DIFFERENCES IN LOWER LEG KINETIC OF SOCCER INSTEP KICKING BETWEEN FEMALE AND MALE PLAYERS

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We aimed to clarify the difference in lower leg segment kinetics of soccer instep kicking between female and male players. Instep kicking of seven female and seven male university soccer players were captured at 500Hz. There was no significant difference between female and male groups for peak forward lower leg angular velocity while female players exhibited significantly smaller angular impulse due to knee joint moment than that of male players. On the other hand, female players showed comparable angular impulse due to the interaction moment acting on the lower leg to that of male players. It can be considered that the interaction moment acting on the lower leg of female players may compensate their reduced exertion of knee joint moment during kicking, thereby achieving comparable lower leg angular velocity to that of male players.

KEYWORDS: instep kick, muslce moment, interaction moment, sex differnece

INTRODUCTION: In soccer, instep kicking is the most common technique when faster shot or long distance kick is required (Inoue, Nunome, Sterzing, Shinkai, & Ikegami., 2014). Among coaches and players, it has been recognized that the instep kicking is an important technique not only for male players but also for female players. A comparison of technical analysis of the FIFA World Cup for female (2003 FIFA Woman's World Cup) and male players (2002 FIFA World Cup) revealed that female players tend to perform the instep kicking more frequently to cover distances by long passes rather than short range activities (Althoff, Kroiher & Henning., 2010). This finding suggested that the instep kicking is more important, practical technique for female players than male players. However, the instep kicking of female players have gathered less research attention from researchers, to date (Kellis & Katis., 2007).

Regarding soccer instep kicking, previous study reported that female players have substantially slower leg swing speed than their male counterparts (Kellies & Katis., 2007). Also female players were found to have significantly lower hip and knee joint moments during instep kicking than those of male players (Sakamoto, Sasaki, Hong, Matsukura & Asai., 2014). However, in another report, the same research group reported comparable magnitudes of peak knee extension moment between female and male players during the instep kicking (Sakamoto, Numazu, Hong & Asai., 2016). Thus, it can be assumed that no consensus has been reached on knee joint moment exertion between female and male players during the instep kicking.

From the view point of segmental dynamics, proximal to distal sequential segment motion generally seen in soccer instep kicking is formed by two types of moments: the moment due to the force from muscle-tendon complex and joint reaction force acting between segments (joint moment and interaction moment; Nunome, Ikegami, Kozakai, Apriantono & Sano., 2006). Previous studies reported that the interaction moment due to proximal end force of the lower leg segment substantially contributed to its angular acceleration immediately before ball impact (Dörge, Andersen, Sørensen, & Simonsen., 2002; Nunome et al., 2006). However, there was no study focused on the segmental dynamics of female players during the instep kicking.

The purpose of the present study, therefore, was to clarify the difference in segmental dynamics of soccer instep kicking between female and male groups. In conjunction with the aim, we set two hypotheses: 1) female players would have a similar magnitude of peak lower leg angular velocity as male players, and 2) female players would have substantially larger interaction moment than that of male players during instep kicking.

METHODS: Seven female (age: 20.0 ± 0 years; height: 160.3 ± 6.1 cm; body mass: 54.3 ± 5.2 kg) and seven male (age: 20.1 ± 0.4 years; height: 173.0 ± 5.9 cm; body mass: 70.0 ± 9.0 kg) experienced university level soccer players volunteered to participate in the present study. All the participants regularly competed in a regional university soccer league and had more than 10 years training history. The experiment protocol was approved by the ethics committee of the graduate school of a university. Before the experiment, informed written consent was obtained from each participant. After an adequate warm-up, they performed maximal instep kicking towards a small indoor soccer goal using their preferred leg. All the participants performed at least ten trials so that three shots could be selected with both a good foot–ball impact and reasonable straight forward ball trajectory.
Three-dimensional coordinates of the kicking leg were collected at 500Hz using an 8-camera optoelectronic motion capture system (Vicon Nexus). The kicking leg was modelled as a two-link kinetic chain composed of the thigh and lower leg (Nunome et al., 2006). The angular velocity of the lower leg segment, the resultant knee joint moment (hereafter termed knee joint moment) and the moment due to the joint reaction force acting on the proximal end of the lower leg (hereafter termed interaction moment) were computed from the procedure of Nunome et al., (2006). A unit vector perpendicular to the thigh and lower leg segments was used as the rotation axis of the angular velocity and moments (Nunome et al., 2006), in which counter-clock wise rotation was defined as forward rotation. To avoid ball impact artifacts, the procedure described by Nunome et al., (2006) was applied using a fourth order Butterworth filter at 25Hz. The instance of ball impact was defined as 2ms before when captured ball markers visually seen a clear onset of forward movement on the software of the motion capture system (Inoue et al., 2014). In the present study, the analyzed portion of instep kicking was defined as the period from the toe-off of kicking side to ball impact and was normalized to 100% (101 points). To minimize the anthropometric difference between female and male groups (Pierrynowski & Galea., 2001), all moments were normalized by the body mass (kg) and height (m) of each participant.
Initial ball velocity, forward angular velocity of the lower leg segment and forward angular impulses due to the two types of moments were calculated. Also, the time when forward interaction moment was initiated and ratio of the two types of angular impulses (interaction moment/knee extension moment) were computed. A two-sample t-test was used for comparisons and statistical significance was set at $P < 0.05$ after Bonferroni adjustment. Effect sizes were also estimated using Cohen's D (d) and evaluated as trivial (0–0.19), small (0.2–0.49), medium (0.5–0.79) and large (0.80 and greater).

RESULTS: Female players exhibited significantly lower ($P < 0.05$) initial ball velocity than that of male players. (Table 1).

Table1: The comparison of average (± SD) peak forward angular velocity of lower leg (rad/s), forward angular impulses (Ns/kg) and forward angular impulse ratio (interaction moment / knee joint moment).

	Female	Male	P-value (d)
Initial ball velocity (m/s)	20.3 (1.3)	26.3 (1.4)	< 0.001* (4.9)
Angular velocity (rad/s)			
Lower leg angular velocity	33.6 (3.4)	38.0 (3.2)	0.195 (1.3)
Forward Angular impulse (Ns/kg)			
Knee joint moment	0.039 (0.016)	0.068 (0.007)	0.005* (2.3)
Interaction moment	0.011 (0.004)	0.007 (0.004)	0.290 (1.0)

[a] **Time (% of time of kicking)**	73.0 (5.2)	85.6 (6.7)	0.017* (2.1)
[b] **Forward angular impulse ratio (%)**	29.9 (14.9)	10.1 (4.7)	0.045* (1.8)

[a]: Time when forward interaction moments was initiated.
[b]: Interaction moment/knee extension moment.
***: Significant difference after Bonferroni adjustment (P < 0.05).**

Figure 1 shows the average (± SD) changes of lower leg angular velocities (panel a), the knee joint moments (panel b) and the interaction moments (panel c). As shown in the panel a, a similar pattern of angular velocity change which reached the peak value at ball impact was consistently observed in both groups. There was no significant difference between female and male groups for peak forward lower leg angular velocities (Table 1).
As shown in the panel b, the SD clouds of the knee joint moment changes of the two groups were apparently separate in the latter part (from 68 to 90% of time) of kicking between female and male groups. Female players exhibited significantly (P < 0.05) smaller forward angular impulse due to the knee joint moment (Table1). On the other hand, as shown in the panel c, the interaction moment of female players initiated to exert a forward interaction moment significantly (P < 0.05) earlier than male players while there was no significant difference for forward angular impulse between the two groups. Additionally, female players exhibited significantly larger angular impulse ratio (interaction moment / knee extension moment) than that of male players with a large effect (Table 1).

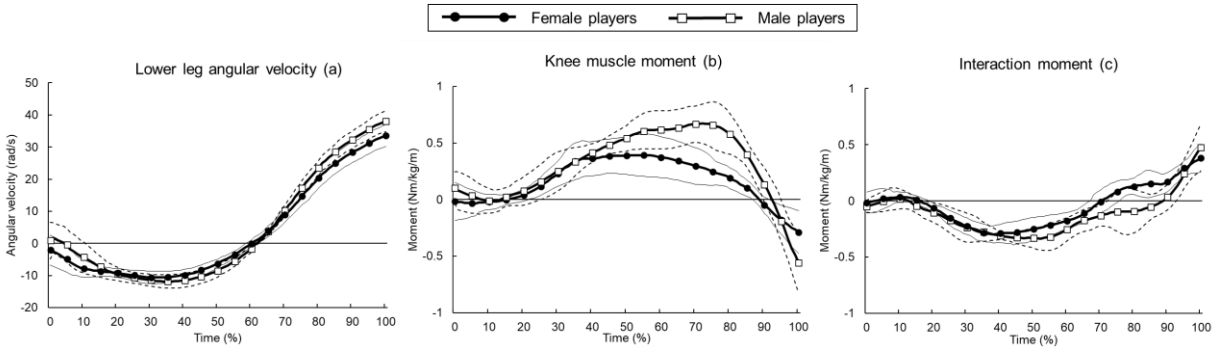

Figure 1: Average (SD) changes of lower leg angular velocities (panel a), knee joint moments (panel b), interaction moments (panel c) of soccer instep kicking: forward (+) / backward (-).

DISCUSSION: In the present study, we aimed to clarify the difference in lower leg kinetics of soccer instep kicking between female and male players. The results showed that there were no significant differences between the two groups for peak lower leg forward angular velocity and forward angular impulse due to the interaction moment. In contrast, female players exhibited significantly smaller forward angular impulse due to the knee joint moment and the forward angular impulse ratio (interaction moment / knee extension moment). These findings supported our first hypothesis but in contrast to the second hypothesis.
In the present study, female players were found to have a comparable peak forward lower leg angular velocity to that of male players. However, to date, it is still unclear on how female players achieve comparable magnitude of lower leg angular velocity with that of male players. Knee joint moment is a likely factor, however, the results of peak knee joint moment in two previous studies were inconsistent (Sakamoto et al., 2014; Sakamoto et al., 2016). This discrepancy is probably due to the difference in physique such as body mass and height between female and male players. These differences in physiques would have substantial effect on the magnitudes of muscle moments and may preclude a fair comparison of the kinetics between female and male players. In the present study, the two types of moments were normalised by body mass and height of each participant (Pierrynowski & Galea., 2001). This normalization procedure allowed us doing a more fair comparison of time-series changes of the knee joint and the interaction moments and angular impulses due to those moments between female and male groups.
For the knee joint moment changes, it can be seen that their SD clouds were apparently

separated in the latter part of instep kicking between the two groups (Figure1 panel b). Thus, it can be considered that female players may not be capable to generate knee joint moment comparable to male players in higher angular velocity condition. In general, peak knee joint moment will decrease as its angular velocity increases due to inherit force–velocity relationship of muscles. One possible explanation for this finding is the difference in skeletal muscle fiber-type proportion between sex. In a previous study, female participants were found to have significantly lower cross-sectional area and proportion of fast-twitch fibres in vastus lateralies (Simoneau & Bouchard., 1989). Thus, sex specific force–velocity characteristics in muscular system regarding knee extension might explain lower generation of the knee joint moment seen in female players in the latter part of the instep kicking. However, in the present study, the participants was university level soccer players, thus, it should be noted that it is still not clear whether more skilled female players follow this sex specific force–velocity characteristics in muscular system regarding knee extension.
On other note, as shown in the Figure 1 (panel c), female players initiated the action of forward interaction moment significantly earlier and exerted comparable amount of forward angular impulse to those of male players. Moreover, female players exhibited a significantly larger angular impulse ratio (interaction moment / knee extension moment) than that of male players (Table 1). From these findings, it can be assumed that the interaction moment acting on the lower leg of female players may compensate suppressed action of the knee joint moment in high angular velocity condition, thereby achieving lower leg angular velocity comparable to that of male players.
A series of findings in the present study implicated that female players might have a different motion strategy to achieve better instep kicking perfromance through improving the action of interaction moment. Therefore, their coaches should pay more attention on the coordinattion of lower leg swing motion rather than improving musculatures regarding knee extension motion during the instep kicking.

CONCLUSION: Soccer instep kicking of female players were characterized by its unique kinetic background; their instep kicking style relies more on the interaction moment acting at knee joint to compensate suppressed knee joint moment action and to achieve comparable lower angular velocity to that of male players.

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