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Original Article

The effect of static and dynamic stretching exercises on lower limbs concentric strength of amateur male volleyball players

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Abstract
The aim of this study was to examine the effects of implementing a dynamic stretching program and a static, stretching regimen, each performed three times a week, over a total of 6 weeks, on the dynamic characteristics of the lower limbs. The sample comprised 42 healthy, physical education students, former amateur volleyball players,with an average age of 21,48 ± 1,851 years, height of 1,821 ± 0,064 m, body weight of 81,229 ± 9,310 kg and training age of 8,15 ± 3,174 years. Participants were randomly assigned to three groups : one performing dynamic stretching, another performing static stretching and a control group undergoing only initial and final measurements. The test participants performed initial and final laboratory measurements in the Department of Neuro Mechanics of the Department of Physical Education and Sports Science of Serres, in order to evaluate the concentric force in the isokinetic dynamometer, with the Bioware and Bioanalysis analysis programs. For data analysis, the analysis of variance with repeated measurements was used, as well as independent and dependent sample tests and the significance level was defined as $p \leq 0.05$. The control group showed no statistically significant changes in all variables measured. In the dynamic characteristics, the dynamic stretching group showed significant improvement. Instead, the static stretching group showed no improvements in dynamic characteristics, as well as in the control group. It is concluded that dynamic stretching technique clearly superior to static, at dynamic features, when both techniques are performed 3 times per week for one and a half months under the same conditions, as defined in the design of the study.
Key words: dynamic stretching, static stretching, force, velocity, volleyball

Introduction

According to the literature, the majority of studies report a decrease in muscle strength after static stretching (Ogura et al., 2007; Hedra, et al., 2008; Winchester, et al., 2009). Winchester et al. (2009) in college students found a negative effect on peak strength of the posterior femoral muscles after static stretching ranging from 30 to 180 seconds. Hedra et al. (2008) also found a negative effect on peak isometric torque of the right posterior femoral muscle in untrained adult males after static stretching performed 4 times for 30 seconds (4x30′). A reduction in peak isometric contraction was also reported by Ogura et al. (2007) in untrained adult males after static stretching in the posterior femurs for 60 seconds and no effect after static stretching for 30 seconds in the same muscles. Molacek et al., (2010) found no decreases, but also no increases in this capacity in football players whether they performed the static stretches twice for 20 seconds (2X20") or 5 times for 30 seconds (5X30").

However, the above studies refer to the immediate effect of static stretching on muscle strength immediately after its application. Studies examining performance in this capacity after several weeks of static stretching are scarce in the literature and their results are contradictory (Worrell et al., 1994? Handel et al., 1997; Behm, et al., 2006; Herman & Smith, 2008; Laroche et al., 2008). Herman and Smith (2008) found no improvement in peak quadriceps muscle torque in wrestlers after a 4-week static lower limb stretching program of 4 weeks duration and frequency of 5 times per week, as did Laroche et al. (2008) and Behm et al. (2006), the former after a 4-week program and frequency of 3 times per week and the latter after a 4-week program and frequency of 5 times per week. Similar results were also observed in Konrad et al., (2015) study on maximal isometric torque of plantar flexors in police cadets after a 6-week duration and 5 times per week frequency program of static PNF-type stretching.

In contrast to the above authors, Worrell et al. (1994) found increases in meiometric and plyometric isokinetic strength of the posterior femoral muscles at low and medium angular velocities in university students following a 3-week static stretching program at a frequency of 5 times per week. Similar improvements in meiometric and plyometric isokinetic strength at low and high angular velocities, as well as isometric strength of the anterior and posterior thigh muscles were reported by Handel et al. (1997) in swimmers, soccer players and

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track and field athletes following an 8-week proprioceptive neuromuscular facilitation type stretching program at a frequency of 3 times per week. Dynamic-type stretching, in contrast, not only does not reduce muscle strength performance following its application, but appears to sometimes contribute to its improvement (Sekir, et al., 2010). These authors found improvements in peak eccentric and concentric lower limb isokinetic torque in women after dynamic-type stretching performed at a slow and fast pace 2 times with 15 repetitions in each leg. In contrast, Hedra et al. (2008), observed no change in peak isometric torque of the right hamstring muscle in untrained men after dynamic stretching performed 4 times for 30 seconds.

However, the above studies refer to the immediate effect of dynamic stretching on muscle strength immediately after its application. Studies examining the performance on muscle strength after several weeks of dynamic stretching are scarce in the literature and their results are contradictory (Herman et al., 2008; Turki-Belkhiria et al. 2014). Herman and Smith (2008) found improvement in peak quadriceps muscle torque in wrestlers following a 4-week program of dynamic lower extremity stretches at a frequency of 5 times per week. Improvements in peak power and vertical jump strength following an 8-week lower limb dynamic stretching program and a frequency of 3 times per week were also reported by Turki-Belkhiria et al. (2014). In contrast to the above authors, Laroche et al. (2008) did not find an increase in lower limb muscle strength in men following a 4-week dynamic stretching program and a frequency of 3 times per week. Given the controversial literature findings the aim of the present study was to investigate the effect of implementing a dynamic stretching program and another static, performed three times a week, for 6 weeks in total, at the dynamic characteristics of lower limbs.

Material & Methods

Participants

In this study, 42 healthy physical education students, who were former amateur volleyball players and participated in volleyball lessons during the protocol, volunteered to participate. Participants were randomly divided into 3 groups, static stretching group (SS), dynamic stretching group (DS) and control group (CG), and were informed about all the details of the measurements and programs. After the detailed briefing, they gave written informed consent. The athletes were previously familiarized with the execution of the exercises and the measurement procedures of the protocol. The 42 participants were 21.48±1.851 years of age, 1.821±0.064 m tall, 81.229±9.310 kg body weight and 8.15±3.174 years of training age. Ethical permission was granted from the Aristotle University's Ethics Committee and all procedures were in accordance with the Declaration of Helsinki for research on human subjects.

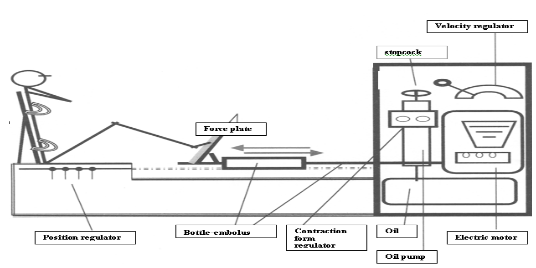
Table 1: Participants

Participants		
N=42	**Mean**	**Std**
Age	21,48	±1,851
Training Age	8,15	±3,174
Height	1,821	±0,064
Weight	81,229	±9,310

Materials

Isokinetic dynamometer

In the research an isokinetic-type device (Ydromechaniki SA) was used (Picture 1), which is located in the Laboratory of Neuromechanics of the University of Serres. Its operation is based on hydraulic pressure. It uses a 15PS electric motor, a 200-litre oil tank and a piston on which the drive platform (PK) is connected. A dynamometer is stabilized on the PK. Through the flow regulator, which adjusts the speed of the platform (piston speed), the speed was adjusted to 0.20m/s.



Picture 1 : Isokinetic Machine

Forceplate

AMTI (ADVANCED MECHANICAL TECHNOLOGY INSTRUMENTS-model number OR 6-6-4000, Serial number 5157, sampling frequency 1000 Hz) Forceplate was used, mounted on a rigid metal frame on the aforementioned isokinetic-type proprietary machine, at an angle of 75° and moved by means of a metal shaft (Picture 2). The Forceplate contains elastic plates, which by applying pressure generate an electrical charge that is transferred to a specific PC.

Procedure

The subjects were assessed on the isokinetic dynamometer, as shown in the picture 1. Specifically, the maximum concentric force (Fmax-syg) of the lower limbs was measured and the instruction was to push the dynamometer with maximum force as it was being pushed away. They were also instructed to keep their pelvis stable and in contact with the seat, as well as their feet with a predetermined surface on the dynamometer, which was marked with a self-adhesive colored tape. At Fmax-syg, the best efforts were selected for analysis based on the maximum force generated.

Picture 2 : Isokinetic machine with Forceplate

Training Protocol

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. 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).

Table 2: Static and Dynamic Stretching Exercise

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

Statistical analysis

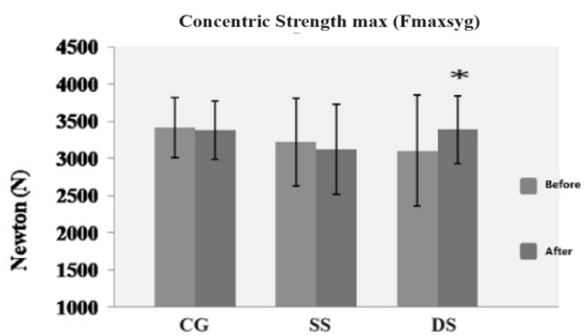
Statistical analysis was performed using the SPSS20 statistical package and the significance level was set at $p<0.05$. To evaluate the effect of the different intervention programs, ANOVA analysis of variance (repeated measures), paired t-test and independent t-test were used to evaluate the effect of the different intervention programs.

Results

A statistically significant interaction (group*time) was found for maximum concentric power (Fmaxsyg) $F(2,39)=7.878$, $p=0.001$, $\eta 2=0.288$, time to achieve maximum concentric power (tFmax) $F(2, 39)=7.082$, $p=0.002$, $\eta 2=0.266$, the time to reach the maximum slope of the force curve (tDF) $F(2,39)=9.328$, $p<0.001$, $\eta 2=0.324$ and the relative force index (RSI), (Fmax/BW), $F(2,39)=5.104$, $p=0.011$, $\eta 2=0.207$.

For the baseline measurement before the intervention programs began, one way ANOVA analysis of variance showed that the means showed no statistically significant difference between the three subgroups, for maximum convergent force (Fmaxsyg) $F(2, 39)=0.949$, $p=0.396$, the time to reach the maximum concentric force (tFmax) $F(2, 39)=1.998$, $p=0.149$, the time to reach the maximum slope of the force curve (tDF) $F(2, 39)=1.101$, $p=0.343$ and the relative force index (RSI), (Fmax/BW), $F(2, 39)=1.208$, $p=0.310$.

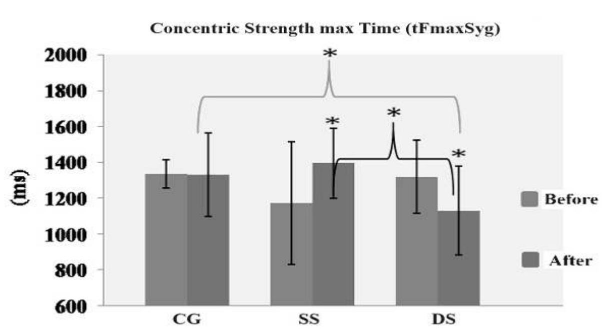
The 281.121 N increase from (M=3104.403, SD=751.464) before the experiment to (M=3385.524, SD=451.338) after the experiment is significant for the dynamic stretching group (t=2.899, df=13, p=0.012, d=0, 775), while a decrease was observed for the static stretching group but not significant (t=2.091, df=13, p=0.057 two-sided), as well as for the control group (t=0.509, df=13, p=0.619) (Graph 1).



Graph 1: Change in Fmaxsyg, before and after the stretching program for all groups, [*= statistically significantly higher for group DS (DSpre vs. DSpost p=0.012).

For the time to achieve peak force (tFmasyg) further analysis showed that the post-experiment mean for the dynamic stretching group (M=1131.071, SD=247, 324) is significantly lower than that of the static stretching group (M=1395, SD=196.126) (t=3.129, df=26, p=0.004 two-sided, d=1.183) and of the control group (M=1331, SD=232.686) (t=2.203, df=26, p=0.037 two-sided, d=0.833).

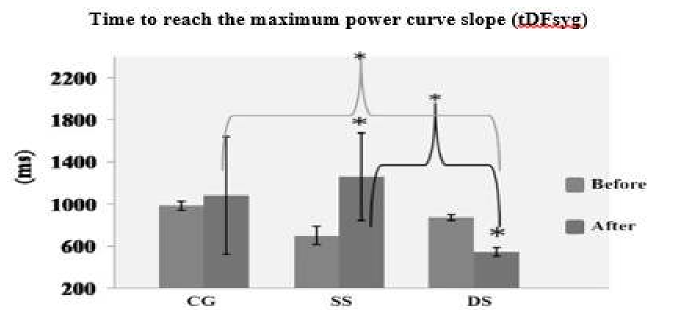
Furthermore, no statistically significant difference was found between the static stretching group and the control group (t=0.787, df=26, p=0.438 two-sided). The decrease of 187.786 ms from (M=1318.857, SD=203.747) before the experiment to (M=1131.071, SD=247.324) after the experiment is significant for the dynamic stretching group (t=2.623, df=13, p=0.021, d=0.701), as well as the increase of 221, 357 ms for the static stretching group from (M=1173.643, SD=342.552) before the experiment to (M=1395, SD=196.126) (t=2.348, df=13, p=0.035 two-sided, d=0.627), while the control group showed a decrease but not significant (t=0.055, df=13, p=0.957) (Graph 2)



Graph 2 : Change in tFmasyg achievement time, before and after the stretching program for all groups, [*= statistically significantly lower for the DS group (DSprε vs.DSpost p=0.021), (DSpost vs.SSpost p=0.004), (DSpost vs.OEpost p=0.037), statistically significantly higher for the SS group (SSpre vs.SSpost p=0.035)]

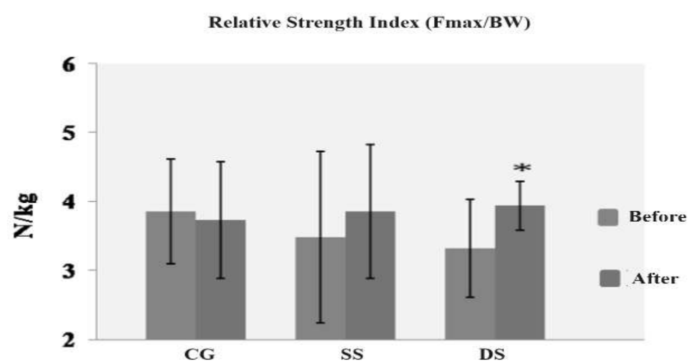
For the time to reach the maximum slope of the force curve (tDF), further analysis showed that the post-experiment mean for the dynamic stretching group (M=544.286, SD=40, 814) is significantly lower than that of the static stretching group (M=1263, SD=414.714) (t=4.669, df=26, p<0.001 two-sided, d=1.765) and than that of the control group (M=1083.214, SD=556.898) (t=2.939, df=23.619, p=0.007 two-sided, d=1.111).

Furthermore, no statistically significant difference was found between the static stretching group and the control group (t=0.974, df=24.027, p=0.340 two-sided). The decrease of 328.571 ms from (M=872.857, SD=28.136) before the experiment to (M=544.286, SD=40.814) after the experiment is significant for the dynamic stretching (DS) group (t=2.475, df=13, p=0.028, d=0.661), as well as the increase of 561, 786 ms for the static stretching group from (702.143±84.731) before the experiment to (M=1263, SD=414.714) (t=3.871, df=13, p=0.002 two-sided, d=1.035), but not the increase for the control group (t=0.621, df=13, p=0.545) (Graph 3)



Graph 3 : Change in time to reach the maximum power curve slope (tDFsyg), before and after the stretching program for all groups, [*= statistically significantly lower for group DS (DSpre vs.DSpost p=0.028), (DSpost vs.SSpost p<0.001), (DSpost vs.OEpost p=0.007), statistically significantly higher for group SS (SSpre vs. SSpost p=0.002)]

For the relative strength index (RSI) (Fmax/BW), the increase of 0.619 N/kg from (M=3.32, SD=0.71) before the experiment to (M=3.939, SD=0.356) after the experiment is significant for the dynamic stretching group (t=3.846, df=13, p=0.002, d=1.013), but not for the static stretching group (t=1.746, df=13, p=0.104 two-sided), and the decrease for the control group (t=1.155, df=13, p=0.269) (Graph 4)



Graph 4 : Change in relative strength index (RSI), (Fmax/BW), pre and post the stretching program for all groups, [*= statistically significantly higher for the DS group (DSpre vs.DSpost p=0.002)

Discussion

In the dynamic characteristics of the athletes derived from the in-lab isokinetic multiarticular dynamometer, the dynamic stretching group showed improvement in maximum concentric force, relative force index, and improvement in the time to achieve the maximum slope of the force curve and the time to achieve maximum concentric force, demonstrating that after the protocol was implemented, the group participants became stronger and faster and more explosive.

The results of the present study are in agreement with similar results of other studies (Herman & Smith, 2008; Turki-Belkhiria et al. 2014). Turki-Belkhiria et al. (2014) found in football players improvements in maximal power, strength and height in the vertical jump with a reclining movement and height in the jump from a semi-sitting position after an 8-week dynamic lower limb stretching program at a frequency of 3 times per week, where two sets of 14 repetitions (2x14) were performed in each leg. Herman and Smith (2008) also found in wrestlers an improvement in peak quadriceps muscle torque in the unweighted long jump after a 4-week lower limb dynamic stretching programme of 4 weeks and a frequency of 5 times per week, where 10 repetitions (1x10) were performed in each leg.

In contrast to the present study are the results of Laroche et al. (2008) and Woolstenhulme et al. (2006). Laroche et al. (2008) found no increase in lower limb muscle strength in men after a 4-week programme of dynamic stretching at a frequency of 3 times per week, where 10 sets of 30 seconds (10X30'') were performed each time. Woolstenhulme et al. (2006) also found no reductions, but no improvements in vertical jump in female basketball athletes after a 6-week programme of dynamic lower limb stretches at a frequency of 2 times per week, performed 2 times for 30 seconds (2 x 30'') in each leg.

The conflicting results may be due to the different methodological approach. In the present study, the dynamic stretching protocol applied had a duration of 6 weeks and a frequency of 3 times per week, whereas in the study by Laroche et al. (2008) the duration of 4 weeks seems to be insufficient duration to increase the length of muscle bundles and create adjustments in joint range of motion and consequently in the speed of muscle contraction and the ability to apply force rapidly (Earp et al. 2010). In the study by Woolstenhulme et al. (2006) the duration was 6 weeks and the frequency was twice a week, which was a shorter duration than the present study and the sample consisted of female basketball athletes, which presumably women have better flexibility than men (Alter, 1996). This sparse frequency of stretching repetitions per week and the sample of subjects appears to be an insufficient stimulus due to the already improved flexibility of the medial gastrocnemius tendon seen in women (Dalrymple et al., 2010).

In the group that performed the static stretching program, in the dynamic characteristics of the athletes derived from the isokinetic multiarticular dynamometer in the laboratory, the maximum concentric force remained unchanged, as well as the index of relative force, but the time to reach the maximum concentric force and the time to reach the maximum slope of the force curve increased.

These results are in agreement with similar results from other studies (Bazett-Jones et al., 2008; Herman & Smith, 2008; Marshall, et al., 2011; Morton et al, 2011; Blazevich et al. 2014) and in contrast to the results of Worrell et al. (1994), Handel et al. (1997), and Kokkonen et al. (2007). Worrell et al. (1994) found in university students increases in meiometric and plyometric isokinetic strength of the posterior femoral muscles at low and medium angular velocities after applying 3-week static stretches to the lower limbs at a frequency of 5 times per week. Handel et al. (1997) observed increases in meiometric, plyometric isokinetic strength, and isometric strength, of the anterior and posterior femoral muscles after applying an 8-week proprioceptive neuromuscular facilitation-type stretching program to a single limb at a frequency of 3 times per week in swimmers, soccer players, and track and field athletes. Finally, Kokkonen et al. (2007) found improvement in vertical jump after 10 weeks of static lower limb stretching in untrained students.

The conflicting results may be due to the different methodological approach, such as the different duration of the stretching programs, the type of stretches and the pre-existing physical condition of the trainees. In the present study, the static stretching protocol applied had a duration of 6 weeks, whereas the research by Worrell et al. (1994) had a duration of 3 weeks, which was a much shorter duration than the present study, and the measurements were performed at low and medium angular velocities. According to these authors the increase observed may have been due to the effect of stretching on the myotendinous system, which in turn may affect neuromuscular transmission. In addition, according to the research of Alipasali (2013), it is possible that static stretching may have a greater effect on joint movements performed at higher angular velocities. In the study by Handel et al. (1997) the stretching programme was 8 weeks long, the stretching was performed on one limb only and was of the proprioceptive neuromuscular facilitation type. The improvement these authors found was compared to the other limb, which did not participate in any type of stretching and was the control limb. Finally, in the study by Kokkonen et al. (2007) the participants were untrained and therefore probably had more rom for further improvement.

The mechanisms that are activated for performance after static stretching appear not to have been fully elucidated in the existing literature. According to Shellock and Prentice (1985), increased muscle temperature appears to positively affect rapid dynamic and explosive muscle contractions. As a result, it is unclear whether the decrease in performance is the result of static stretching or the decrease in muscle temperature caused by the immobility resulting from static stretching. The decrease in performance following static stretching in stretching conditions of a training unit is likely to be due to neurological factors (Avela et al., 1999; Avela et al., 2004), to a decrease in muscle stiffness, which probably reduces the transmission of force from the musculature to the musculoskeletal system (Wilson et al., 1994), the reduction in blood flow during static elongation (Poole et al., 1997) and possibly the increase in calcium ion levels induced by repetitive stretching (Westerbland, et al., 2000). The decrease in performance after static stretching may also be due to muscle tissue destruction. Smith et al. (1993) found an increase in creatine kinase after long-duration static stretching.

Conclusion

Based on the limitations of the present study, it is concluded from the results that the dynamic muscle lengthening technique is clearly superior to the static one on the lower limb concentric strength when both techniques are performed 3 times a week for one and a half month under the same conditions, which were defined during the study design.

The results of the study also suggest to coaches that stretching technique that they should possibly apply systematically to their athletes, since the sport of volleyball requires its players to have effective blocks, putting the player in an advantageous position over the opponents, in order to achieve a positive outcome of the game.

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