South African Journal for Research in Sport, Physical Education and Recreation, 2012, 34(2): 15-25.
Suid-Afrikaanse Tydskrif vir Navorsing in Sport, Liggaamlike Opvoedkunde en Ontspanning, 2012, 34(2): 15-25.
ISBN: 0379-9069

EFFECTS OF DYNAMIC STRETCHES ON ISOKINETIC HAMSTRING AND QUADRICEPS FEMORIS MUSCLE STRENGTH IN ELITE FEMALE SOCCER PLAYERS

Serap COLAK
School of Physical Education and Sport, Department of Recreation, Kocaeli University, Kocaeli, Turkey

ABSTRACT

This study investigated the effects of dynamic stretches on isokinetic hamstring (H) strength, quadriceps femoris (Q) strength, and the H/Q ratio in elite female soccer players. Fifteen elite female soccer players (age: 22.13±2.69; height: 164.53±7.57; weight: 57.8±7.86) participated in the study. The length of the lower extremity and the circumference of the thigh were measured for each subject. On different days, isokinetic muscle strength of the participants was measured twice using a Biodex dynamometer and concentric/concentric 60˚/s, 180˚/s and 300˚/s test protocols. Knee flexion-extension range of motion (ROM) was measured using goniometry at two different times. After a non-stretching warm-up, the peak torque (PT) of the H and Q muscles at 60˚/s, 180˚/s and 300˚/s were measured. The H/Q ratios were calculated for 60˚/s, 180˚/s and 300˚/s. In addition, the PT values for the latter were calculated after dynamic stretches for H and for Q. Comparisons between the H and Q measurements showed a significant difference between peak torques, H/Q ratios, and ROM (p<0.01). In conclusion, dynamic stretches have positive effects on muscle strength, H/Q ratios and ROM. Therefore, dynamic stretches may increase performance and reduce the risk of injury to athletes.

Key words: Quadriceps; Hamstrings; Muscles Isokinetic; Dynamic stretches.

INTRODUCTION

Hamstring injuries are common in many sports, including running, soccer, football and basketball (Zakas *et al*., 1995; Orchard & Seward, 2002; Arnason *et al*., 2004; Woods *et al*., 2004; Bamac *et al*., 2008; Silder *et al*., 2010). Playing soccer requires high speed and strength of the lower extremities. Thus, a reduced range of motion due to weakness or shortness in the muscles of the lower extremities increases the risk of injury (Yamamoto, 1993; Worrell, 1994; Alter, 1997). In previous studies, 80% of injuries in soccer players were found to affect the lower extremities, and of these, 47% were in the hamstring muscles (Ekstrand & Gillquist, 1983). In a more extended study, 10% of the injuries in one season of soccer were found to be injuries in the hamstring muscle (Morgan & Oberlander, 2001).

Awareness of the morphology, flexibility and strength of the hamstring muscles will reduce the risk of injury (Silder *et al*., 2010). Stretching is typically believed to increase joint range of motion or flexibility, which promotes greater sporting ability by improving muscular performance and reducing the risk of musculoskeletal injury (Shellock & Prentice, 1985; Alter, 1997; Sekir *et al*., 2010).

To prevent injury, muscles should be subjected to stretching and strengthening exercises. Athletes and coaches use many different types of stretching. The type of stretching performed is usually based on personal preference only. No optimal type or amount of stretching has been identified. There are various techniques of stretching, including ballistic, proprioceptive neuromuscular facilitation (PNF), static and dynamic stretches (Sekir *et al*., 2010). Stretching exercises are known to have immediate and late effects depending on the subjected muscle group. Stretching has been found to increase flexibility and thereby increase muscle performance (Shellock & Prentice, 1985; Alter, 1997; Gleim & Mchugh, 1997; Gallon *et al*., 2011).

However, some authors have argued that stretching exercises have only a limited effect on muscle strength and resistance (Fowles *et al*., 2000; Behm *et al*., 2001; Church *et al*., 2001; Young & Behm, 2003). Dynamic stretches (DS) involve using the weight of the body to increase the flexibility of muscle fibres. DS involve contraction of the muscle fibres while they are being stretched. No study to date has directly investigated the effect of dynamic stretches on musculoskeletal injury risk characteristics. Therefore, the role of dynamic stretching remains unknown (Sekir *et al*., 2010).

Muscular imbalances between agonist and antagonistic muscles have been suggested as a possible cause of sport-related injuries (Grace, 1985; Aagaard *et al*., 1997; Soderman *et al*., 2001; Devan *et al*., 2004; Bamac *et al*., 2008). The most common method used to assess muscular imbalance is the ratio of isokinetic agonist to antagonist muscle strength. Isokinetic testing can be used to evaluate quadriceps and hamstring muscle strength, allowing the determination of the magnitude of the torque generated and subsequently the hamstring to quadriceps (H/Q) muscle strength ratio (Bamac *et al*., 2008). The H/Q isokinetic peak torque ratio has been used to assess muscle balance and the functional ability of the knee (Holmes & Alderink, 1984; Aagaard *et al*., 1995; Bamac *et al*., 2008). An abnormal H/Q muscle ratio may reflect a predisposition to injury (Knapik *et al*., 1991; Aagaard *et al*., 1997; Devan *et al*., 2004; Bamac *et al*., 2008). Dauty *et al*. (2003) have shown that an H/Q ratio of less than 0.6 at 60˚/s represents a 77.5% probability of injury to the hamstring muscle in elite soccer players.

The quadriceps femoris and the hamstring muscle groups are involved in several important motor abilities such as running and jumping in soccer. This study aimed to investigate the effects of DS on isokinetic hamstring (H) strength, quadriceps femoris (Q) strength and the H/Q ratio in elite female soccer players. Imbalance in the H/Q ratio is known to increase the risk of injury. To eliminate the imbalance and prevent injury, athletes can practise stretching and strengthening of the muscles.

MATERIALS AND METHODS

Subjects

Fifteen (N=15) elite female soccer players (age: 22.13±2.69; height: 164.53±7.57; weight: 57.8±7.86) participated in this study. They had been active in high-level soccer competitions (they were members of the team that won the 2010 Turkish inter-university soccer tournament and was placed 4th in the 1st European Universities Football Championship in Futsal) for 4.6 (range: 3 to 8) years and practised 8 hours/week. Before the initiation of the study, the subjects were asked to complete a questionnaire to determine whether they had any musculoskeletal pain, discomfort or known injury in a lower extremity. Soccer players were excluded from the study if they had a current or recent lower extremity injury, if they had complaints of pain, swelling, or functional limitations in these joints, or if they had apparent limitations in their knee range of motion.

Each soccer player was informed of the testing procedures, and their written informed consent was obtained. This study was conducted according to the guidelines of the Declaration of Helsinki and was approved by the ethics committee of Kocaeli University.

All the measurements were obtained before the soccer season. First, anthropometric dimensions of the players were measured, such as the height, weight, body mass index (BMI), the length of the dominant lower extremity, thigh circumference and knee ROM at flexion and extension. This was followed by measuring hamstring strength using an isokinetic dynamometer (Biodex Multi-Joint System 3, Biodex Medical Systems, Inc., Shirley, NY, USA). These measurements were acquired on different days after two different warm-up exercises were performed by the same players. For the first measurement, the players were asked to refrain from stretching before the test (non-stretching) and then to do mild warm-up exercises immediately before the test. For the second measurement, isokinetic muscle strength measurements were taken immediately after the subjects did warm-up exercises mostly consisting of DS.

Anthropometric measurements

The measurements were conducted at the Physical Education and Sport Department laboratory of Kocaeli University. All the measurements were taken in a ventilated area at 22-25˚C. The measurement times were between 10h00 and 16h00 during 4 days of the week.

The height (cm) and weight (kg) of the players were measured with Tanita, and their BMIs were calculated. The length (cm) of the dominant lower extremity and the thigh circumference (cm) of the players were measured using a measuring tape. The length of the lower extremity was defined as the distance between the anterior superior iliac spine and the medial malleolus. The thigh circumference was measured at midway between the anterior superior iliac spine and the lateral condyle of the femur (Otman *et al*., 1995).

Knee flexion-extension ROM was measured with a goniometer. The measurements were conducted with players in a prone position. The pivot point was the lateral condyle of the femur. The fixed handle of the goniometer was placed on the lateral midpoint of the hamstring, and the mobile handle was placed on the fibula during the measurements (Otman *et al*., 1995).

Dynamic stretches

Isokinetic muscle strength measurements were performed on different days. For the first measurement, isokinetic muscle strength of the hamstring and quadriceps were measured after non-stretching (NS) mild warm-up exercises. For the second measurement, a DS protocol was used to warm-up the hamstring and quadriceps prior to isokinetic muscle strength assessment. The DS protocol consisted of 2 stages (the 5 repetitions of slow stretching the first stage and 10 repetitions of quick stretching in the second stage). The DS procedure was applied to both the hamstring and quadriceps muscle groups. Stretching was performed 5 times slowly and then 10 times as quickly and powerfully as possible without bouncing. Between each stretching repetition, the players stood upright for a 15 second rest period. The DS procedure lasted for 7±1 minutes for each player.

Three DS exercises for the quadriceps femoris muscle were performed. First, in an upright standing position, the subject touched her heel to her buttock (*stork stand*) so that the knee was fully flexed and stretched. In the upright standing position, the player leaned forward and raised her foot from the floor with her hip and knees slightly flexed. Finally, the player contracted her hip extensors and hamstring muscles so that her leg was extended towards the posterior aspect of the body while the hips nearly came to full extension and the knee to full flexion (Sekir *et al*., 2010).

Three DS exercises for the hamstring muscles were performed. First, in the upright standing position, the knee was fully extended, and the hips were flexed to achieve a stretch. In the upright standing position, the player contracted her hip flexors and flexed her hip joint, raising her thigh parallel to the ground with her knee joint flexed at approximately 90°. Finally, the player contracted her quadriceps while maintaining the height of her thigh and extended her knee joint so that her leg extended toward the anterior aspect of her body (Sekir *et al*., 2010).

Isokinetic strength testing

The researcher conducted all isokinetic strength measurements. The dominant lower extremity was used for each test. Three trial repetitions were allowed for the isokinetic testing. The first measurement was made without the players' doing any stretching exercises (non-stretching) and the second measurement was made after the players' performed DS. The second test was conducted on the same players on different days. The soccer players were informed of the content of the isokinetic test before the test was initiated.

The female soccer players were positioned on an isokinetic dynamometer (Biodex Multi-Joint System 3, Biodex Medical Systems, Inc., Shirley, NY, USA) with the hip flexed to 90° and the dynamometer and knee joint axes were aligned (Silder *et al*., 2010). To restrict the motion of joints other than the knee, the body and the thigh were fastened to the dynamometer chair using crossties. The leg was then tied to the axis of the dynamometer using a special apparatus for the knee joint.

The maximal gravity corrected concentric peak torque was obtained for the knee extensors (quadriceps femoris) and flexors (hamstring) during isokinetic knee joint movement at angular velocities of 60°/s, 180°/s and 300°/s. The four parameters studied in this investigation were the peak torque (PT) (deg/second), peak torques per kg of weight (PT/Kg BW), total work (TW), and H to Q muscle ratio (Bamac *et al*., 2008). For the dominant lower extremities of the players, the range of motion of the knee joint was set at 0-90˚. Leg isokinetic concentric/concentric (Con/Con) knee flexion and extension was performed at 60˚/s (5 repetitions), 180˚/s (10 repetitions), and 300˚/s (15 repetitions). The highest PTs were obtained from the Biodex computer after the measurements. Between velocity tests, the soccer players were allowed to rest for 1 minute. The most frequently reported strength ratio of the muscles of the knee has been the concentric hamstring-quadriceps muscle ratio (Hcon/Qcon) (Coombs & Garbutt, 2002). The H/Q muscle strength ratio was calculated by dividing the maximal knee flexor (H) moment by the maximal knee extensor (Q) moment measured at identical angular velocities in concentric mode. Peak concentric torque (Nm) values of the Q and H, as well as their ratios were used in the statistical analyses (Bamac *et al*., 2008).

Statistical analyses

The data were analysed using the Statistical Package for Social Sciences (SPSS) (SPSS for Windows v 15.0, SPSS, Chicago, IL, USA). The means and standard deviations of all the measurements were calculated. The differences between group means were determined using a non-parametric test for independent samples (Mann-Whitney U test). A p-value of 0.05 was considered statistically significant.

RESULTS

The mean anthropometric data of the soccer players (age, height, weight, BMI, length of the dominant lower extremity, and thigh circumference) are presented in Table 1.

TABLE 1: **BIOMETRIC DATA OF THE SOCCER PLAYERS (N=15)**

Variables	**Mean±SD**
Age (years)	22.13±2.69
Height (cm)	164.53±7.57
Weight (kg)	57.80±7.86
BMI (Body Mass Index)	21.19±1.32
Circumference of dominant thigh (cm)	49.06±3.08
Length of dominant lower extremity (cm)	85.93±5.92

The isokinetic muscle strength measurements of the dominant lower extremity are summarised in Table 2. In all the test velocities, both quadriceps and hamstring muscles concentric PT, PT/kg BW and TW were higher in the second (DS) than first (NS) measurements. A high level of concentric knee flexion strength was observed for the DS compared to the NS at 60˚/s, 180˚/s and 300˚/s ($p<0.05$).

In the 60˚/s test, there were significant differences between NS and DS with respect to the hamstrings and quadriceps (PT ($p=0.027$ and 0.039, respectively). There were significant differences between NS and DS with respect to the hamstrings (PT/kg BW and TW ($p=0.020$

and 0.048, respectively). However, no significant differences were found between NS and DS for the quadriceps (PT/kg BW and TW (p=0.081 and 0.462, respectively).

TABLE 2: **MEAN±SD VALUES FOR DOMINANT QUADRICEPS AND HAMSTRING CONCENTRIC PEAK TORQUE PER KG OF WEIGHT AND TOTAL WORK (N=15)**

Variables	**Test 1 (Non-stretching/NS) Mean±SD**		**Test 2 (Dynamic Stretches/DS) Mean±SD**		**p-Value**	
	Hamstring (H)	Quadriceps (Q)	Hamstring (H)	Quadriceps (Q)	H	Q
PT (60˚/s)	62.95±17.27*	138.30±24.34*	78.94±15.35*	162.32±22.95*	**0.027**	**0.039**
PT/kg BW (60˚/s)	110.45±20.35*	248.69±43.14	127.07±17.15*	273.35±36.88	**0.020**	0.081
Total Work (60˚/s)	320.11±114.29*	642.62±193.16	391.87±95.22*	683.95±184.62	**0.048**	0.462
PT (180˚/s)	47.33±11.20*	94.77±20.25*	58.66±9.13*	110.67±14.48*	**0.009**	**0.027**
PT/kg BW (180˚/s)	85.84±11.20*	170.57±27.09	97.56±11.64*	190.69±22.98	**0.012**	0.054
Total Work (180˚/s)	446.92±118.37*	877.00±200,57*	562.08±117.83*	1001.89±108.50*	**0.015**	**0.048**
PT (300˚/s)	39.71±7,48*	73.52±15,14	46.08±7,12*	75.40±12,48	**0.039**	0.696
PT/kg BW (300˚/s)	70.34±10.78*	130.07±19.46	78.54±9.65*	133.67±17.09	**0.039**	0.566
Total Work (300˚/s)	551.40±128.46	1127.17±251,97	599.30±125.91	1164.10±178.34	0.352	0.462

*Significant differences between Test 1 and Test 2 (p<0.05).

In the 180˚/s test, the hamstring and quadriceps muscles PT revealed significant differences between NS and DS (p=0.009 and 0.027, respectively). The TW of the hamstring and quadriceps revealed significant differences between NS and DS (p=0.015 and 0.048, respectively). The data concerning PT/kg BW between NS and DS showed significant differences with respect to the hamstring muscles at 180˚/s (p=0.012). However, no significant differences were found for the quadriceps muscle (p=0.054). In the 300˚/s test, the hamstring muscles PT and PT/kg BW revealed significant differences between NS and DS (p=0.039 and 0.039, respectively). No significant differences were found for TW (p=0.352). There were no statistical differences PT, PT/kg BW and TW of NS and DS (p=0.696, 0.566 and 0.0462, respectively). These results showed that the stretches caused lengthening of the muscle tendon unit and increasing muscle visco-elasticity and joint range of motion.

The first measurement presented lower H/Q muscles ratio at the speed of 60˚/s, 180˚/s and 300˚/s (Table 3). The data concerning H/Q muscles ratio between the NS and DS measurements showed significant differences at 60˚/s. The results of the NS and DS of knee flexion-extension ROM indicated that dynamic exercises increase knee joint range of motion (p=0.001) (Table 3).

TABLE 3: **MEAN±SD FOR H/Q MUSCLES RATIOS AND RANGE OF MOTION (N=15)**

Variables	**Test 1 (Non-stretching) (NS)**	**Test 2 (Dynamic Stretches) (DS)**	**p-Value**
Muscle ratio			
60˚/s	0.46±0.05*	0.51±0.05*	**0.021**
180˚/s	0.51±0.05	0.54±0.06	0.197
300˚/s	0.54±0.07	0.57±0.06	0.357
ROM			
Knee flexion-extension	134˚±12˚	135˚±11˚	**0.001**

*Significant differences between Test 1 and Test 2 (p<0.05). ROM = Range of motion

DISCUSSION

Stretching exercises are traditionally recommended before most physical activities; therefore, it is important to determine the extent to which a stretching routine influences the performance of the activity and the injury risk to the related joints or muscles (Sekir *et al*., 2010). Stretching exercises have immediate and late effects (Rejeski *et al*., 1995; Gleim & Mchugh, 1997). These exercises (stretching) facilitate improvement of muscle flexibility and joint motion with prolonged beneficial effects. The immediate effects, which last for approximately one hour, can be explained by the visco-elastic response of the muscle (Gleim & Mchugh, 1997). A 6-week stretching exercise program results in more permanent changes in muscle visco-elasticity and joint range of motion (Magnusson *et al*., 1996; Gleim & Mchugh, 1997). DS may improve muscle performance and possibly reduce the risk of injury. Therefore, according to the results of this study it is recommended that dynamic stretching should be performed before every activity.

In the study by Renström (1993), 60 to 80% of injuries were found to be associated with extrinsic factors, such as training errors and changes in running activities. Intrinsic factors were also common, especially misalignments, including excessive pronation and cavus foot. These changes are associated with common over-use injuries, but specific anatomic abnormalities and abnormal biomechanics of the lower extremity are not correlated with specific injuries on a predictable basis. Factors such as leg-length discrepancy, poor flexibility, muscle weakness and imbalance, deficits in neuromuscular coordination and ligamentous laxity can cause running injuries. Acquired or secondary factors, such as kinetic chain dysfunctions, are more common than previously acknowledged.

A concentric hamstring-to-quadriceps ratio that is lower than 0.6 and a hamstring asymmetry of more than 10% do not help identify previous hamstring injuries. A mixed eccentric-hamstring-to-concentric-quadriceps ratio that is lower than 0.6 is the best indicator (probability: 77.5%). The rate of recurrence is 30% (3 out of 10 cases) and the rate of new hamstring muscle injuries is 31% (5 out of 16 cases) (Dauty *et al*., 2003). Soderman *et al*. (2001) demonstrated the relationship between a lower H/Q muscle ratio and knee injury risk in studies involving soccer players.

In a previous study, it was reported that regarding isokinetic strength, volleyball players had lower H/Q muscle ratios than soccer players (Magalhaes *et al*., 2004). The authors suggested that this low H/Q muscle ratio found in volleyball players could contribute to enhanced knee injury susceptibility, with a particular emphasis on the tensional stress on the anterior cruciate ligament (ACL) due to decreased joint stabilising strength (Bamac *et al*., 2008).

The hamstring muscles play a key function in maintaining knee joint stability (Coombs & Garbutt, 2002). The role of the hamstring muscles during leg extension is to assist the anterior cruciate ligament in preventing anterior tibial drawer forces. Tensile stress on the ACL is significantly reduced when the hamstring and quadriceps muscles are co-active during extension compared to when the quadriceps are active alone (More *et al*., 1993). A ‘normal’ H/Q strength ratio of 0.6 is frequently used as an injury prevention and rehabilitation goal (Sekir *et al*., 2010). In the present study, DS applied on certain muscle groups increased isokinetic muscle strength and improved muscle performance. Moreover, DS exercises positively affected the H/Q ratio, which reflects a muscle imbalance. This may reduce the risk of injury in these muscles.

Bamac *et al*. (2008) found that a highly developed quadriceps muscle contributes to decreased antagonist hamstring muscle co-activation in volleyball players. The mean quadriceps peak torque was found to be significantly higher in volleyball players than in basketball players and control subjects. The volleyball players had a lower H/Q muscle ratio than the basketball players and the controls at 300°/s due to exacerbated quadriceps strength related to hamstring muscle strength. This functional imbalance could be a specific volleyball adaptation or/and could reflect insufficient hamstring compensatory strength training. Although the sport represented in the current study (soccer) requires similar movements (running, jumping, acceleration and deceleration), different training skills may be responsible for the differences in the H/Q muscle ratios among the sports examined.

Some researchers have reported that landing technique has significant implications on the kinematics and muscle activation patterns of the lower extremity. To decrease the risk of injury as a result of muscular imbalance, attention must be given to proper muscle balance between the hamstring and quadriceps muscles (De Vita & Skelly, 1992).

Previous studies have shown that elite athletes in various sports have different isokinetic muscle strengths. In the present study, athletes of the same sport were evaluated because their motion and muscle biomechanics would be similar. Knapik *et al*. (1991) demonstrated that female collegiate athletes with low H/Q strength ratios based on high-speed isokinetic measurements had a higher incidence of ACL injury. In the current study the elite female soccer players performed routine dynamic stretching exercises for their knee flexor (hamstring) and extensor (quadriceps) muscles. DS may reduce the risk of injury and improve performance due to their positive effect on the H/Q ratios, muscle strength of the knee extensors and flexors, as well as knee ROM.

CONCLUSIONS

Hamstring/Quadriceps muscle imbalances can be seen as an injury risk for elite athletes. They could benefit from specific strength training of hamstring muscles. In the current study the elite female soccer players performed routine dynamic stretching exercises for their knee flexor (hamstring) and extensor (quadriceps) muscles. DS may reduce the risk of injury and improve performance due to their positive effect on the H/Q ratios, muscle strength of the knee extensors and flexors, as well as knee range of motion.

Acknowledgment

Thanks to Enis Colak for his assistance with the isokinetic strength testing.

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Dr. Serap COLAK: Kocaeli University, School of Physical Education and Sport, Department of Recreation, Umuttepe, 41380, Kocaeli, Turkey. Tel.: 00 90 262 3033624, Fax.: 00 90 262 3037510, E-mail: srpclk@gmail.com

(Subjet Editor: Prof. Ernst Krüger)