Kinematics Analyses Related to Stretch-Shortening Cycle during Soccer Instep Kicking After Different Acute Stretching

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Abstract

Amiri-Khorasani, M, MohammadKazemi, R, Sarafrazi, S, Riyahi-Malayeri, S, and Sotoodeh, V. Kinematics analyses related to stretch-shortening cycle during soccer instep kicking after different acute stretching. J Strength Cond Res 26(11): 3010–3017, 2012—The purpose of this study was to examine the effects of static and dynamic stretching within a preexercise warm-up on angular velocity of knee joint, deepest knee flexion (DKF), and duration of eccentric and concentric contractions, which are relative to the stretch-shortening cycle (SSC) during instep kicking in professional soccer players. The kicking motions of dominant legs were captured from 18 Olympic professional male soccer players (height: 180.38 ± 7.34 cm; weight: 69.77 ± 9.73 kg; age: 19.22 ± 1.83 years) using 4 digital video cameras at 50 Hz. There was a significant difference in the DKF after the dynamic stretching (−3.22 ± 3.10°) vs. static stretching (−0.18 ± 3.19°) relative to the no-stretching method with p < 0.001. Moreover, there was significant difference in eccentric duration after the dynamic stretching (0.006 ± 0.01 seconds) vs. static stretching (−0.003 ± 0.01 seconds) relative to the no-stretching method with p < 0.015. There was a significant difference in the concentric duration after the dynamic stretching (−0.007 ± 0.01 seconds) vs. static stretching (0.002 ± 0.01 seconds) relative to the no-stretching method with p < 0.001. There was also a significant difference in knee angular velocity after the dynamic stretching (4.08 ± 3.81 rad·s⁻¹) vs. static stretching (−5.34 ± 4.40 rad·s⁻¹) relative to the no-stretching method with p < 0.001. We concluded that dynamic stretching during warm-ups, as compared with static stretching, is probably the most effective way as preparation for the kinematics characteristics of soccer instep kick, which are relative to the SSC.

Key Words kicking velocity, knee, SSC, warm-Up

Introduction

Performing stretches before a physical activity is a common practice that is believed to reduce the risk of injury and enhance performance. Although there are many types of stretching exercises used during the warm-up (27), static stretching is the easiest and most frequently used stretching method. The intent of static stretching during the warm-up is to improve the range of motion (ROM) of a joint (26) to allow maximal force production, is the main reason for increasing performance in the activities that follow, and reduce the possibility of muscle tears during activity. However, numerous studies have shown that static stretching can induce muscle strength and force deficits (1,3,5,7,8,10,13,16).

Dynamic stretching is another stretching technique that has become popular to an increasing degree in sport (18). Recent studies have demonstrated that dynamic stretching can improve power output during concentric resistance contractions (28), sprint running time (15), vertical jump, and other performance (1,3,5,7,9,23). This issue suggests that the inclusion of dynamic stretching in a warm-up may supply a practical option to static stretching (17).

Some researchers investigated the acute effect of different stretching on soccer performance and skill. Little and Williams (23) reported that dynamic stretching showed a significant increase in speed, acceleration, and agility. In addition, Amiri-Khorasani et al. (7) also reported higher agility after dynamic stretching as compared with static stretching in soccer players. Furthermore, in soccer skill, Amiri-Khorasani et al. (5) reported increased dynamic ROM in the hip joint during...
instep kicking after dynamic stretching against static stretching in professional soccer players. In another study, Amiri-Khorasani et al. (1) stated that dynamic stretching increased lower joint angular velocity more than static stretching did in professional soccer players. Furthermore, vastus medialis showed greater activity after dynamic stretching as compared with static stretching during soccer instep kicking (3). According to this literature, it seems that dynamic stretching increases soccer instep kicking velocity, but study with more details (such as coordination between phases) of kicking performance after different stretching is still unclear.

The backward and forward phases of soccer instep kick determine the final kick velocity and also the final ball velocity. During the backward phase, the players perform eccentric contraction, and then by concentric contraction, the forward phase starts (22). When an activated tensed muscle is stretched just before contraction, the resulting contraction is more forceful than the absence of the prestretch. This pattern of eccentric contraction is followed immediately by concentric contraction, which is known as the stretch-shortening cycle (SSC) (4,24). The SSC plays an important role in most sport skill and performance, such as soccer instep kicking, which is one of the offensive actions during soccer training and competition (24,6). It is proposed that in simulated kicking actions, the speed of the movement can be increased by up to 21% when using an SSC rather than a purely concentric muscular contraction to extend the knee joint (22). It has already been noted that, in the mature kicking action, the thigh is brought forward while the knee is still flexed. This action serves to stretch the extensor muscles of the thigh before they are required to shorten, so that they are able to aid in the generation of large end-point speed (4,22).

A study of the changes in the biomechanics of soccer instep kick, which is one of the offensive actions during soccer games resulting from stretching, might provide information on the mechanism of the acute inhibition of performance typically seen after stretching. Therefore, a question arises as to which acute stretching methods (dynamic or static) increase SSC performance during soccer instep kicking to produce a higher ball velocity. Hence, the purpose of this study is to measure the acute changes in kinematic variables related to SSC muscle actions as a result of static and dynamic stretching during instep kick in professional soccer players. The hypothesis of this study is that dynamic stretching would demonstrate a significant increase in kinematic variables related to SSC muscle actions during instep kicking in professional soccer players.

**METHODS**

**Experimental Approach to the Problem**

The methodology of this research is a quasiexperimental design, in which the subjects were each serving as their own control. A counterbalanced within-subject experimental design was used for this study. Therefore, soccer players conducted 3 different warm-up protocols on 3 nonconsecutive test days within 1 week. Each test day was conducted
72 hours after a match or hard physical training to minimize the fatiguing effects from previous exercise. The warm-up protocols differed only in the stretching methods that were used, whereas all other exercises used in the warm-up were identical. The stretching modes used were static and dynamic stretching. Soccer Instep Kicking was captured after each warm-up protocol and finally kinematics parameters related to SSC analyzed after different stretching by analyzing the motion. Therefore, dynamic stretching and static stretching were independent variables, and the dependent variables include (a) maximum knee joint angular velocity (KAV), (b) deepest knee flexion (DKF), (c) the duration of eccentric contraction of quadriceps, and (d) the duration of concentric contraction of quadriceps during soccer instep kicking (Time of test conducting).

Subjects
Eighteen Olympic professional male soccer players from Iran’s Premier league (height: 180.38 ± 7.34 cm; mass: 69.77 ± 9.73 kg; age: 19.22 ± 1.83 years), who had no Record of major lower limb injury or disease, volunteered to participate in this study in the middle of the season 2010–2011. All the subjects were accustomed to a professional training workload of >6 training sessions per week and were involved in soccer training and matches for 10 years (mean of experience: 10.22 ± 1.11 years). The sport center committee of university gave approval for all the procedures. The subjects were properly informed of the experimental risks, nature of the study without being informed of its detailed objectives, and both signed an informed consent document before the study. All subjects who were under 18 and their
parents were informed about our study and we asked them to sign informed consent forms.

Procedure
The experimental protocol was designed and conducted according to Little and Williams (23) and Amiri-Khorasani et al. (5,1). Therefore, as presented in Table 1, the subjects were divided into 3 groups, and they regularly performed 3 warm-up protocols on 3 noncontinuous days. The protocol was performed in a manner that on the first day, 3 groups performed 1 of the 3 warm-up protocols, and on the following days, the duties in lieu of doing the stretching method were changed regularly by means of rotation. Finally, the results of all the participants in all the methods were collected separately, showing that all 18 participants had performed the whole research. The aims were to randomize the treatment order for each subject and also divide all the subjects into 3 different groups to control some limitations, such as effects of testing or interactive, weather, pitch, time.

As illustrated in Table 1, the protocol plan was jogging exercise for 4 minutes, performing stretching programs (except for the no-stretch protocol), 2 minutes of rest, and eventually 5 soccer instep kicks, respectively. As all the participants preferred to kick the ball using their right leg, the

![Figure 2. Different dynamic stretching methods.](image-url)
right leg was considered the preferred leg. After 2 minutes of rest, the players were randomly assigned to a series of 5 maximal velocity instep place kicks of a stationary ball with the dominant limb; essentially, this corresponds to the penalty kick in soccer. A ball was kicked 11 m toward a target; middle of goal post around 2 \times 2 m in size. To minimize movement in the frontal plane, the participants were restricted to a 3-m straight run-up from a position directly behind the ball at an approach angle of 0°. An International Federation of Association Football–approved size 5 soccer ball (mass = 0.435 g) was used for each kicking session, and its inflation is controlled throughout the trials at 700 hPa.

The lower extremity muscle groups involved in soccer instep kicking, which were stretched according to Amiri-Khorasani et al. (1,5,7), were the gastrocnemius, hamstrings, quadriceps and hip flexors, gluteus, and the adductors. The muscles are also the main force producers to move lower extremity segments during soccer instep kicking. As illustrated in Figure 1, static stretches used 6 different exercises, which were described by Amiri-Khorasani et al. (1,5,7). The subjects performed the stretch action for 15 seconds on each leg before changing immediately to the contralateral side. The participants held to stretch until they approached the end of the ROM but within the pain threshold. The subjects performed the dynamic stretches on alternate legs for 30 seconds at a rate of approximately 1 stretch cycle every 1 second or unilaterally for 15 seconds. They then repeated this on the other leg at a rate of approximately 1 stretch cycle every second. The dynamic stretches used also 6 different exercises for lower extremity muscles (quadriceps, adductors, gluteals, hamstrings, gastrocnemius, and hip flexors), which was described by Amiri-Khorasani et al. (1,5,7) (Figure 2). The subjects were instructed to try and attain the maximal ROM during the 15 seconds of dynamic stretching.

Statistical Analyses

Four digital video cameras (Panasonic NV-GS60, Tokyo, Japan) were used to capture limb motion at 50 Hz. All 4 video cameras adjusted the reference point as the penalty point and were spaced equally to ensure that the spacing between 2 consecutive cameras covers an angle of 90° from the penalty point. An external audio refer to football impact sound was used to synchronize the 4 video cameras. The calibration frame with 16 calibration points that covers a 1.5-m-long, 1.5-m-wide, 1.5-m-high space was used to calibrate the space in which the subjects performed instep kicking. Reflective spherical markers (9 mm in diameter) were fixed securely onto the lateral side of the bony anatomical landmarks of the right and left legs, including the fifth metatarsal head, the heel, the lateral malleolus, and the lateral epicondyle of the knee, the lateral greater trochanter, anterior superior iliac spine, posterior superior iliac spine, and center of ball. Peak Motus version 9 video graphic data acquisition system (Vicon Motion Systems, Lake Forest, CA, USA) was used to digitize the video records of the calibration frames manually, and sample performances. This software also was used to estimate 3D coordinates of 14 body landmarks and the center of the soccer ball for each trial from dominant leg toe-off to at least 10 frames after the soccer ball left the kicking foot. Finally, 1 kick could be selected with a good football impact and adequate center of goal targeting for final analyzing.

Several biomechanical variables have been used to document the potential benefit of stored elastic energy in SSC movements (4). The dependent variables were selected as the peak KAV during forward (from hip flexion until before contact with the ball) and impact (contact the ball) phases, DKF, and the durations of the eccentric (Te) and concentric (Tc) phases of soccer instep kicking. These variables were selected to document an overall measure of performance and several linear and angular measures related to the SSC in soccer instep kick. The durations of the eccentric and concentric phases were operationally defined relative to flexion motion of the knee from toe-off to DKF, and from the knee extension to impact the ball, respectively. For a better understanding and presenting, all data variables from the
dynamic and static stretching trials were normalized to no-stretching data. Therefore, relative variables were calculated as (2) relative KAV (5), relative DKF (1), relative Te, and (6) relative Tc.

Statistical analyses were conducted with SPSS 15.0 for Windows software (SPSS Inc., Chicago, IL, USA). According to the conditions correlated in a within-subjects design, the repeated-measure analysis of variance was used to determine the difference between the stretching methods in all the subjects. A significance level of $p \leq 0.05$ was considered to be statistically significant for this analysis. When justified, paired $t$-tests were performed to confirm the significant changes within each condition. The effect size was $\geq 0.74$, and also power was $\geq 0.78$. Test-retest reliability values for the testing order of tests intraclass correlation reliabilities were $\geq 0.81$.

RESULTS

The results for the SSC analysis during soccer instep kicking after the different warm-up procedures are presented in Figures 3–6.

There was a significant difference, as presented in Figure 3, in DKF after the dynamic stretching ($-3.22 \pm 3.10^0$) vs. static stretching ($-0.18 \pm 3.19^0$) relative to the no-stretching method with $p < 0.001$. In addition, there was a significant difference in Te after the dynamic stretching (0.006 ± 0.01 seconds) vs. static stretching ($-0.003 \pm 0.01$ seconds) relative to the no-stretching method with $p < 0.015$ (Figure 4). As illustrated in Figure 5, there was a significant difference in Tc after the dynamic stretching ($-0.007 \pm 0.01$ seconds) vs. static stretching (0.002 ± 0.01 seconds) relative to the no-stretching method with $p < 0.001$. There was also a significant difference in KAV after the dynamic stretching (4.08 ± 3.81 rad·s$^{-1}$) vs. static stretching (−5.34 ± 4.40 rad·s$^{-1}$) relative to the no-stretching method with $p < 0.001$ (Figure 6).

DISCUSSION

The findings of this study showed that there were significant differences in KAV, DKF, Te, and Tc (kinematics variables related to SSC) after dynamic stretching vs. static stretching relative to the no-stretching condition. The current finding is similar to previously reported results in soccer players in whom dynamic stretching caused higher agility, speed, acceleration, and power (23), faster agility time (7), increased dynamic range of motion in hip joint during instep kicking (5), increased lower joint angular velocity (1), and greater vastus medialis activity during soccer instep kicking (3).

There are some hypotheses that describe the underlying mechanism of acute dynamic stretching on different performances and skills. In this regard, Herda et al. (19) suggested that the positive acute effect of dynamic stretching is the result of some level of postactivation potentiation (PAP). The PAP is prevalently defined as the temporary increase in muscle contractile performance after a previous "conditioning" contractile activity (25). The PAP may raise the rate constant of crossbridge attachments (20), which in turn may enable a greater number of crossbridges to form, resulting in an increase in force production (8). In addition, Faigenbaum et al. (14) and Yamaguchi and Ishii (27) hypothesized that the increases in force output after dynamic stretching were caused by an intensification of neuromuscular function, and they hinted that the dynamic stretching had a PAP effect on performance. Therefore, it appears that, compared with static stretching, dynamic stretching by PAP effect on leg extensors causes more force production that produces a higher moment about the knee joint and extends the lower leg in a higher angular velocity. Therefore, dynamic stretching causes a higher activation level because of PAP in the SSC and also it seems that strong contraction resulting from high force production of leg extensors causes significantly less Te after dynamic stretching during soccer instep kicking. This is supported by the underlying mechanism of acute dynamic stretching, which is reported in previous researches. Clearly, a fast Te occurs by high lower leg force output after dynamic stretching were caused by an intensification of neuromuscular function, and they hinted that the dynamic stretching had a PAP effect on performance.
Acute Effect of Stretching on Stretch-Shortening Cycle

On the other hand, static stretching induced a decrease in the SSC (10) by changing neural factors such as decreased muscle activation or altered reflex sensitivity. Static stretching may also decrease stretch reflex responses causing the muscle to relax and contract with less force because of a reduction in muscle spindle activity. In brief, static stretch increases the length of the muscle fibers causing less overlap between actin and myosin during crossbridge formation. Hence, force production is decreased because of less musculotendinous stiffness and less crossbridge formation. Therefore, static stretching decreases SSC because of less activation level, less stretch velocity, greater muscle length, and time during SSC performance.

Furthermore, it is quite likely that a higher active state, reflex activity, the potentiation of contractile machinery, and storage and release of elastic energy interact in some manner to produce SSC enhancement. The amplitude of enhancement may depend on activation level, stretch velocity, muscle length, and time-dependent characteristics of the motion (11). It seems that the action of the quadriceps group muscle as leg extensors during the eccentric phase influenced the subsequent concentric phase, which creates more significant Tc and KAV. These influences probably occurred in both the elastic components of the leg extensors and in the neural input. The series elastic component and its intracellular parts and tendon and aponeurosis constituted a major part of elastic structures of the tendomuscular system (21). The proprioceptive reflex systems and the central nervous system are required to adjust the motor program to regulate the elastic potentiation (12), which is a characteristic of SSC. It has been well demonstrated that prestretching of an active muscle enhances its performance in the subsequent concentric work (15). Although the elastic potentiation may have many complex reasons, based on the present finding, it seems that the ability of leg extensors to store and use the elastic energy after dynamic stretching is higher than static stretching.

In summary, kinematic analyses of the knee joint relative to SSC showed that all SSC parameters significantly increased after dynamic stretching relative to the no-stretching condition. Dynamic stretching as compared with static stretching causes a higher activation level, a higher stretch velocity, shorter muscle length and time during the SSC performance. It seems that because of the PAP effect on leg extensors that cause more force production which produces faster Tc and then higher KAV.

**Practical Applications**

According to the current finding, dynamic stretching during warm-ups, as compared with static stretching, is probably most efficient and productive as a preparation for the soccer instep kicking with increasing angular velocity of the knee joint and duration of concentric contraction relative to SSC. It seems that dynamic stretching is more useful and optimal than static stretching for dynamic motions in skills or body performance, which includes the SSC condition. Therefore, coaches, trainers, etc., should use dynamic stretching during warm-ups or even before SSC performance to enhance SSCs during different performances and skills. The findings of this study could help fitness coaches to use dynamic stretching during warm-ups for producing faster performance or skills in which SSC plays an important role in producing force. In addition, players can probably use dynamic stretching before SSC performance during training or competition.

**References**


