes. It is already mentioned that SS may decrease spinal reflex excitability (Behm et al., 2013; Guissard andDuchateau, 2006) but to the best of authors' knowledge, scientific data regarding neuromuscular acute effects of different types of stretching in team-sport athletes, including changes in the H-reflex, M-waves and motor neuron excitability, are missing, with only one similar research done on recreationally active subjects (Clark et al., 2014). In addition, vertical jump appeared to be consistent correlators to playing time in one basketball game (Hoffman et al., 1996) and likely presents a key fitness attribute in basketball (Delextrat and Cohen,2008). Possible alterations in vertical jump height because of different pre-game or pre-practice activities are of significant importance for everyday basketball practice. Taking together all aforementioned, the aim of this study was to examine the acute effects of static and dynamic stretching methods, alone and in combination with sport-specific warm-up, on the neuromuscular excitability and vertical jump height in basketball players. We expected that SS will decrease values in both variables, but that SSWU will attenuate negative effects, and that DS will have positive effects isolated and in combination with SSWU.

Methods

A within-treatment study was designed to determine acute effects of different types of warm-up on neuromuscular adaptation and vertical jump performance. All participants completed two different stretching treatments (static and dynamic), performed on different days at least 14 days apart, in the same period of training microcycle, in a counterbalanced order. In one day, only one participant was tested, in the same time as others. After completing a self-paced jogging warm-up until first signs of perspiration (6 min on average) led by the primary investigator, subject proceeded to the 10-minute testing (T0), which involved eliciting H reflex and M waves, followed by three trials of a vertical jump test. An associate investigator, who was unaware of the subject's planned stretching treatment, provided all the tests. Participants then performed one of the treatment protocols with the primary investigator. After another test (T1), participants conducted 8-minute specific basketball warm-up, also with the primary investigator, and then one more testi (T2) (Figure 1). The time between each part of session (warm-up, testing, treatment, sport-specific warm-up) was approximately 1 minute.

The exercises in each stretching method were chosen with the intention of reproducing the stretching in common basketball practice. Each stretch was held for 15 seconds (two times per exercise) with a 15-second rest period between each stretch. The static stretching consisted of six exercises (Table 1). Dynamic stretching protocol was performed at basketball court and consisted of eight exercises (Table 2). Duration of static and dynamic stretching were volume-equated, targeting same muscle groups. Dynamic stretching consisted of controlled movement through the active ROM for each of the eight lower-extremity drills (Curry et al., 2009).

Sport-specific warm-up was identical to common warm-up before basketball game, at a self-paced 70% of maximum velocity, performed at the one half of the basketball court: running to the center line, receiving the ball, dribbling the ball, lay-up; four minutes from the right side, four minutes from the left side.

Subjects

Twelve healthy young male basketball players participated in the study (18.0 ± 0.42 years; 17.4 – 18.6 age range; 1.88 ± 0.09 m; 76.5 ± 9 kg). All the players had >four years of experience (8.83 ± 2.4 years) and practiced basketball at least four times per week (5.67 ± 1.6 practices per week). To be included in the study, the participants should have had the following characteristics: a) actively playing basketball at least four years; b) have four or more practices in one week; c) not taking any medication; d) have no relevant medical history that could affect testing results; e) maintained the same level of physical activity, diet and supplementation during the course of the study. Written informed consent was obtained from all the participants after they given a verbal and written explanation of the experimental design and the potential risks involved in the study. For participants younger than 18 years, parental or guardian signed consent was also obtained. The study was conducted according to the Declaration of Helsinki, and the protocol was approved by the local Ethics Committee of Institute for Medical Research, University of Belgrade, before the commencement of the assessments. All the participants were fully accustomed to the procedures used in this research and were informed that they could withdraw from the study at any time without penalty.

Procedures

The excitability of α-motoneuron was taken for the evaluation of neuromuscular adaptation. It is presented as a ratio of the maximal amplitudes of Hoffman (H) reflex and M wave (H_{max}/M_{max}). Surface electromyography was used to assess the H-reflex and M-wave. With the participant in the prone position on a treatment table, electrode placement sites on the left leg were shaven and cleaned. Two recording electrodes (Ag-AgCl) were placed over the medial gastrocnemius muscle and Achilles tendon, in a "belly-tendon" montage. The stimulating electrodes were positioned over the tibial nerve in the popliteal space. To correctly identify stimulating electrode placement, the electrode was moved over the nerve until a muscle response was elicited. To ensure reproducibility between tests, electrodes were secured with tape and outlined using a permanent marker to be placed in the same location during all testing sessions (Figure 2).

The H-reflex was measured by electrical stimulation of the tibial nerve with the Medelec ST-10 stimulator (Medelec, Old Woking, UK). After acquiring proper placement, consistent increments of the intensity were increased until the maximum H-reflex and M-wave amplitudes were obtained. First we determined the sensitivity threshold at the beginning of the recording. Barrage of stimuli were given at five in the series, while increasing the intensity of stimulation at 0.2 mV. Recording ended when reached a plateau in response to M wave. EMG activity was amplified (x100) and filtered (1 Hz to 1 kHz) using DAM 50 amplifiers (World Precision Instruments, Sarasota, USA), and then digitized (at 2 kHz) and saved for later off-line processing by CED 1401 (Cambridge Electronic Design, Cambridge, UK). Maximal peak-to-peak amplitudes of H reflex and M wave responses were used in following "off line" analysis.

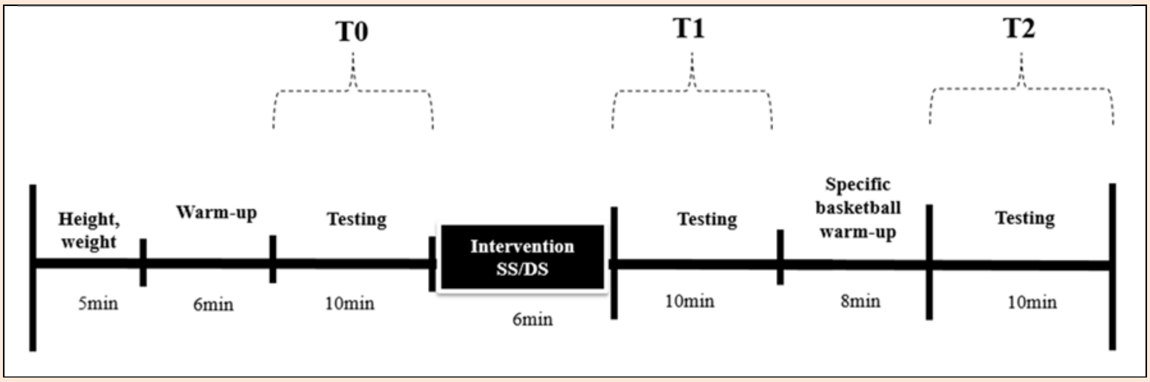

Figure 1. Research design summary.

Table 1. The static stretching protocol

Exercise	Performance description
Crossleg	The participant sitting on the floor with one leg bent across the other leg (which is in straight position). The participant is turning body towards the bent knee side with anchoring elbow round the bent knee and pulling the knee further over the opposite side (both legs, alternately 2x15s).
Butterfly stretch	While seated on the ground the participant bends both legs putting both feet together. The knees are then lowered sideway as far as possible with the help of the elbows (2x15s).
Sit and reach	The participant sits on the ground with both legs straight out in front, and bends forward while keeping the back straight (2x15s).
Kneeling hip flexor stretch	Kneel on knees with upper body lifted. Plant one foot on the floor until 90º angle is reached between the front and back legs. Shift the weight forward while keeping the upper body lifted (both legs, alternately 2x15s).
Kneeling quadriceps stretch	Similar position like previous exercise, but back foot is pulled with the same hand towards the buttock (both legs, alternately 2x15s).
Calf stretch	The participant stands straight on both feet at a distance of 2- steps distance from a wall. One leg is stretched in its place while taking a step forward with the other leg, using both hands on the wall for balance. Care must be taken not to lift the heels of the stretched foot off the ground (both legs, alternately 2x15s).

Table 2. The dynamic stretching protocol.

Exercise	Performance description
High knee and foot walk	While walking each knee is pulled towards the chest with the help of both hands for one court length. While walking back, each foot is pulled towards the chest on the same way (2 court lengths).
Carioca	The subject runs sideways while crossing both feet in front of each other. This is repeated in both direction (2 court lengths).
Butt kicks	While running, the heels are raised to touch the buttocks, with arms swinging in rhythm (1.5 court lengths, half court walking).
High skip	While running, with every skip as each knee goes up, the opposite hand goes up, and the elbows remain bent, swinging in rhythm with the legs (1.5 court lengths, half court walking).
Spiderman	Assume push-up position. Drive left knee up to left armpit, then place left foot flat on ground outside left hand. Maintaining position and keeping right leg straight, activate right glute and push both hips forward until right knee almost ouches ground. Hold stretch at point of tension for three counts than make a step and repeat with opposite leg (1.5 court lengths, half court walking).
Lateral slide with floor touch	Doing deep squats while lateral sliding every second step (1.5 court lengths, half court walking).
Low skip (half court) + long jumps (half court)	After a skips for half court, continue with high jumps with power skips for another half court (3 court lengths).
Dynamic calf stretches	Same position as in "Calf stretch". Alternately stretch both legs, every 2s change the leg (2x30s, 15s pause)

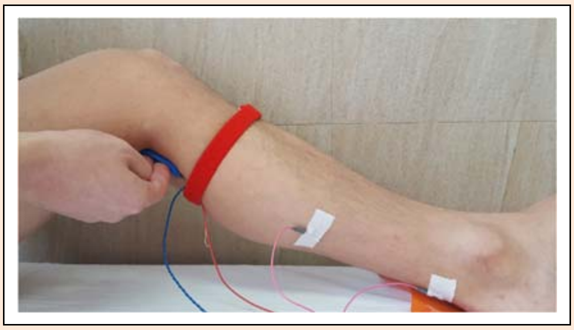

Figure 2. Electrodes arrangement. Pink electrodes are EMG recording electrodes. Blue electrodes are stimulating electrodes. Red cuff is the ground.

Vertical jump height was measured with a jump force plate (Just Jump, Probotics, USA) that calculated height based on time in the air. Jump heights were measured for a two-leg, standing take-off, in which subjects first bent their knees and then jumped upward as high as possible with an arm swing (Delextrat andCohen,2008). Three trials were performed at each test, with a 5-second rest interval between each trial. Vertical jump height was determined as the best of the three trials.

Statistical analysis

Baseline values were compared between groups by t-test for dependent samples. For assessment of variability between and within groups, VJ values were normalized relative to their corresponding T0 values and expressed as percentages of the mean value at T0, for each participant separately (formula: (Tx-T0)/T0*100). For testing the neuromuscular adaptation, we used H-reflex and M-wave ratio (H_{max}/M_{max}). Both variables were analysed using a 3 (time: T0, T1, T2) x 2 (stretching protocol: static stretching – SS; dynamic stretching – DS) analysis of variance with repeated measures on both factors (SPSS, version 20.0). Post hoc pair-wise analyses following ANOVAs were carried out using the least-square difference (LSD) test to determine significance of both factors, and interaction of factors. Statistical results were considered significant if $p<0.05$.

Results

The H_{max}/M_{max} ratio ($T_{(df=11)} = -0.86$, $p = 0.41$) and the vertical jump height ($T_{(df=11)} = 0.5$, $p = 0.96$) were similar between SS and DS groups at the baseline (T0).

The ANOVA showed significant effect of Time ($F_{(2,10)} = 5.371$, $p = 0.026$, $\eta_p^2 = 0.52$) and Time x Group interaction ($F_{(2,10)} = 4.391$, $p = 0.043$, $\eta_p^2 = 0.47$), whereas Group effect was not significant ($F_{(1,11)} = 2.051$, $p = 0.18$, $\eta_p^2 = 0.16$) in the H_{max}/M_{max} ratio. The post hoc analyses showed that protocols differ at the T1, i.e. H_{max}/M_{max} ratio was significantly lower after SS (T0 to T1, $p = 0.015$, $d = -0.38$, percentage of change = -20.55%). After SBWU, ratio continued to decrease (T1 to T2, $p=0.019$, $d=-0.45$, percentage of change=-30.23%), so difference between basiline and final values was significant (T0 to T2, $p = 0.006$, $d = -0.93$, percentage of change = -44.57%). Conversely, after DS, H/M ratio did not change significantly, upward trend was evident (T0 to T1, $p = 0.13$; $d = 0.35$; percentage of change = 29.2%), but, conversely, had trend toward decreasing after SBWU (T1 to T2, $p = 0.06$, $d = -0.59$, percentage of change = -39.1%; T0 to T2, $p = 0.2$, $d = -0.33$, percentage of change = -21.4%) (Figure 3).

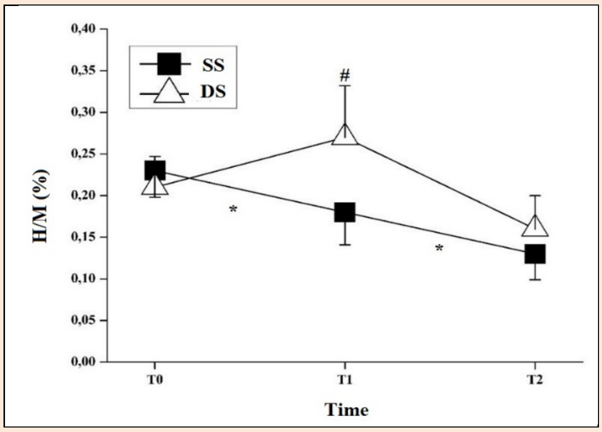

Figure 3. Comparison of H/M ratio after static (SS) and dynamic (DS) stretching across three time blocks. Mean group data are presented; vertical bars represent standard error. Star (*) represent significance p<0.05 during time in one protocol; Hashtag (#) represent significance p<0.05 between two protocols in one time point.

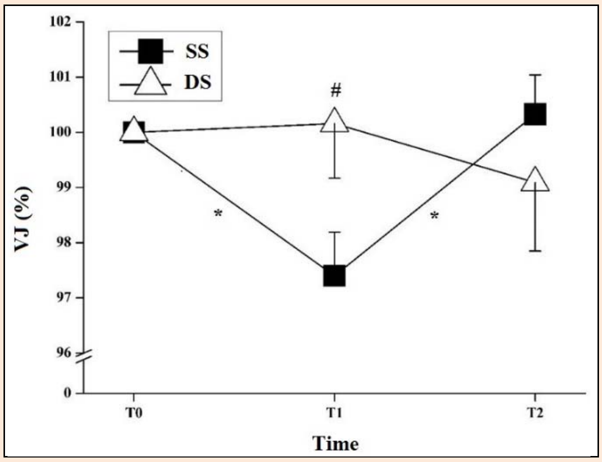

Figure 4. Comparison of vertical jump (VJ) heights after static (SS) and dynamic (DS) stretching, across three time blocks. Mean group data are presented; vertical bars represent standard error. Star (*) represent significance p<0.05 during time in one protocol; Hashtag (#) represent significance p<0.05 between two protocols in one time point.

Static stretching significantly decreased vertical jump height (T0 to T1) (Figure 4), but after specific basketball warm-up increased significantly (T1 to T2). The two-way ANOVA with repeated measures revealed that the effect of the Time x Group interaction was significant ($F_{(2,10)} = 5.025$, $p = 0.031$, $\eta_p^2 = 0.50$), whereas the effect of Time ($F_{(2,10)} = 1.662$, $p = 0.238$, $\eta_p^2 = 0.25$) and Group ($F_{(1,11)} = 0.489$, $p = 0.499$, $\eta_p^2 = 0.04$) were not. The post hoc analyses showed significant difference between two protocols at T1 ($p = 0.05$), SS significantly reduced vertical jump height. Analyzing SS protocol only, vertical jump height significantly decreased immediately after intervention (T0 to T1, $p = 0.007$, $d = -1.91$, percentage of change = -2.6%), and significantly increased after specific basketball warm-up (T1 to T2, $p = 0.006$, $d = 1.13$, percentage of change=3.01%). There was no difference between initial and final values (T0 to T2, $p = 0.656$, $d = 0.26$, percentage of change = 0.33%). In contrast, for DS protocol, there was no significant difference at any time point (T0 to T1, T1 to T2, T0 to T2; $p > 0.4$).

Discussion

The purpose of this study was to examine acute effects of two types of stretching (SS and DS), isolated and in combination with specific basketball warm-up, on the neuromuscular excitability and vertical jump height in young basketball players. The main findings were that SS significantly decreased spinal excitability and vertical jump height, but after SSWU was applied, vertical jump height increased, while H_{max}/M_{max} ratio continued decreasing. Acute effects of DS, alone and in combination with SSWU were not significant.

As we hypothesized, VJ height was reduced immediately after SS, which had been already shown by several studies (Cornwell et al., 2002; Paradisis et al., 2014), although we used shorter stretching (30sec per muscle group), which was suggested not to have negative effects on power (Reid et al., 2018; Behm et al., 2016; Samson et al., 2012). Mechanically, the SS may induced prolonged and more prominent reduction in musculotendinous stiffness, which inhibited the production of force in the contractile component of the muscle (Taylor t al., 2009). The ability of the MTU to store and transfer elastic energy after SS could also decreased (Cornwell et al., 2002). Moreover, the SS changes viscoelastic properties of human tendon structures in vivo by decreasing the viscosity of tendon structures, as well as by increasing the elasticity (Kubo et al., 2001). More compliant muscle and tendon could be responsible for less efficient force transfer from the muscle to tendon, thereby resulting in a lower rate of force production. Studies that did not find any negative effects of SS on VJ height, had some methodological differences with our experimental design, such as using shorter SS (3x5sec) (Holt et al., 2008), implementation of 10 submaximal vertical jumps before the SS protocol (Clark et al. 2014), non-homogenous (eight men and three women) sample of subjects that were recreational athletes (Stafilidis and Tilp, 2015), or different static stretching exercises and different subjects' characteristics (Reid et al., 2018).

Although it was expected that DS will increase vertical jump height, there was no significant change in our study, which is in accordance with some previous studies (Christensen and Nordstrom, 2008; Jaggers et al., 2008). It is important to say that VJ involves not only power and velocity but also the coordination and sequencing of the power and velocity of each limb segment (Turki et al, 2011). If segmental coordination was altered by dynamic stretch exercises, there may not be an appropriate summation of forces leading to no improvement in VJ height. Literature also indicates (Behm and Chaouachi, 2011) that shorter durations of dynamic stretching (less than 10 minutes, six in our study) do not affect performance.

Certain neural factors may affect changes in muscle's force production after SS. Decreased motor unit activation, firing frequency, and/or altered reflex sensitivity are only some of them (Avela et al., 1999; Fowles et al.,2000). Fowles et al. (2000) even claimed that 60% of the stretching-induced decreases in force production of the triceps surae muscle (up to 15 min post-stretching) were due to neural factors, while Behm and Chaouachi (2011) suggested that at least part of the decreases in maximal force production of the leg extensors, after stretching, was due to decreases in muscle activation.

We observed effects on spinal excitability, more precisely, on H_{max}/M_{max} ratio, which can be interpreted as the proportion of the entire MN pool capable of being recruited (Misiaszek, 2003). We found that, acutely, SS significantly reduced H_{max}/M_{max} ratio, as already previously reported (Guissard and Duchateau, 2006; Behm et al., 2013). We can assume that impairment after SS is due to inhibition of H reflex. It is known that the SS increases the flexibility and the length of the muscle, while at the same time increases the presynaptic inhibition from the proprioceptive organs (Clark et al.,2014), or reduces synaptic transmission of Ia afferent fibers to α motor neuron, causing the inhibition of the H reflex. The reduction in the excitation of motor neurons during muscle stretching is caused by mechanisms located at both presynaptic and postsynaptic sites (Guissard and Duchateau, 2006).

Reduction in the H_{max}/M_{max} ratio after stretching was also found in the study of Avela et al. (1999). They concluded that there was only a reduction in excitability of α motor neuron. The same authors reported that the magnitude of the H reflex, in general, is affected by the ongoing net excitatory mechanisms onto the α-motor neurons. The most likely explanation for the reduction of H reflex, is a reduction in the excitatory drive from the Ia afferents onto the α-motor neurons, which probably causes decreased resting discharge of the muscle spindles because of increased muscle compliance (Avela et al. 1999).

Another factor that could affect transmission in the H-reflex arc was post-activation depression (PAD). Any prior activity can be expected to lead to reduction in the available neurotransmitter stores in the Ia afferent terminals. PAD could be particularly important factor during movements that would change the length of the target muscle. Changing the length of the muscle, by static stretching in our case, could activated the muscle spindle stretch receptors, that could result in activation of the Ia afferents, which further could be led to suppression of the H-reflex due to PAD (Kubo et al.,2001). This is also the main reason why vertical jump testing was conducted after H reflex testing in our study. Acutely, DS produce no significant change in H_{max}/M_{max} ratio, but upward trend is evident.

Specific basketball warm-up is regular part of basketball pre-game activities. Use of SSWU after SS in our study reduced negative effects of stretching on the vertical jump height, which was already confirmed in some previous studies (Taylor et al., 2009; Youngand Behm, 2003) but H_{max}/M_{max} ratio continued to decrease. Time elapsed between the end of the stretching and the termination of the

H-reflex measurement is a crucial element for looking at the variation of spinal excitability (Budini and Tilp, 2016). This decrease of H_{max}/M_{max} ratio and, in the same time, increase of vertical jump height could be a possible indication that some other neural factors got involved beside spinal excitability, which remain largely unexplored (Budini and Tilp, 2016; Budini et al., 2017) Also, stretching training programs seem to induce long-term adaptations of spinal excitability, but it is not correlated or at least has a different time course compared to the mechanical adaptations (Budini and Tilp, 2016).

Probably, SSWU caused increase in muscle temperature, nerve conduction velocity, and reduction in muscle viscosity (Bishop, 2003). It is known that decreased force and rate of force development related to stretching could be returned after 10 minutes if followed by dynamic movements that mimic the tasks that follow (Rosenbaum and Hennig, 1995. This additional activity both similar movements and neuromuscular/ energetic demands as basketball game (and vertical jump testing in our case) (Young and Behm, 2003), which could lead to post-activation potentiation (PAP; Behm and Chaouachi, 2011). In addition, SSWU could decrease muscle stiffness by breaking the stable bonds between actin and myosin filaments (Taylor et al., 2009).

Another explanation why height of vertical jump came back to same values is that effects of SS disappeared because of elapsed time between stretching and testing after SSWU (approximately 18 minutes). In Behm et al. review (2016), authors reported that in studies that conducted tests more than 10 minutes after stretching, performance changes were typically statistically trivial unless extreme stretch protocols were used. Even effect of significantly reduced stiffness in the MTU after static stretching that lasts longer (5x1min) disappears within the 10min (Mizuno et al., 2013).

Also, trained athletes may be resistant to stretching-induced force deficit (Egan et al., 2006). Usual practice that our subjects had in their clubs may provide the chronic training adaptations necessary to avoid any adverse long-term effects of stretching on performance. Combination of DS and SBWU did not lead to increasing VJ height nor H_{max}/M_{max} ratio. These two activities are both dynamic and maybe the combination of them fatigued subjects.

The only study that had similar goals and experimental design to ours, was conducted by Clark et al., (2014). Authors wanted to determine the isolate acute effects of SS and DS on H reflex, motor neuron excitability and presynaptic inhibition of the m. soleus. They had 21 subjects (13 female, 8 male students; 19.8 years), who participated in two experimental sessions. In two separate days, H reflex and vertical jump power were tested, before and after either SS (3x30sec, 10sec pause) or DS (3x20m, 30sec pause) protocol, conducted on soleus muscle. The results showed that presynaptic inhibition remained the same after SS, but it was significantly reduced after DS. However, peak power significantly increased after SS, while after DS there was no significant increase. The difference in these findings and in our study lies in the few limitations that are specified by the authors themselves. First of all, Clark etal. (2014) included participants who were not screened for previous athletic experience. Excitability of the spinal motor neuron pool is known to undergo adaptive changes in response to various factors including long-term physical training (Koceja et al., 1993). In power-trained individuals, H-reflex is lower than in non-trained subjects, probably because of relatively high fast-twitch fiber percentage and high activation thresholds of such motor units (Ross et al., 2001). Also, in Clark et al. (2014) study, subjects were men and women, while in ours it was only men (more homogeneous sample). Further, the authors have focused solely upon the soleus muscle, predominantly comprised of slow twitch fibers while we measured medial gastrocnemius muscle, which has higher proportion of fast twitch fibers.

In future studies, some methodology aspects during spinal excitability measurements should be more precisely determined. Stretch and lengthening of the muscle should be limited to a single joint and the movement should be controlled in terms of displacement speed and amplitude. Degree of the applied stretch should be clearly stated and concomitant muscle contraction of either agonists or antagonists should be controlled, because it could reduce the inhibition of H-reflex (this could also be the limitations of present study). Also, additional neural assessment measurements should be provided, enabling detailed analysis of the underlying mechanisms that mediate neural responses to stretching.

Conclusion

The results of this study show that sport-specific warm-up, attenuates acute negative effects of static stretching on vertical jump height but not on neuromuscular excitability in young basketball players. Additionally, our results provide evidence that dynamic stretching appears to cause no significant acute effect on power outputs for this population, isolated or used in combination with a specific basketball warm-up. Practitioners and coaches should not avoid static stretching unnecessarily before practice or competition, especially those that last 30sec per muscle group, because its implementation in the common warm-up practice is unlikely to produce any detrimental effects on vertical jump height in basketball players.

Acknowledgements

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Key points

- Sport-specific warm-up attenuates acute negative effects of static stretching on performance but not on neuromuscular excitability in young basketball players.
- Dynamic stretching, both isolated and with sport-specific warm up, cause no significant acute effect on power outputs.
- Short-duration static stretching implementation in the common warm-up practice is unlikely to produce any detrimental effects on vertical jump height in basketball players.

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