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Original Article

The effect of static and dynamic stretching exercises on the jumping ability of recreational male volleyball players

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Abstract
In the literature, a limited number of trials have examined the long-term effects of static (SS) and dynamic stretching (DS) protocols on the physical performance, while their results appear to be ambiguous. Therefore, the aim of the study was to examine the longitudinal effects of a SS and a DS protocol, on the jumping ability of recreational male volleyball athletes. A total of 50 adult male recreational volleyball players, apparently healthy volunteers, were randomized into three intervention groups: a) the first implemented a SS protocol 3 times/week, b) the second followed a DS program in the same frequency, while c) the third one formed the control group, refraining from practicing in any stretching exercises. All groups participated in a 6-week intervention and the baseline and final countermovement jump field tests. Eight participants were excluded from the final sample due to injuries or other problems, thus, the final sample consisted of 42 athletes (14 in each group). Greater post-test jump heights were noted in the DS group ($p \leq 0.025$, $d=0.678$) in comparison to the pre-test values. A large height × group interaction was observed in the jump tests ($p \leq 0.028$, $\eta^2=0.651$), with the DS group values being greater post-intervention in comparison to the baseline, while no differences were pointed out in either the SS or the control group. Therefore, the implementation of a 6-week DS intervention, at a frequency of 3 sessions/week, is efficient in improving the countermovement jump height of recreational male volleyball players, under the same circumstances, as determined in the protocol herein.
Keywords: **Performance, 3D software, digitizing, countermovement block, coaching.**

Introduction

Stretching exercises consist of a routine task for most athletes, being implemented in-between the general and specific warm-up sessions of an exercise program. Among the distinct stretching techniques, the acute dynamic stretching (DS) seems to be much more effective as compared to the acute static one (SS) (Alipasali et al., 2019). Apart from improving flexibility in the body joints (Harvey et al., 2002; Kamankesh and Shirinbayan, 2018) and upgrading the biomechanical characteristics of athletic movement, stretching exercises also provide the athletes with the maximum possible power as a result of increased range of motion (ROM) (Van Gyn, 1986).

Although in the literature, a plethora of studies have assessed the acute effects of SS and DS exercises on the body muscle performance (Alipasali et al., 2016; Kay and Blazevich, 2012; Kyranoudis et al., 2018), studies assessing the long-term effects of SS (Bazett-Jones et al., 2008; Worrell et al., 1994) and DS exercises on the physical performance are limited, while their results appear to be ambiguous (Herman and Smith, 2008; Woolstenhulme et al., 2006).

Improved performance is linked to a corresponding improvement of muscle flexibility (Medeiros and Lima, 2017), while according to Taber (1995), passive and energetic stretching with eccentric and concentric muscle elongation respectively. Moreover, Göktepe et al. (2010), Kerckhoffs et al. (2011) and their associates linked passive stretching with the formation of new sarcomeres arranged in series and energetic stretching with parallel, perimetrical, fiber formation.

In volleyball, athletes incorporate stretching exercises in the pre-training warm up sessions, employing high vertical jumps and rapid-explosive movements (Barnes et al., 2007). Vertical jumps are usually performed during a block jump, such as the squat block jump (SQBJ), or the countermovement block jump (CMBJ) (Amasy, 2008) in order to counteract the opposed attack spike over the net. Rodriguez-Ruiz et al. (2011) suggested that an efficient block jump may contribute in increasing the effectiveness of front-row defense, especially during the crucial fifth set, or in sets played over 25 points.

Although stretching exercises consist of a routine procedure, a large number of studies indicate that the adoption of acute SS techniques during the warm-up session might reduce physical performance (Behm et al., 2016), by hampering the jumping ability of athletes (Young and Behm, 2003). Nevertheless, current research on

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the athletes' jumping ability after a long-term execution of SS exercises is scarce, while the provided data and the findings are in contrast (Bazett-Jones et al., 2008; Herman and Smith, 2008; Hunter and Marshall, 2002; Woolstenhulme et al., 2006; Yuktasir and Kaya, 2009) compared to the above acute static exercises. According to the available research, the implementation of a 4-week (Herman and Smith, 2008), 6-week (Bazett-Jones et al., 2008; Woolstenhulme et al., 2006; Yuktasir and Kaya, 2009), or even 10-week SS protocol (Hunter and Marshall, 2002) doesn't appear to affect the jumping ability of the lower limbs.

In direct contrast, the jumping performance is clearly enhanced after the implementation of an acute DS program (Curry et al., 2009). On the other hand, only a handful of studies have attempted so far to examine the impact of a few weeks' adherence to a DS protocol on the jumping performance to date, while unfortunately, this was done with questionable success, as their findings are controversial (Göktepe et al., 2010; Herman and Smith, 2008; Wilson et al., 2010). Furthermore, Herman and Smith 2008) as well as Turki-Belkhiria et al. (2014) suggested that the execution of a dynamic stretching protocol of the lower limbs lasting for either 4, or 6 weeks, is efficient in improving the jumping ability in a remarkable degree. Woolstenhulme et al. (2006) reported a lack of differences in the jumping ability after the implementation of a 6-week protocol. The aforementioned results, controversial as they were, encouraged the design of a new study, to review the relationship between differential stretching protocols and the athletes' jumping ability. Therefore, the aim of this study was to examine the effect of two distinct stretching protocols, a dynamic (DS) and a static (SS) one, performed thrice weekly for a total of 6 weeks, on the jumping ability of recreational volleyball players.

Material and Methods

A total of 50 adult male, apparently healthy volunteers, were initially recruited for the study. All participants were university students studying at the Department of Physical Education and Sports Science of the Aristotle University of Thessaloniki, with their schools being situated either in Thessaloniki, or Serres. Participants were all undertaking elective volleyball courses during the time of the study. A total of 8 participants were excluded from the study for either being injured (*n*=6) or for abandoning the procedure (*n*=2), thus the final sample consisted of 42 students. Participant characteristics are detailed in Table 1.

Table 1. Characteristics of the participants in the study groups (Mean ± SD)

Characteristics	Total (*n*=42)	Study Groups: Static Stretching (*n*=14)	Dynamic Stretching (*n*=14)	Control (*n*=14)
Age (yrs)	21.5 ± 1.8	21.1 ± 1.8	22.1 ± 1.6	21.2 ± 2.0
Weight (kg)	81.2 ± 9.0	78. ± 7.5	84.5 ± 9.9	81.0 ± 8.9
Height (m)	1.82 ± 0.06	1.79 ± 0.03	1.85 ± 0.08	1.82 ± 0.04
BMI (kg/m^2)	24.5 ± 2.4	24.3 ± 2.3	24.5 ± 1.7	24.6 ± 3.2
Years of experience	8.1 ± 3.0	7.8 ± 3.6	9.0 ± 2.0	7.4 ± 3.2

Note: BMI = Body Mass Index, SD = standard deviation

All subjects were randomly allocated in three study groups, using blocks of 1:1:1, (1) static stretching (SS) (*n*=14), (2) dynamic stretching (DS) (*n*=14) and (3) control group (*n*=14). All participants had been informed in detail about the purpose of the study and the included procedures, before providing their informed consent. All procedures were performed according to the declaration of Helsinki for research on human subjects and under the approval of the Aristotle University of Thessaloniki's Ethics Committee.

The study lasted between mid-February 2015 until the end of March of the same year. Both stretching and testing protocols were carried out in the inside court of the Department of Physical Education and Sports Science (Aristotle University of Thessaloniki).

Static and dynamic stretching sessions were managed by the study main researcher and lasted for a total of 6 weeks, in agreement to the literature, reporting a 6-week period as the minimum duration required for the detection of improvements on the joints ROM (Rodriguez-Ruiz et al., 2011). Throughout the trial, participants were encouraged to maintain their usual daily activities and, in addition, to include their own stretching exercises. The SS and DS groups performed their distinct stretching protocols at a frequency of 3 times per week, while the control group refrained from performing any type of stretching exercises throughout the study period. At baseline and after the implementation of the stretching protocols (at 6 weeks' time), countermovement jump tests were performed in random order, by all participants.

The SS group performed static stretching exercises of the lower limbs, in the maximum joint ROM, avoiding any soreness. The intervention included six static stretching exercises of the lower limbs performed twice, lasting for 10 seconds each (2x10 sec), with 10 sec rest intervals between the modules when both limbs were used concurrently (Posterior tibial muscles) and without any rest intervals when each leg was stretched separately and alternately (Alipasali et al., 2019) (Table 2).

The DS group performed dynamic stretching exercises of the lower limbs, in the maximum joint ROM, avoiding any soreness, similarly with the SS participants. The protocol consisted of dynamic stretching exercises of the lower limbs, performed twice, while lasting for 10 sec each (2 x 10 sec) with a 10 sec rest interval between exercises using both legs simultaneously (Posterior tibial muscles), for 20 sec (10 sec for each leg) performed twice with a 10 sec rest interval between exercises using both legs alternately (Anterior femoral muscles) and performed twice for each leg without any rest intervals when each limb was stretched separately and alternately (Alipasali et al., 2019) (Table 2).

Jumping tests were performed in the interior of a volleyball court at baseline, and 6 weeks post-intervention initiation. Two JVC 9800 video cameras (120 Hz) were used to record the jumping height, placed at an angle of about 70^o between each other. The first camera was positioned perpendicular to the sagittal plane and the second one was placed behind the participants' back. At first, participants jogged at submaximal power for 5 minutes, followed by their usual volleyball-related dynamic exercises of the lower extremities (for another 5 minutes) (Amasay, 2008) without any jumping efforts.

Table 2: Static and Dynamic Stretching Exercise

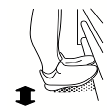
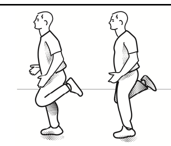
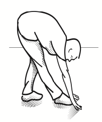
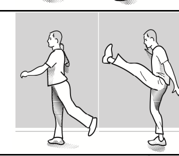
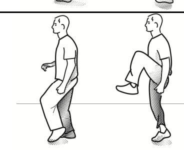
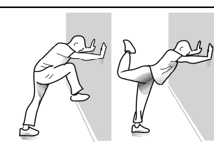
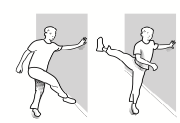
Muscles	Static Stretching Exercises	Dynamic Stretching Exercises
Posterior tibial		
Anterior femoral		
Posterior femoral		
Hip extensor		
Iliopsoas		
Adductor		

Fig. 1: Block Area

The initial jump tests were carried out in a pre-defined rectangular area spanning 82.5 cm long and 45 cm wide, 30 cm away from the court's centerline, in front of the volleyball net, accurately placed in the middle of the centerline (Ficklin et al., 2014). A red ribbon was attached as a mark on the net's top area indicating the block position (Ficklin et al., 2014). Each participant approached and put his feet in the pre-defined area, in random order (Fig. 1). Then they performed a downward movement before going upward (countermovement), penetrating their palms over the net, while keeping the red ribbon between them.

The countermovement block jumps were carried out as high as possible, in order to counteract the opposed attack spike over the red ribbon. Three maximal countermovement block jumps tests were carried out, and the one with the best results was kept and evaluated for each participant. The jump height assessment was carried out with the Ariel Performance Analysis System (APAS, Ariel Dynamics Inc, Trabuco Canyon, CA, USA). Nineteen body landmarks (head, shoulders, elbows, wrists, fingers, hips, knees, ankles, heels, toes) were digitized using 3D software.

Jump height was defined as the height of the vertical displacement of the center of the body mass at takeoff, to the highest point.

Statistical analyses

Statistical analyses were conducted using the Statistical Program for Social Sciences software (SPSS, IBM, Armonk, NY, USA), with the level of significance being set at α=0.05. A 3 x 2 model was performed (3 teams x 2 measurements each) and the assessment of the effects of the different jumping protocols was performed with repeated measures ANOVA, paired t-tests (before-after), and independent t-tests (between-groups comparisons).

Results

Table 3,4 details differences in jump height before and after the intervention, in each study group and between them. Before the intervention, a one way ANOVA analysis showed no significant differences ($F_{(2.39)=}$1.524, p=0.230) between the three groups (SS-DS-OE). A large main effect of height was noted between groups ($F_{(2.26)=}$7.949, p≤0.002, η^2=0.926). Additionally, a large height × group interaction was calculated ($F_{(2.26)=}$4.996, p≤0.028, η^2=0.651), with the DS group demonstrating greater jump height in the final test as compared to the initial measurements (t=2.541, df=13, p≤0.025 two-tailed, d=0.678). On the other hand, no differences were observed in the SS (t=1.281, df=13, p≤0.223 two-tailed) and control groups (t=0.803, df=13, p≤0.437 two-tailed) and between them (SS vs Control) post intervention, (t=1.786, df=26, p≤0.086 two-tailed), but significant differences were showed between DS vs Control group (t=3.469, df=26, p≤0.002 two-tailed) post intervention.

Table 3. Jump height (m) according to the CMBJ test at baseline and after implementation of the two stretching protocols (Mean ± SD)

Group	Baseline (m)	At 6 weeks (m)	Significance (baseline *vs*. 6 weeks)
DS (*n*=14)	40.1 ± 3.9	43.1 ± 3.1*	*p*≤ 0.025
SS (*n*=14)	37.4 ± 4.3	36.0 ± 2.6†††	*p*≤ 0.223
Control (*n*=14)	38.2 ± 4.4	38.3 ± 4.1	*p*≤ 0.437

*Note: CMBJ = countermovement block jump, DS = Dynamic stretching, SD = Standard deviation, SS = Static stretching * Statistically different compared to the baseline values of the same group, according to the paired t-test (* p≤ 0.05)††† Statistically different compared to the DS group at the end of the intervention, according to the independent t-test (††† p≤ 0.001)*

Table 4. Jump height (m) according to the CMBJ test after implementation of the two stretching protocols (Mean ± SD)

	Group (DS)	(Control)	Significance (DS *vs*. Control)
At 6 weeks	43.1 ± 3.1 **	38.3 ± 4.1	*p*≤ 0.002

* *

*Statistically different compared to the Control group values at the end of the intervention, according to the independent t-test (** p≤ 0.002)*

Discussion

The present study examined the efficacy of two distinct stretching protocols, a static and a dynamic one, performed for a total of 6 weeks, on the countermovement block jumping ability of recreational volleyball players. The results indicate a significant improvement in the jumping performance following the implementation of the DS protocol and they are in agreement with those of Herman and Smith (2008) and Turki-Belkhiria et al. (2014). Herman and Smith (2008) used wrestlers to reveal akin improvements on the broad jump performance as the result of a 4-week adherence to a DS protocol, carried out at a frequency of five times per week. In parallel, a study conducted among football players (Turki-Belkhiria et al., 2014) reported similar improvements on countermovement and squat jump performance after 8-weeks of DS performed thrice weekly. On the other hand, Woolstenhulme et al. (2006) failed to observe any improvements on the jumping ability after 6-weeks of DS warming-up sessions, performed twice every week. However, the different methodological approaches used in each of the aforementioned studies might account for the conflicting results. For example, Woolstenhulme et al. (2006) used a sample of basketball athletes of both sexes, with a higher proportion of women than men (27 women *vs*. 16 men). This limitation might have resulted in gender differences in the observed flexibility, given that the female internal tendon of the gastrocnemius muscle is more flexible compared to the male, and thus less susceptible to the effect of stretching exercises ((Dalrymple et al., 2010). Moreover, in the same study (Woolstenhulme et al., 2006), the frequency of implementation of the stretching exercises was rarer (twice per week) when compared to either the protocol suggested by Herman and Smith (five times weekly) (2008), Turki-Belkhiria (three times per week) (2014) or even the present study's (thrice-weekly).

Longitudinal adherence to a DS scheme seems to improve jumping height, as the epiphenomenon of the muscles' dynamic elongation, the increased blood flow, and the improved body coordination (Behm and Chaouachi, 2011). Additionally, Mann and Jones (1999) related long-term DS with enhanced balance, kinesthetic, proprioception, and pre-activation abilities, all of vital importance for any sports activity. Moreover, long-term DS seems to decrease the energy cost of exercise (Weber and Kraus, 1949), while encouraging the re-use of the elastic strain energy (Wilson et al., 1992). According to Shellock and Prentice (1985), DS elevates muscle temperature by inducing rapid, dynamic, and explosive muscle contractions during the jumps.

On the other hand, the SS protocol group failed to improve jumping height, thus revealing its lack of susceptibility to chronic SS adaptations. Similarly, when a 4-weeks SS program was implemented by wrestlers in a frequency of five times each week (Herman and Smith, 208), no improvements were observed in the broad jump. Akin findings were also reported following a 10-week SS workout (four times per week) concerning the countermovement and drop jump of basketball players (Hunter and Marshall, 2002). In agreement to the present findings, no improvements were noted in the vertical jump of female track and field athletes (6-weeks SS, four times per week) (Bazett-Jones et al., 2007), or on the drop jump among physical education university students (6-weeks SS, four times weekly) (Yuktasir and Kaya, 2009). In contrast, improvements were noted on the vertical jump among Hawaiian male and female University students, performing a 10-week SS protocol at a frequency of three times per week (Kokkonen et al., 2007). The dissimilar methodological approach may explain the contradictory results. For example, the recruitment of untrained students in Kokkonen et al. study (2007), indicates that participants had low flexibility and thus might have been affected more by the regular execution of SS exercises, resulting in the reported improvement. Furthermore, Yuktasir and Kaya (2009), suggested that the implementation of SS exercises had detrimental effects on the elastic energy storage and turnover, while Hunter & Marshall (2002) described the jumping performance as the combination of multiple elements involved, including the Golgi tendon organ inhibition, the use of elastic energy, and the connection of the contractile component. Also, Avela et al. (2004) attributed the low performance to the induced changes in the muscle mechanics and the neural actions of the muscles. Finally, as depicted by the results of this study, by abstaining from stretching and thus from muscle elongation throughout the 6-weeks of the trial, participants in the control group failed to display any improvements.

Regarding the aforementioned results, similar findings were noted in the SS and control groups. It is argued however, that stretching exercises reduce the risk of injury (Wilson et al., 1992) and have been proposed to increase the range of motion about a joint, and therefore they are preferred to no stretching, despite the results herein. Moreover, the DS group results were superior to the SS ones, however the total DS stretching time was equal to that of the SS protocol used within this study. This would recommend the way the DS protocol was performed might have had a positive effect on the results of the present study. Possible physiological benefits may be related to increases in core temperature, heart rate and according to Weber and Kraus (1949), the dynamic stretching is more efficient than the static one at enhancing flexibility but the mechanism explaining the vertical jump improvements post-DS are not clear, as the direct measurements of them were not performed in the present study.

Conclusions

Adherence to a DS protocol, performed thrice weekly for a total of 6 weeks, has a positive effect on the jumping height of athletes. Thereafter, the regular implementation of the aforementioned practice by both trainers and athletes might not only serve as a factor enhancing their jumping ability but also as a determinant of high-quality performance in many sports.

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