DOI 10.26773/smj.201002

ORIGINAL SCIENTIFIC PAPER

# Electromyography Comparisons of Lower Extremity Muscles during Maximum Velocity Instep Soccer Kicks

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**Abstract**

This study was conducted to compare the muscle activation of selected lower extremity muscles during maximum velocity instep kicks and establishing a relationship between muscle activation and ball velocity. Thirty-three male subjects were recruited for the study, and muscle activity of the rectus femoris, vastus lateralis, biceps femoris and tibialis anterior of both the kicking leg and the supporting leg was recorded. A significant difference was found between the muscle activation of selected muscles ($F (7,256) = 20.63$, $p<0.001$, partial eta squared $=0.361$). Further analysis revealed that the tibialis anterior of the supporting leg had the highest muscle activation during instep kicks. The study also revealed higher muscle activity in the biceps femoris of the kicking limb. A Pearson product-moment correlation found a negative relationship between the vastus lateralis of kicking leg and ball velocity ($r=-0.454$, $p=0.008$). The study concludes that the ankle muscles of supporting legs are responsible for absorbing and resisting the external force from the ground during instep kicks; it also demonstrates greater activation among all muscles. Greater muscle activity is shown by biceps femoris in the kicking leg; therefore, strengthening exercises for ankle and hamstring muscles are necessary and should be included in training sessions of soccer players.

***Keywords:*** *electromyography, maximum velocity, soccer, instep kick, analysis*

## Introduction

The total of 210 men and 155 women soccer team rankings in the FIFA/Coca-Cola World Ranking shows the popularity of soccer around the world. The rising popularity of soccer has also increased the number of research studies being conducted to enhance the performance of the players. The instep kick is one of the most important skills to be studied in soccer (Kellis, Katis, & Gissis, 2004). There are many different types of kicks in soccer, based on the type of players, position and velocity during contact, and the intention of making a new move. Of these, the most reported version of a kick in soccer is the maximum velocity instep soccer kick with the static ball (Kapidzic, Huremović, & Biberovic, 2014).

Electromyography (EMG) is a developing field of study in dynamic actions related to sports, in which muscle activity is investigated during specific technique execution; this analysis of muscle activity in technique in soccer may lead to novel evidence that might have been deficient from the literature. Many researchers have conducted studies in muscle activity during the soccer instep kick, such as Dörge et al. (2007) who studied EMG activity of iliopsoas muscles during soccer place kick and attempted to relate it with the kinetics involved. Brophy, Backus, Pansy, Lyman and Williams (2007) examined the muscle activity of nine lower extremity muscles of kicking limb and seven in supporting limb during instep kick and side-foot kicks. Scurr, Abbott and Ball (2011) recruited six soccer players to examine muscle activation in the vastus lateralis (VL), vastus medialis (VM) and rectus femoris (RF) of kicking leg during soccer kicking at four different targets. Cerrah et al. (2011) selected the RF, VL, VM, BF, and gastrocnemius of

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the kicking leg and compared the muscle activation pattern in professional and amateur players, while Thapa, Kumar, Sharma, Rawat, and Narvariya, (2019) studied the muscle activation of four lower limb muscles of both kicking limb and supporting limb when kicked from different approach angles. All these studies were reviewed by the authors of the present paper and resulted in the conclusion that most of the studies conducted in EMG used muscles of the kicking limb, and that studies that included muscles of supporting leg did not report the contribution of ankle muscles (tibialis anterior) of the supporting limb. The previously mentioned studies also lacked an overall comparison between the contribution of muscles of kicking and supporting leg during instep kick.

This study was conducted with a purpose of identifying the muscle, (among vastus lateralis, rectus femoris, biceps femoris and tibialis anterior of kicking and supporting leg) whose contribution is the highest during maximum velocity instep soccer kick, irrespective of the role of the leg (kicking or supporting). A separate analysis was also conducted among those four muscles for the contribution of muscles in the kicking leg and supporting leg.

## Method

*Subjects*

In this study, 33 male university soccer players who were right-foot dominant were included (age 21.2±2.3 years, height 171.9±7.8 cm and body mass 66.2±6.9 kg). Limb dominance was selected by asking the subjects about which foot they would prefer to kick the ball for maximum velocity (Thapa et al., 2019). The subjects had a minimum playing experience of six or more years during the collection of data. Only physically active players were selected as subjects, who had no recent records of lower extremity, spinal or neurological injury which could limit the maximum velocity kick. The subjects were asked to sign written consent forms before data collection, and the procedure for EMG recording was thoroughly explained to them. The Lakshmibai National Institute of Physical Education's departmental research committee approved the conduct of the study in conformity with the Helsinki Declaration.

*Procedure*

As a part of the warm-up, the subjects performed five minutes of dynamic stretching (Scurr et al., 2011) followed by a few short sprints. Rectus femoris (RF), vastus lateralis (VL), biceps femoris (BF), and tibialis anterior (TA) of both the kicking leg and supporting leg (Thapa et al., 2019) were selected for the electromyography study. The SENIAM (Surface Electromyography for Non-Invasive Assessment of Muscle) group's recommendations were followed for the procedure of electrode placement in the muscles. Wireless surface electromyography with eight channels (BTS FREEEMG, S.P.A., Italy) was used for the acquisition of EMG signals from the selected lower extremity muscles.

The ball velocity of an instep kick was measured using a Doppler radar gun (Bushnell, USA) with ± 2 kph error (Figure 1). The radar gun was positioned three metres behind the goal (Sterzing & Hennig, 2008). The ball used was the FIFA-approved Adidas Capitano, and a pressure of 1.0 atmospheres was maintained throughout the data collection. A two-step approach run with an approach angle selected by the subject was allowed for the kick. A total of three trials was performed by each subject for maximum velocity, and a rest period of 30 seconds was allowed in between each trial. The trial with maximum velocity was selected for the study.

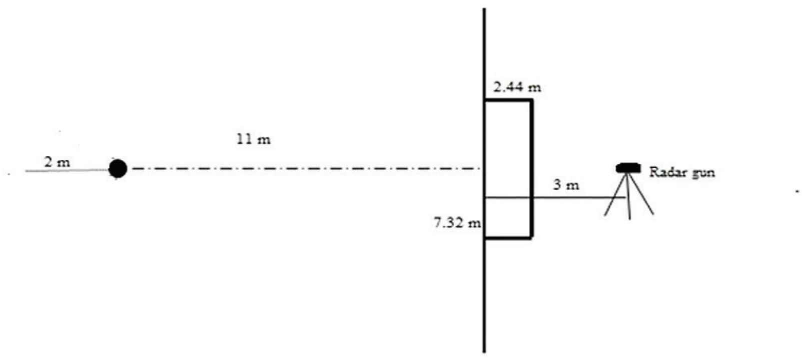


FIGURE 1. Set up for maximum ball velocity instep kicking and EMG recording

*Data analysis*

Analysis of the EMG signals was carried out in BTS EMG-Analyzer software (version 2.9.40.0). The EMG signals were bandpass-filtered using the Butterworth smoothing technique with a lower cut-off frequency of 20 Hz and higher cut-off frequency 400 Hz. A fixed window of 100 ms was used to calculate the RMS (root mean square) value of the signals. The normalization of the EMG signal was carried out by using peak activation of each muscle recorded during the instep kick (Halaki & Gi, 2012).

*Statistical analysis*

IBM SPSS (version 20.0.0) software was used for statistical analysis of the acquired data. The Shapiro-Wilk test detected normal distribution of the data, and parametric tests were thus applied. One-way ANOVA was conducted to compare muscle activation in the lower extremity (including muscle activation in both kicking leg and supporting leg), and separate one-way ANOVAs for kicking leg and supporting leg were also performed. A post-hoc test was conducted using the Games Howell test because the data violated the assumption of homogeneity of variances. The effect size was estimated using partial eta squared, with a value of 0.01 defining small, 0.06 defining a medium, and 0.14 defining a large effect size (Cohen, 1988). A Pearson product-moment correlation was used to study the relationship between muscle activation of different muscles and ball velocity, and the correlation coefficient (r) was determined. A correlation value of r=0.10 meant low correlation, r=0.30 meant medium correlation, and r=0.50 meant a higher correlation (Cohen, 1988).

## Results

A one-way ANOVA aimed at comparison of normalized muscle activity of all the muscles involved in instep kicks revealed significant differences in muscle activity among various lower extremity muscles (F (7,256) = 20.63, p<0.001, partial $\eta^2$ =0.361; Table 1). A Games-Howell post-hoc test further revealed significant differences between rectus femoris and biceps femoris of kicking leg (p=0.002), rectus femoris of kicking leg and biceps femoris of supporting leg (p<0.001), biceps femoris of kicking leg and rectus femoris of supporting leg (p=0.004), biceps femoris of kicking leg and vastus lateralis of supporting leg (p=0.001), biceps femoris, tibialis anterior, rectus femoris, vastus lateralis of kicking leg and tibialis anterior of supporting leg (p<0.001).

**Table 1.** Mean and standard deviation of muscle activity of selected muscles of kicking and supporting leg

| | KRF | KVL | KBF | KTA | SRF | SVL | SBF | STA | p (Kicking Leg) Partial $\eta^2$ | p (Supporting leg) Partial $\eta^2$ | p (overall) Partial $\eta^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean ± SD | | | | | | | | | | |
| **Muscle activation (% of Peak activation)** | 19.73 ±2.74 | 21.50 ±3.23 | 23.13 ±3.63 | 21.85 ±4.65 | 19.96 ±2.69 | 19.47 ±2.89 | 24.11 ±4.13 | 28.05 ±4.52 | 0.003* (0.485) | 0.000* (0.104) | 0.000* (0.361) |

Legend: *denotes significant differences at 0.01 level of significance; SD: standard deviation; RF: rectus femoris; VL: vastus lateralis; BF: biceps femoris; TA: tibialis anterior; K: kicking leg; S: supporting leg.

Likewise, further analysis of the muscle activation using one-way ANOVA showed (Table 1) significant differences between selected muscles in the kicking leg (F (3,128) =4.929, p=0.003, partial $\eta^2$ =0.485) as well as in the supporting leg (F (3,128) =40.142, p<0.001, partial $\eta^2$ =0.104).

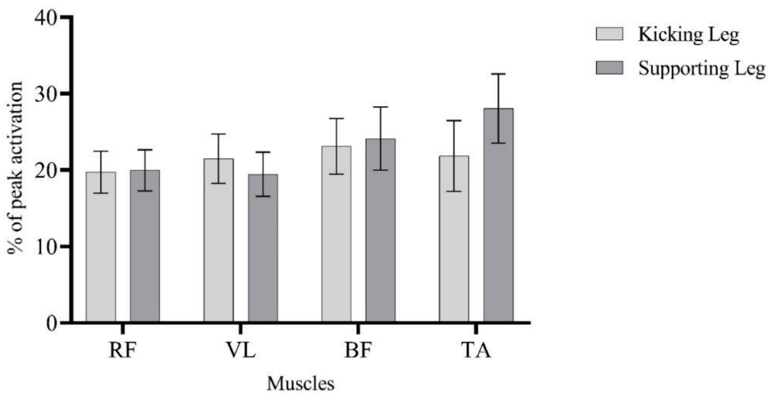


FIGURE 2. Normalized muscle activation of rectus femoris (RF), vastus lateralis (VL), biceps femoris (BF), and tibialis anterior (TA) of kicking leg and supporting leg

While, product-moment correlation revealed a negative correlation between vastus lateralis of kicking leg (KVL) and ball velocity (r=-0.454, p=0.008), there was no significant correlation between ball velocity and other activation of the muscles.

**Table 2.** Correlation table of muscle activity of selected muscles of kicking and supporting leg with ball velocity

| | KRF | KVL | KBF | KTA | SRF | SVL | SBF | STA |
|---|---|---|---|---|---|---|---|---|
| **Ball Velocity (r)** | -0.279 | -0.454** | 0.004 | -0.031 | -0.222 | 0.045 | -0.211 | -0.084 |
| **p-value** | 0.115 | 0.008 | 0.981 | 0.862 | 0.214 | 0.803 | 0.237 | 0.641 |

Legend: **denotes significant differences at 0.01 level of significance

## Discussion

The main objective of the study was to determine the muscle that contributed the most during the maximal velocity instep kick. A significant difference with large effect size was observed between muscle activation of different muscles involved in the study. The findings of this study showed maximum contribution by the tibialis anterior muscle of the supporting leg during the instep kick. Since no earlier studies have been found for muscle activation of the tibialis anterior of supporting limb during instep kick, comparisons could not be made based on muscle activity. However, studies had been conducted on the biomechanical aspects of the instep kick, which reported the supporting leg (Inoue, Nunome, Sterzing, Shinkai, & Ikegami, 2014; Katis & Kellis, 2010; Kellis et al., 2004). These studies reported that the ground reaction force received by the supporting leg was two times the bodyweight of the subjects. Likewise, Inoue et al. (2014) reported two major roles of the supporting leg in their research findings: (1)

resisting the large external force to stabilize the body and (2) transferring of mechanical energy to the proximal segment, thus contributing to a proximal-distal sequential motion of the kicking leg. One of the results from that study showed that in most support leg joints, the joint motions were not counteracted by joint moments and also were not associated, which may be the reason for the lower contribution of thigh muscles of supporting leg. A similar result was also obtained in our study in which vastus lateralis, rectus femoris and biceps femoris were less active than the tibialis anterior muscle. The previously cited study (Inoue et al.2014) also reported that the ankle joint did not exhibit positive power during the support phase, and thus it was interpreted that the ankle joint absorbs the large external force from the ground. Tibialis anterior is one of the major muscles of the ankle joint and, therefore, may be responsible for absorbing and resisting the external force from the ground, and thus supports the finding of the studies conducted on the biomechanical aspect of the support leg during the instep kick.

The second objective was to find out the muscle of the kicking limb, which contributed the most during the maximum velocity soccer kick. Large effect differences were also observed in comparisons of muscle activation of the kicking limb. During the instep kick, the biceps femoris of the kicking leg displayed the maximum contribution. Earlier EMG studies in instep kick did not include biceps femoris muscle for amplitude comparisons, and only one study was found (Cerrah et al., 2011) which included biceps femoris of kicking limb in its study; however, the study was confined to patterns of muscle activity during different phases of the soccer instep kick, and no comparisons were made between the muscle activity during the kick. Cerrah et al. (2011) reported that biceps femoris was activated early during the kick action, which might contribute to the horizontal propulsion provided by the hip extension (Lees et al., 2009), and later muscle activity increased after the impact with the ball. A detailed observation over the graph of rectus femoris, vastus lateralis, and biceps femoris activation presented by Cerrah et al. (2011) may result in the conclusion that the biceps femoris peak resembles plateau at near 70-80 % MVIC, and the graph is constant with fewer fluctuations. However, in the graph of the rectus femoris and vastus lateralis, the peaks are sharp and fluctuate heavily throughout the kicking movement. This graph partially supports the findings of our study, in which we can observe the differences in muscle activity patterns between the three muscles.

The third objective of the study was the relationship between muscle activation and ball velocity. The results revealed a negative relationship between the activity of vastus lateralis of kicking leg and ball velocity. Due to the lack of studies in this field, the authors of the present paper are uncertain about this finding, and more research is required to determine the cause.

The findings of this study revealed activation of tibialis anterior of the supporting leg to be the highest among other muscles of both kicking and supporting legs during maximum velocity instep kicks; also, in the kicking leg biceps femoris showed higher activation, which might be a reason for a greater number of ankle and hamstring injuries in soccer players. Players especially amateurs and those in the developmental phase often neglect ankle and hamstring muscles strengthening exercise, and are prone to injuries. This study provides sufficient evidence for coaches to include strengthening ankle and hamstring muscles in their training plan and encourage players to actively involved in it.

**Acknowledgements**
There are no acknowledgements.

**Conflict of Interest**
The authors declare the absence of conflict of interest.

**Received:** 04 March 2020 | **Accepted:** 17 May 2020 | **Published:** 01 October 2020

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