KINETICS OF SOCCER SIDE-FOOT KICKING WITH VARIED EFFORT LEVELS

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We aimed to illustrate joint kinetics during submaximal effort of soccer side-foot kicking. Side-foot kicks with three effort levels (50, 75 and 100% effort levels based on maximal effort) of eight male university soccer players were captured at 500 Hz while intial ball velocities were monitored simultaneously. Kinetic differences (angular impulses due to resultant joint moments) were clearly illustrated for hip flexion and knee extension thereby supporting the interpretation that the velocity of the distal end of the leg (foot) is controlled in a context of a proximal to distal segmental sequential system similar to instep kicks. Moreover, among joint moments responsible for out of thigh-shank plane motion, hip external rotation moment was found to be systematically adjusted between three effort levels. Additionally, an inconsistent trend was observed for hip external rotation angular velocity, suggesting some kinematic change in particular for the contribution of hip external rotation likely occured in submaximal side-foot kicks.

KEYWORDS: submaximal effort, side-foot kick, soccer, joint moment.

INTRODUCTION: Among numerous types of kick in soccer, the side-foot kick is the most frequently used technique when a shorter and precise pass or shot is required (Nunome, Asai, Ikegami & Sakurai, 2002). Mitschke and Milani (2014) also reported that players use the side-foot kicks to complete 59.6% of the total number of passes and mainly use it for low/short passes in high level soccer competition (UEFA Euro 2012).
During a soccer match, players are more often required to kick the ball with a wide range of velocities (Hanson, Harland, Holmes & Lucas, 2012). There have been a few attempts to illustrate kinematic aspects (Andersen & Dörge, 2011; Teixeira, 1999) or muscle recruitment patterns (Katis, Giannadakis, Kannas, Amiridis, Kellis, & Lees, 2013; Scurr, Abbott & Ball, 2011) of soccer kicks for accuracy with submaximal effort. However, the information about the kinetics of submaximal kicking motion has been limited except for one study investigated various effort levels of soccer instep kicking (Nunome, Inoue, Watanabe, Iga & Akima, 2018). To date, there is no study focused on soccer side-foot kicking with various effort levels.
Similar to instep kicks, it can be expected that lower limb joint kinetics during soccer side-foot kicking with various effort levels would provide in-depth insight into how players adjust their kicking motion. Moreover, as the side-foot kick is the most frequently used technique for passing (Mitschke & Milani, 2014), coaches can get more practically relevant information on how to control its intensity in an actual course of a match.
The purpose of the present study was to compare lower limb joint kinetics of soccer side-foot kicking among different effort levels to improve our understanding on how the kinetics change with the demands of the task (decreased ball velocity). We set two hypotheses 1) systematic adjustments would be conducted in joint kinetics of both the proximal and distal segment motions within thigh-shank plane, and 2) players also regulate out of the plane motion using hip adduction and external rotation moment to achieve the necessary submaximal ball velocity.

METHODS: Eight male university level soccer players (age = 20.4 ± 1.5 years, height =172.4 ± 4.6 cm, body mass = 63.3 ± 5.2 kg, soccer experience = 13.1 ± 3.1 years) volunteered to participate in the present study. The experiment protocol was approved by the Human

Research Committee of a university. All participants preferred to kick the ball with their right leg and were free from any lower limb injuries. After a warm-up, participants were asked to perform side-foot kicks with three effort levels, towards the centre of a small indoor soccer goal 7 m ahead. These effort levels were defined by the resultant ball velocity on an individual basis. To obtain the target ball velocity baseline (100% effort), participants were asked to perform their maximal effort kick twice before the trials. The target velocity of each effort level was determined for each individual (at 50±5%, 75±5% and 100% of their maximum ball velocity) and monitored by a pair of photocells (aligned towards the goal with a 1 m interval). All participants repeated kicks at each effort level until three 'good' shots with ±5% of the target velocity with adequate centre targeting in the goal (straight forward trajectory along the floor).
Three-dimensional coordinates of the kicking leg were collected at 500 Hz using a 10-camera optoelectronic motion capture system (Vicon Motion Systems, Oxford, UK). The participants wore the same type of soccer shoes for indoors although differing in size. Resultant joint moments were computed using the procedure of Nunome et al. (2002). To exclude artefacts caused by smoothing through ball impact, the smoothing procedure defined by Nunome, Ikegami, Kozakai, Apriantono and Sano (2006) was applied using a fourth-order Butterworth filter at 12.5 Hz.
Initial ball velocity, final foot CG velocity immediately before ball impact, ball/foot velocity ratio, angular impulses due to the moments and segmental angular velocities were calculated. One-way ANOVA with repeated measures was used for comparisons between effort levels and statistical significance was set at P<0.05. Multiple comparisons using the Bonferroni adjustment were used for post-hoc testing.

Table 1. Average (±SD) values of the velocity of ball and foot centre of gravity (CG) and foot CG–ball velocity ratio.

Effort level	100%	75%	50%	
Initial ball velocity (m/s)	23.6 (1.4)	17.9 (1.3)	12.6 (1.0)	*†‡
Final foot CG velocity (m/s)	17.4 (0.8)	13.5 (0.9)	10.1 (1.2)	*†‡
Ball/foot velocity ratio	1.35(0.04)	1.32 (0.03)	1.25 (0.07)	*†

* : Significantly different between 100% and 75%
† : Significantly different between 100% and 50%
‡ : Significantly different between 75% and 50%

RESULTS and DISCUSSION: Significant differences (P<0.001) were evident for initial ball velocity, final foot velocity and ball/foot velocity ratio between each effort level (Table 1). During submaximal side-foot kicks (75% and 50% effort levels), the players in the present study used 76.2% and 58.0% of final foot velocity for producing 75.8% and 53.3% of initial ball velocities respectively. It has been reported for instep kicks that there are considerable differences between final foot velocity and resultant ball velocity when players kick the ball with submaximal effort levels (Nunome et al., 2018). These players tended to hit off-centre part of ball using a more medial side of the foot and with a less upright foot posture, suggesting they added some fine-tuning of the resultant ball velocity by changing the manner of ball impact. In the present study, differences in final foot velocity seen in submaximal side-foot kicks were rather smaller (up to 3.3%) than those reported for submaximal instep kicks (up to 8.3%), also the ball/foot velocity ratio did not change systematically (non-significant between 75% and 50%). From these findings, it can be suggested that final foot velocity was rather precisely regulated during the side-foot kicking than the instep kicking, thereby demanding players a narrower range of adjustment of ball impact manner to achieve target ball velocities.
Apparent kinetic differences for soccer side-foot kicks were clearly identified for planar motions within thigh-shank plane: hip flexion moment and knee extension moment. For this kicking technique, there has been little information on how players adjust the swing velocity of the foot to meet lower ball velocity demands. Angular impulses due to these moments were found to

be systematically reduced in lower effort levels and significantly different (P<0.001) between each effort level (Table 2). These findings supported our first hypothesis, thereby confirming the foot swing velocity of the side-foot kick is controlled through a proximal to distal segmental sequential system within thigh-shank plane as well as the instep kick.

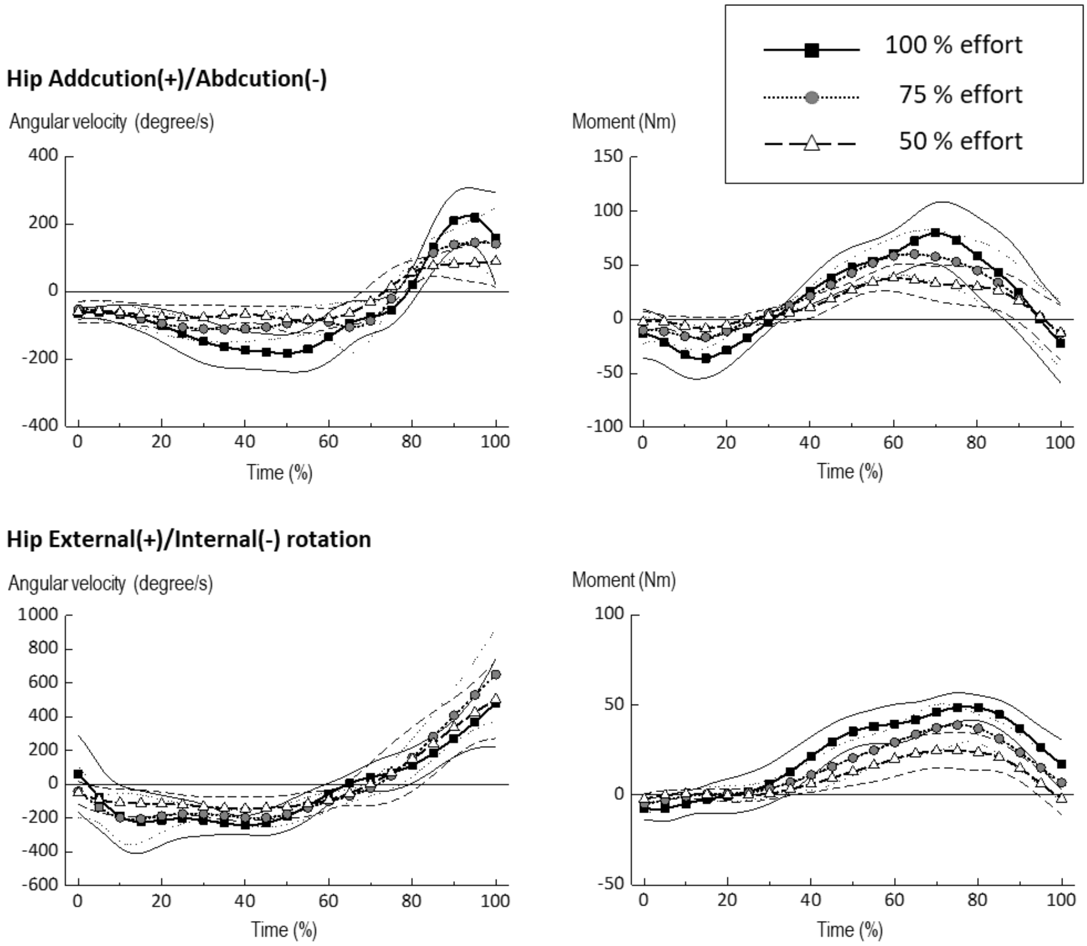

Figure 1: Average (±SD) changes of angular velocities (left panel) and joint moments (right panel) of hip adduction/abduction (top) and external/internal rotation (bottom) in three effort levels of soccer side-foot kicking.

On the other hand, two previous studies reported the importance of out of thigh-shank plane motions in soccer side-foot kicks. Levanon and Dapena (1998) through their kinematic analysis, highlighted the importance of hip adduction motion which adds the velocity component normal to the thigh-shank plane allowed players to hit the ball squarely with the medial side of foot. Nunome et al. (2002) demonstrated another style of side-foot kicking. In this style, players take a unique posture, in which the thigh-shank plane pointing outward while the knee joint is not fully extended. In this posture, the hip joint can utilize its external rotation motion to increase directly the forward velocity of the medial side of the foot. Thus, it is expected that systematic control of these motions should be done by regulating joint moments of these motions. As shown in Figure 1 and Table 2, angular impulses of external rotation moment were systematically changed and significantly (P<0.001) different between each effort level while those of hip adduction moment in two submaximal effort levels did not change significantly compared to that of maximal effort level. From these findings, it can be interpreted that among out of thigh-shank plane motions, the players are more reply on hip external rotation moment to regulate final foot velocity during submaximal side-foot kicks, thereby partially supporting our second hypothesis. Interesting to note, while angular impulse due to hip external rotation moment was systematically regulated, angular velocity of hip external rotation did not match with this systematic change. Trials of 75% effort level showed the highest peak angular velocity among three effort levels and the value was not significantly different from that of 100% effort level. This inconsistent change may imply some change of kicking kinematics in particular for the contribution of hip external rotation during the side-foot kicking. Further kinematic analysis should be warranted to clarify the cause of this inconsistent change.

Table 2: The average (±SD) of peak angular velocities (in degree/s) and angular impulses (in N.m.s) due to moments throughout side-foot kicking motion.

Effort level	100%	75%	50%	
Hip Joint				
Peak Angular Velocity				
Adduction	263.4 (97.0)	180.1 (78.8)	130.6 (45.4)	†
Flexion	500.1 (89.4)	407.9 (76.9)	335.4 (41.7)	*†‡
External Rotation	520.9 (176.2)	658.8 (255.0)	516.1 (213.9)	‡
Angular Impulse				
Adduction	7.4 (3.8)	6.5 (2.7)	4.7 (1.9)	*†‡
Flexion	25.5 (2.7)	19.5 (2.5)	14.7 (3.5)	*†‡
External Rotation	5.9 (0.9)	4.2 (0.9)	3.0 (1.0)	*†‡
Knee joint				
Peak Angular Velocity				
Extension	1529.3 (192.1)	1022.7 (258.4)	679.3 (344.8)	*†‡
Angular Impulse				
Extension	5.8 (0.9)	4.1 (0.7)	3.0 (1.0)	*†‡

* : Significantly different between 100% and 75%
† : Significantly different between 100% and 50%
‡ : Significantly different between 75% and 50%

CONCLUSION: In response to three target effort levels (50, 75 and 100%), systematic adjustments of joint moments were demonstrated for planar motions (hip flexion and knee extension) as well as the instep kicking. Moreover, among out of thigh-shank plane motions, hip external rotation moment was extracted as the kinetic source whose angular impulse is controlled in proportion to the three effort levels.

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