Effects of Varying Volumes of Dynamic Stretching on Active Range of Motion, Reaction Time, and Movement Time in Female Soccer Players

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ABSTRACT

Chatzopoulos D, Kapodistria L, Doganis G, Messaritakis V, Lykesas G. Effects of Varying Volumes of Dynamic Stretching on Active Range of Motion, Reaction Time, and Movement Time in Female Soccer Players. JEPonline 2019;22(5):147-156. The aim of this study was to examine the acute effects of varying volumes of dynamic stretching (DS) on active range of motion (ROM), reaction time (RT), and movement time (MT). Twenty-four female soccer players (age, 15.08 ± .88 yrs) participated in 4 randomly ordered experimental conditions: (a) control containing 5-min jog; (b) 5-min jog and 6 repetitions of DS (DS-6); (c) 5-min jog and 12 repetitions of DS (DS-12); and (d) 5-min jog and 18 repetitions of DS (DS-18). ROM, RT, and MT were measured following all conditions. Flexibility increased following all DS conditions compared to the control. Moreover, MT was significantly improved after DS-6 and DS-12 compared to the control values, but there were no significant differences between DS-18 and control. In relation to RT, there were no significant differences between the experimental conditions. These results suggest that a DS protocol of 6 repetitions results in similar increases in ROM compared to 12 and 18 repetitions. In addition, dynamic stretch volumes with more than 18 repetitions may impair MT. According to the results of the study, the optimal volume of DS to improve active ROM and MT seems to be between 6 to 12 repetitions.

Key Words: Range of Motion, Reaction Time, Soccer, Stretching.
INTRODUCTION

Traditionally, static stretching is an integral part of a warm-up to improve performance and prevent injuries (6). Recent studies revealed that static stretching used in warm-up protocols impairs strength, speed, and jumping performance and suggest that instead, athletes should perform dynamic stretching exercises (4,20). Dynamic stretching (DS) involves the repetition of a movement through the full range of motion several times in a controlled manner without a held end position (14).

Many studies using DS reported better strength and speed performance compared to static stretching (4), and the majority of the trainers (e.g., Brazilian soccer trainers, track and field, and American football) use nowadays DS protocols before sport activities (27,28). However, the previous studies focused mainly on the effects of DS on strength parameters and only a limited number of the studies examined the effects on flexibility (12).

Flexibility is the ability to move a joint through its complete range of motion (ROM), which is important in sport and daily activities (1). Although sport performance demands mainly active ROM, the majority of the studies examined the effects of DS on static ROM (i.e., ROM was measured in a static position of the target joint) (3,14,15). However, success in many sports activities depends more on active rather than static ROM, and it is well documented that there is no relationship between them (2). Therefore, the first purpose of the study was to investigate the effects of DS on active ROM.

Previous studies demonstrated that the volume (repetitions) of DS influences strength, power, and speed properties (10,24). According to Yamaguchi and Ishii (28), explosive performance becomes impaired due to fatigue as the volume (repetitions) of DS increases. In relation to ROM, the few studies that have examined the effects of various volumes of DS on static ROM reported conflicting results (12,18). For instance, Ryan et al. (2014) reported that 6 repetitions of DS resulted in significant ROM improvements; whereas, Mizuno (12) reported no improvements after 15 repetitions of DS. According to Mizuno (12), improvements in ROM were observed after 4X15 repetitions of DS. Hence, more studies are needed to determine the optimal number of DS repetitions to improve ROM.

Reaction time (RT) and movement time (MT) are important variables for successful participation in sports. For instance, a defender in soccer needs a rapid RT and MT to block a shoot and a goalkeeper to make a successful save. However, only a limited number of studies have investigated the effects of DS on RT and MT and their results are inconsistent (7,8,19). For example, one study used 15” DS and reported no significant effects on RT and MT (8), while another study used 30” DS and reported positive effects on MT (7). Moreover, studies comparing the effects of static versus dynamic stretching, reported that 5 to 8 DS repetitions did not significantly improve explosive performance (9,26) and Paradisis et al. (17) reported that 20 DS repetitions impaired performance. It seems that there is a dose-dependent response of performance to varying numbers of DS repetitions.

Therefore, the purpose of this study was to investigate the effects of varying repetitions of DS on RT, MT, and active ROM performance.
METHODS

Subjects
Twenty-four female soccer players with no history of lower limb injury or neuromuscular diseases specific to the lower limb volunteered to participate in this study (age, 15.08 ± .88 yrs; body mass, 56.85 ± 8.37 kg; height, 161.83 ± 5.75 cm; training years, 3.35 ± 1.25; 3 training unit wk⁻¹, and Sunday match). Informed consent was obtained from the guardians and the participants, and they could withdraw from the study at any time. This study was conducted in accordance to the ethical guidelines of the local University and all procedures followed the latest version of the declaration of Helsinki.

Procedures
Before data collection, the subjects attended 1 orientation session 7 days before the inception of the protocols, in which they were familiarized with the stretching procedures and the performance measures. The subjects performed 4 experimental protocols at the same time of the day (17:00 to 19:30 hr), with a period of 48 hrs between them. The order of the protocols and the tests were counterbalanced per subject and per day to avoid carry over effects. Each protocol began with a 3-min jog at a self-selected moderate intensity. After the jog the subjects performed 1 of the 3 DS protocols: (a) 6 repetitions of DS (DS-6); (b) 12 repetitions of DS (DS-12); or (c) 18 repetitions of DS (DS-18). The test measures were performed 2 min after completing the assigned protocol. In the control condition, the subjects performed the test measures after a 3-min jog and a 2-min rest.

Dynamic Stretching Exercises
Participants were instructed to try and attain the maximal ROM during dynamic stretching in a controlled manner without bouncing. The exercises were performed at a rate of ~1 stretch cycle every 2 sec, however this inevitably varied due to the range of movement used by each participant.

The DS exercises included the:

- **Quadriceps Stretch (Figure 1A):** The subjects flexed the knee until the heel touched the buttock.

- **Hamstring Stretch (Figure 1B):** In the standing upright position, the subjects lifted one extended leg and then return to starting position.

- **Iliopsoas Stretch (Figure 1C):** The subjects flexed the hip and knee as close to the chest as possible. When maximum knee height was reached, the subjects brought forcefully the hip into extension. In order to isolate the iliopsoas, the subjects maintained an upright trunk posture and avoided any internal and external rotation of the hip throughout the motion.
Dynamic Flexibility Measurement
All measurements were conducted with the dominant leg. Dynamic flexibility was measured with an electro-goniometer (0.02° accuracy, sampling frequency 100 Hz, www.vernier.com) using the active straight leg raise test. The reference point for the axis of the goniometer was the greater trochanter, and the other reference point was the lateral femoral epicondyle (0°). The subject lifted the leg as high as possible 2 times, while keeping the knee extended. The better of the 2 performance was used for data analysis.

Reaction Time (RT) and Movement Time Measurement (MT)
RT and MT were measured using a reaction timer apparatus (Lafayette Instruments Co., model 63017). The apparatus comprises a start button and a stop button that are situated on the floor (50 cm distance). From a standing position, the subject pressed the start button with her dominant foot. Upon illumination of the light bulb, the subject released the start button and moved her foot forward to touch the stop button. This action involved hip flexion (iliopsoas) and knee extension (quadriceps). The RT was defined as the time between the light stimulus and the release of the start button. The MT was defined as the time between the initiation of the movement (i.e., the release of the start button) and pressing the stop button. The subjects performed 1 practice attempt and 3 trials with a 30-sec rest period between each trial.

Statistical Analyses
In order to investigate the differences between the 4 protocols, the data were analyzed using a one-way Analysis of Variance (ANOVA) repeated measures. The distribution of all variables was examined using the Shapiro-Wilk test and no significant difference was found. In cases where the assumption of sphericity was violated, the Greenhouse-Geisser correction was employed. Post hoc analyses were conducted using Bonferroni pairwise comparisons. Intra-session (within 1 session) and inter-session (between sessions) reliability was quantified by
the Intraclass Correlation Coefficient (ICC). All statistical analyses were conducted using SPSS (version 20). The statistical significance was set at P ≤ 0.05.

RESULTS

Descriptive statistics of the dependent variables are presented in Table 1.

Table 1. Reaction Time (RT), Movement Time (MT) and ROM of Control, After 6 (DS-6), 12 (DS-12), and 18 Repetitions (DS-18).

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>DS-6</th>
<th>DS-12</th>
<th>DS-18</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROM (deg)</td>
<td>109.50 ± 10.58</td>
<td>116.30 ± 11.24*</td>
<td>117.15 ± 12.04*</td>
<td>118.23 ± 11.49*</td>
</tr>
<tr>
<td>RT (ms)</td>
<td>360.91 ± 53.52</td>
<td>340.08 ± 56.55</td>
<td>346.33 ± 61.81</td>
<td>350.04 ± 69.03</td>
</tr>
<tr>
<td>MT (ms)</td>
<td>613.95 ± 83.41</td>
<td>577.66 ± 71.42*</td>
<td>579.20 ± 72.72*</td>
<td>594.79 ± 85.47</td>
</tr>
</tbody>
</table>

*Significant difference between the corresponding condition and control (P < 0.05).

ROM

Mauchly's Test of Sphericity indicated that the assumption of sphericity had been violated, χ² = 15.37, P=0.009 and, therefore, a Greenhouse-Geisser correction was used. There was a significant effect of the different conditions on ROM (F₂.₁₆, ₄₉.₆₇ = 11.07, P=0.001, partial eta squared η_p² = .325).

Bonferroni correction revealed that ROM of the control condition was significantly smaller compared to DS-6 (t_{DS-6} = 4.06, P=0.003, 95% CI [3.34, 10.25], Cohen’s d = .62), DS-12 (t_{DS-12} = 3.72, P=0.007, 95% CI [3.40, 11.89], Cohen’s d = .67) and DS-18 (t_{DS-18} = 6.49, P=0.001, 95% CI [5.49, 11.51], Cohen’s d = .79). There were no significant differences between the other DS conditions.

The Intraclass Correlation Coefficient (ICC) for intra-session reliability (within one session) was good to excellent (ICCs between .73 and .82). The ICC for inter-session reliability (between sessions) was .73.

Movement Time

Repeated measures ANOVA indicated a significant difference between the experimental conditions (F = 4.168, P=0.009, partial eta squared η_p² = .153). Bonferroni correction revealed that the DS-6 and DS-12 performed significantly better compared to the control (t_{DS-6} = 2.96, P=0.04, 95% CI [10.95, 61.62], Cohen’s d = .46 and t_{DS-12} = 4.13, P=0.02, 95% CI [17.38, 52.11], Cohen’s d = .44, respectively). There were no differences between DS-18 and the other conditions.

The ICC for inter-session reliability was .76 and the intra-session reliability was excellent (ICCs between .77 and .87)
Reaction Time
Mauchly's Test of Sphericity indicated that the assumption of sphericity had been violated, $\chi^2 = 19.747$, $P=0.001$, and therefore, a Greenhouse-Geisser correction was used. There was no significant effect of the experimental conditions on RT ($F_{2.17, 50.03}=2.16$, $P=0.122$, partial eta squared $\eta_p^2 = .086$).

The ICC for inter-session reliability MT was .73 and the intra-session reliability was good to excellent (ICCs between .71 and .82).

DISCUSSION
The purpose of this study was to examine the effects of varying repetitions of DS on active ROM, RT, and MT. According to the results of the study, ROM improved significantly after 6 DS repetitions (DS-6) compared to the control condition, but did not increase further after 12 (DS-12) or 18 repetitions (DS-18). Regarding MT, DS-6 and DS-12 showed better results compared to the control condition, but there was no significant difference between DS-18 and control. In relation to RT, there were no significant differences between the conditions.

Active ROM is an important component for successful sport participation. The present study revealed that the increase in active ROM after DS plateaued after 6 repetitions. This finding is in agreement with Ryan et al. (18) who demonstrated that 6 repetitions of DS improved static ROM compared to the control and reported no significant differences between 6 and 12 repetitions. Moreover, Taylor and colleagues (21) reported that after 4 repetitions there was little alteration of the muscle-tendon unit. They suggested 4 repetitions as the minimum number to increase flexibility. On the other hand, Mizuno (12), investigated the effects of DS on static ankle ROM and reported the following: (a) no differences between 15 DS repetitions and the control condition; (b) increased ROM after 4X15 repetitions compared to 15 and the control; and (c) the increase plateaued after 4X15 repetitions with no significant difference to 7X15. The different findings may be attributed to several factors, such as muscle group and stretch velocity. For example Ryan et al. (18) stretched the muscles of the lower body at a high tempo; whereas, the subjects in the study by Mizuno (12), performed active dorsiflexion and passive plantarflexion of the ankle at a slow tempo. Considering the fact that fast velocities of DS result in greater muscle performance than slow ones, the comparison of the results between studies with different DS velocities should be done with caution (11).

Other factors that may affect the magnitude of the DS-induced effects on ROM may be related to the testing protocols (e.g., sit-and-reach test vs. isolated muscle measurements), sex, age, and physical training (5,14). The subjects in the present study were adolescent females while those of Ryan et al. (18) and Mizuno (12) were male adults. Therefore, the comparison of results between the studies should be done with caution as the viscoelastic properties of the muscle-tendon units between females and males and between adolescents and adults differ (e.g., muscle stiffness is greater in males than in females) (13). Moreover, the subjects in the present study were trained athletes while the subjects in the other studies were recreational athletes. Also, there is the concern as to whether trained athletes react differently to stretching than untrained subjects who are less susceptible to stretching-induced changes (25).
Several studies reported improvements in ROM after DS, but the underlying mechanisms are still unclear. The suggested mechanisms for ROM improvements following DS are increased muscle temperature and changes in certain neural and/or mechanical factors (12,16). Some researchers supported the view that repeated muscle contraction during DS increases the subjects’ muscle temperature and decreases the viscous resistance, which leads to an enhancement of tissue extensibility (18). On the other hand, Mizuno (12) attributes the ROM increase after DS to changes in specific neural factors that allowed for an increase in pain tolerance; whereas, Pamboris (16) attributed the improvement to increase tendon elongation. Therefore, it is not clear whether ROM improvements after DS can be attributed to neural or mechanical factors, or both.

Regarding MT, the results of the present study showed that performance improved after DS-6 and DS-12 compared to the control, but decreased after DS-18 with no significant difference compared to the control. The better performance after DS-6 and DS-12 could be attributed to the post-activation potentiation effect (PAP), which refers to the phenomenon by which muscle performance is enhanced as a result of their contractile history (23). The content of the DS protocol in the current study consisted of similar movements to the procedure of the MT test, therefore, the pre-test contractions may have elicited a PAP response contributing to the significant improvements after DS-6 and DS-12. In relation to the non-significant finding between DS-18 and the control, it seems that muscle potentiation and fatigue coexisted during the DS and the subsequent performance depended upon the balance between the two factors. Consequently, it is possible that both the DS-6 and DS-12 conditions potentiated the MT performance, but after DS-18 the accumulation of fatigue may overcome positive stretch-induced effects. Therefore, it seems that the DS enhanced the subsequent MT performance up to the onset of fatigue. Given that the current study failed to reveal any alterations in RT between the DS conditions and the control, it appears that the fatigue after DS-18 may be primarily of muscular origin. Clearly, more studies are needed to clarify this point.

The results of the present study are not consistent with those reported by Chatzopoulos et al. (8), that 12 DS repetitions do not improved MT compared to the control. In the current study, MT was examined in the lower limbs while Chatzopoulos et al. (8) examined the upper limbs. Given the differences in reflex behavior between different muscles (22) and the significant differences in the functional requirements required of the upper and lower limbs muscles, comparison of the results involving different muscle groups should be done with caution.

**Limitation in this Study**

Although the examiner instructed the subjects during the DS “to stretch as high as possible”, it was not possible to determine that they actually performed full extensions with each stretch.

**CONCLUSIONS**

The findings in this study indicate significant improvements in ROM and MT after 6 repetitions relative to the control. Moreover, there were no significant differences between 6, 12, and 18 repetitions, which indicate that the initial increase in active ROM and MT plateauded after 6 repetitions. Accordingly, dynamic stretch volumes with more than 6 repetitions do not seem to further increase ROM and MT performance (i.e., for as long as fatigue stays insignificant). In relation to RT, there were no significant differences between the various DS conditions and
the control. It seems that the optimal DS protocol to improve active ROM and MT ranges between 6 to 12 repetitions.

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