KNEE JOINT KINEMATICS OF SUPPORT LEG DURING MAXIMAL INSTEP KICKING IN FEMALE SOCCER PLAYERS

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The purpose of this study was to investigate the effect of knee motion of support leg during maximal instep kicking on female soccer players. Their kicking motions were recorded by a motion capture system. The range of motion of knee angle (knee variation) was caluculated. There were significant negative relationships of foot velocity with knee variation (r =0.73, p < 0.05). The participants were divided into small (n = 8) and large (n = 8) variation groups based on their change amount of support leg knee angle during forward swing. Foot velocity, vertical hip velocity of kicking leg, and vertical centre of pelvis displacement during forward swing phase of small knee variation group than those of large variation group were found significant differences (p < 0.05). These results suggested that training for female players should focus on reducing knee angular displacement (flexion) of support leg during forward swing phase in instep kicking.

KEYWORDS: soccer, instep kick, female player, knee angle, support leg.

INTRODUCTION: In soccer, the instep kicking is one of fundamental and important techniques when the fast shot and pass are required. Women's soccer games are played with the same rules and conditions as men's soccer, despite the fact that the physical abilities of female soccer players are lesser than those of male soccer players. As the subjective effort when hitting the ball faster is higher than that for males, the technique of kicking a strong ball efficiently is required for female players. Theoretically, it is considered that male players tend to have a higher body mass than female players which contributes to greater kicking velocity. Shan (2008) examined the influence of gender and experience on the maximal instep soccer kick among male and female players. She reported that male players naturally follow through with a jump to dissipate residual leg momentum, on the other hand, female players avoid this airborne phase. The ballistic stretch-shortening cycle using knee flexion/extension range of the support leg has been accomplished effectively in powerful kick of male players. To obtain kicking techniques with a jump like male player (generate vertical velocity of body centre of gravity) could be improved kicking technique for female players. The previous study regarding to jumping reported that knee angle behaviour (extension/flexion) contributed to the vertical body centre of gravity (Shimizu *et al*. 2018). We hypothesized that the knee behaviour of the supporting leg would be a technical point for improving the foot velocity in female soccer players and observed the knee extension and flexion movements of the supporting leg among female players.

METHODS: Sixteen experienced female university soccer players volunteered to participate in this study. The experiment protocol was approved by the Human Research Committee of a University. Informed written consent was obtained from each participant before testing. After adequate warm up, all participants were instructed to perform maximal instep kicks towards a goal 5 m away, using the dominant leg (right). The kicking motion were captured using 10 infrared cameras (Vicon Motion Systems, Oxford, UK). three-dimensional coordinate data for each body part (47 anthropometric points with reflective markers attached) during the kicking motion were collected at 250 Hz. The stationary coordinate system was defined as a right-handed system in which the x-axis is the direction orthogonal to the horizontal kicking direction at the start of the task, the y-axis is the horizontal kick direction at the start of the task, and the z-axis is the vertical direction. The data, including the extrapolated points, were smoothed using a fourth-order phase-shift-free Butterworth digital filter to determine the optimum cut-off frequency (20 Hz) (Winter, 2004). Foot velocity immediately before ball impact was calculated as an index of the kicking performance. The hip vertical velocity of kicking leg, knee angle of support leg, and centre of pelvis displacement which can be considered as primary variables to express characteristics of the instep kicking, were calculated (Augustus *et al*., 2017). An upward movement of the hip with support knee extension during forward swing has been associated with increase foot velocity at impact (Inoue *et al*., 2000; Nunome and Ikegami, 2005). The kicking motion was defined by three events in this study. According to the definition described by Lees *et al*. (2009), support foot touch-down was determined from the force platform data instance the vertical force exceeded 20 N. Ball impact was determined the instance that the kicking foot first contacted the ball. End of trial was the instance that foot CG displacement first shifted to a downward during follow through. The period from 0% to 100% (from the touch-down to the ball impact) and that from 100% to 200% (from the ball impact to the end) were termed forward swing phase and follow through phase, respectively (Figure 1). In this study, the participants were divided into small (n = 8) and large (n = 8) variation groups based on their change amount of support leg knee angle during forward swing in order to investigate that the support leg behavior affects foot velocity. On the basis of the average value of the knee variation , the players were assigned to a small value (knee variation < mean value) or a large group (knee variation > mean value). As for height, weight and experience of participants, there were no significant differences between each variation group. Unpaired *t*-tests were used for atatistical comparisons between small variation group and large variation group. Significance was set at $p < 0.05$.

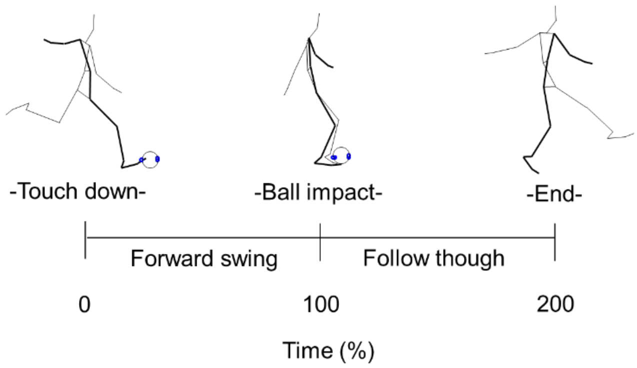

Figure 1: Definition of phases during kicking.

RESULTS: Figure 2 shows the relationship between foot velocity and knee variation. There were significant negative relationships of foot velocity with knee variation. (r =0.73, $p < 0.05$). The participants were divided into small (n = 8) and large (n = 8) variation groups based on their change amount of support leg knee angle during forward swing in order to observe the knee behaviour which is the main viewpoint in this study, and kinematic parameters of two groups were compared (Table 1).

Table 1: The average (±SD) values of kinematic parameters for the small (n = 8) and large knee variation group (n = 8).

	Small variation group	Large variation group	
Foot velocity (m/s)	19.1 (0.7)	17.6 (3.4)	*
Knee angle at support foot touch-down (deg.)	163.3 (5.8)	175.1 (3.9)	*
Peak of knee flexion during forward swing phase (deg.)	140.0 (6.5)	132.8 (3.3)	*
Knee angular variation during forward swing phase (deg.)	23.3 (3.9)	42.4 (3.5)	*

*: Significantly different between small and large variation group ($p < 0.05$)

The average foot velocity before ball impact of small variation group was larger than that of large variation group ($p < 0.05$). The average knee angle at touch down of small variation group was smaller than that of large variation group ($p < 0.05$) (Table 1). Figure 3 shows the change of average support leg knee angle during forward swing and follow through phase in both groups. Knee of support leg flexed dramatically from support foot touch down until approximately 70% during forward swing phase in both groups. Peak value of knee angle (flexion) of small variation group was smaller than that of large variation group ($p < 0.05$). The value of knee angle at ball impact of small variation group was larger than that of large variation group ($p < 0.05$). Afterward, knee of support leg extended until ball impact, and continued to be extended after ball impact.

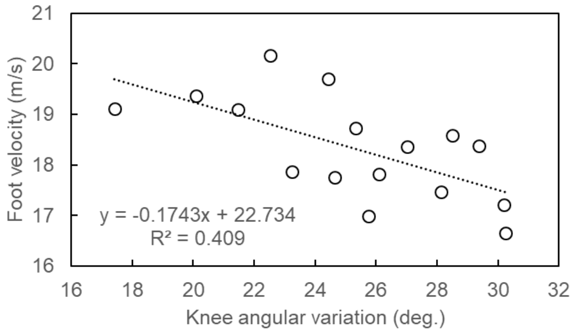

Figure 2: The relationship between foot velocity and knee angular variation.

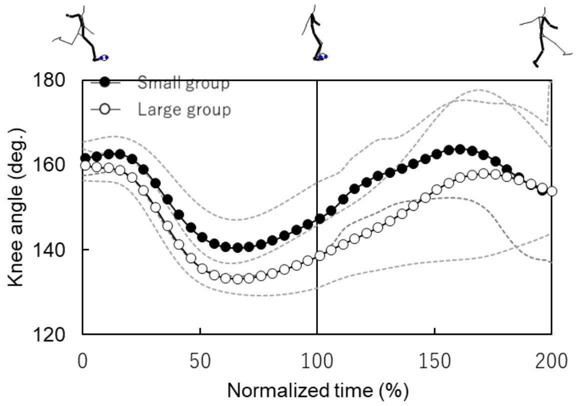

Figure 3: The average (±SD) changes of support leg knee angle during forward swing and follow through phase.

Figure 4 shows the average of vertical pelvis displacement in small variation group was higher than that of large variation group during forward swing phase (45~108%) ($p < 0.05$). The vertical pelvis displacement slightly decreased from start to around 50%, after that, it gradually increased until end. Figure 5 shows the change of average vertical hip velocity of kicking leg during forward swing and follow through phase in two groups. The vertical hip velocity of kicking leg gradually increased from touch down to ball impact, and it remained steady after ball impact to end. The average of vertical hip velocity of kicking leg in small variation group was higher than that of large variation group during forward swing phase (78~84% and 109~119%) ($p < 0.05$).

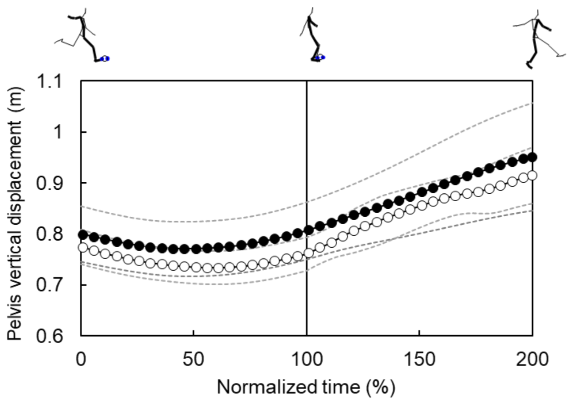

Figure 4: The average (±SD) changes of vertical pelvis displacement.

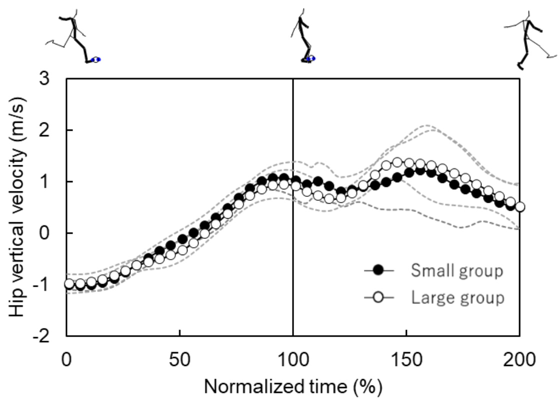

Figure 5: The average (±SD) changes of vertical hip velocity during forward swing and follow through phase (kicking leg).

DISCUSSION: The purpose of this study was to investigate the effect of knee motion of support leg during maximal instep kicking on female soccer players. The average of vertical pelvis displacement in small variation group was higher than that of large variation group during forward swing phase (Figure 4). This result suggested that knee extension involved in lifting pelvis (hip), the knee extension immediately before ball impact were accompanied by those extension joint moments and contribute to acceleration of the kicking foot. Inoue *et al*. (2000) reported that players who obtain larger vertical displacement generated the higher shank angular velocity of kicking leg. Nunome and Ikegami (2005) reported that extension of support knee related to lift the kicking hip, generating a motion dependent moment which accelerates the kicking leg shank. Additionally, Inoue *et al*. (2014) suggested that knee extension motions immediately before ball impact were accompanied by those extension joint moments and would contribute to acceleration of the swing of kicking leg. The average of vertical hip velocity in small variation group was higher than that of large variation group during forward swing phase (Figure 5). The proximal-to-distal sequencing of the kicking leg initiate from pelvis motion was well known (Nunome and Ikegami, *et al*., 2006). The accelerating the hip joint of the kicking leg in the vertical direction during the forward swing could be assumed to increase the vertical foot velocity produced the resultant foot velocity (Lees *et al*. 2009). Generated vertical hip velocity during forward swing phase also might be the technical element that could be improved to increase foot velocity in female players.

Augustus *et al*. (2018) showed that the kicking performance (ball velocity) could improve by the technical intervention. studies have attempted to improve maximal instep kicking performance through resistance training programs Campo *et al*. (2009) reported that the swing velocity could enhance by the pyrometric training. It was therefore speculated that the foot velocity could be improved by technical and physical training.

CONCLUSION:

In this study, we investigated the effect of knee motion of support leg during maximal instep kicking on female soccer players. The results indicated that the knee movement affected kicking foot velocity. We suggest that for female players, improvement of techniques to accelerate the hip joint of the kicking leg upwards and techniques to inhibited knee flexion during forward swing will be crucial for generating higher foot velocity. The coaches and physical trainers should provide the appropriate training corresponding to physical characteristics of a female player because the knee injury incidence of female soccer player is higher than that of male players.

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