A THREE-DIMENTIONAL KINEMATICS ON CONTRIBUTION OF EFFECTIVE LOWER BODY SEGMENT ROTATIONS IN PRODUCING FOOT VELOCITY IN SOCCER VOLLEY KICKING

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The purpose of this study was to illustrate the contribution of lower body segment rotations in producing foot velocity of soccer volley kicking. Ten experienced male university soccer players conducted to kick balls in varied heights. Their kicking motions were captured at 500 Hz. According to the procedure of Sprigings et al (1994), the effectiveness of pelvis and hip, knee and foot joint rotations in producing forward and vertical velocities of the foot centre of gravity were computed. Apparent unique contribution of the pelvis horizontal rotation to the forward foot velocity, and of the pelvis frontal and the hip internal rotations to the upward foot velocity were observed in volley kicking. These results endorsed the findings of Sugi et al (2016a) regarding emphasized joint motions during soccer volley kicking.

KEY WORDS: kicking leg, joint angular motion, lower leg configuration, coaching cues

INTRODUCTION: Volley kicking; to strike the ball directly in the air, is an advanced kicking technique in soccer. This kicking technique has been recognized as one of the most difficult one to make fast, accurate shot during the match. When the volley kicking is used offensively, it can play a crucial role in scoring straight goals. In the 2014 FIFA World Cup in Brazil, of all 171 goals, 33 goals (accounts for 19.2%) were scored by volley kicking (Sugi et al., 2016a). Recently, Sugi et al (2016a) clarified the three-dimensional joint kinematics of soccer volley kicking to a varied ball heights (25cm, 50cm and 75cm). They succeeded in extracting the following unique motions required for the volley kicking: 1) larger knee flexion angle, 2) larger range of hip joint internal/external rotation, 3) larger trunk lean angle and 4) larger range of pelvis rotation within the horizontal plane. Althoguh the foot velocities of the volley kicking consistently decresed when ball hight increases, these motions were even systematically emphasized with an increase of ball heights. However, it is still unknown how these unique motions contribute in producing foot resultant velocity.
Sprigings et al (1994) developped a mathamatical method for determining the effectiveness of arm segment rotations in producing racquet-head speed in tennis. Miyanishi et al (1996) applied the method to detect the contributions of upper torso and throwing arm rotations to the resultant ball velocity during baseball throwing (1996). In contrast, to date, there is no study which demonstrated the contribution of the kicking leg and the pelvis rotations in prodicing foot velocity during soccer kicking, in particular for the volley kicking.
We aimed to provide the data which will describe essential functions of the lower body segment rotations typically seen in the volley kicking. The information would deepen our understanding about the volley kicking and provide a novel insight for coaches. The purpose of this study, therefore, was to illustrate the effectiveness of the lower body segment ratations in producing foot velocity of soccer volley kicking.

METHODS: Ten experienced male university soccer players (age = 21.5±0.9yrs; height = 172.7±1.6cm; mass = 66.7±3.2kg; career = 14.7±1.4yrs) volunteered to participate in this study. To mimic the situation of volley kicking, the ball was set on light weight paper pipes of three different heights (25cm, 50cm and 75cm). The participants were asked to conduct the three types of volley kicking and a static instep kicking (0 cm) towards a goal (2mx3m) 7m ahead using their preferred leg. Kicking trials repeated so that we obtained five good trials having a good foot-ball impact and straight forward ball trajectory to the goal. The quality of the impact was judged in each trial by both the participant and an experienced soccer coach.

A FIFA standard, regulation soccer ball was used and its internal pressure (900 hPa) was controlled throughout the experiment. The participants wore the same type of training shoes, compression spats and compression shirts. Their kicking trials were captured by a 8 cameras optical motion capture system (VICON) at 500 Hz. Eight reflection markers were attached on the ball and twenty three reflection markers were placed on the both sides of subject's lower body (greater trochanter, anterior superior iliac spine, posterior superior iliac spine, lateral surface of thigh, lateral epicondyle of femurs, medial epicondyle of femurs, lateral surface of shank, lateral malleolus, medial malleolus, the fifth metatarsal head, tips of toe and heel).
According to the method of Sprigings et al (1994), the contributions of pelvis and the kicking leg segment rotations in producing two velocity components (forward and vertical) of the foot centre of gravity (fCG) were computed from the raw (non-smoothed) three-dimensional coordinate data. The time of leg swing motion was normalized to 100% following the precedure of Nunome et al (2002). 0% of time corresponds to the moment of toe-off the ground, and 100% of time corresponds to the moment of ball impact.

RESULTS: Initial ball velocities of the four conditions were 24.0±1.5m/s (0 cm, placed ball), 23.3±1.3m/s (25cm), 21.8±2.2m/s (50cm), 19.6±2.4m/s (75cm), respectively. Compared with the place kick, the initial ball velocities of the volley kicks were systematically decreased as the ball heights increased.

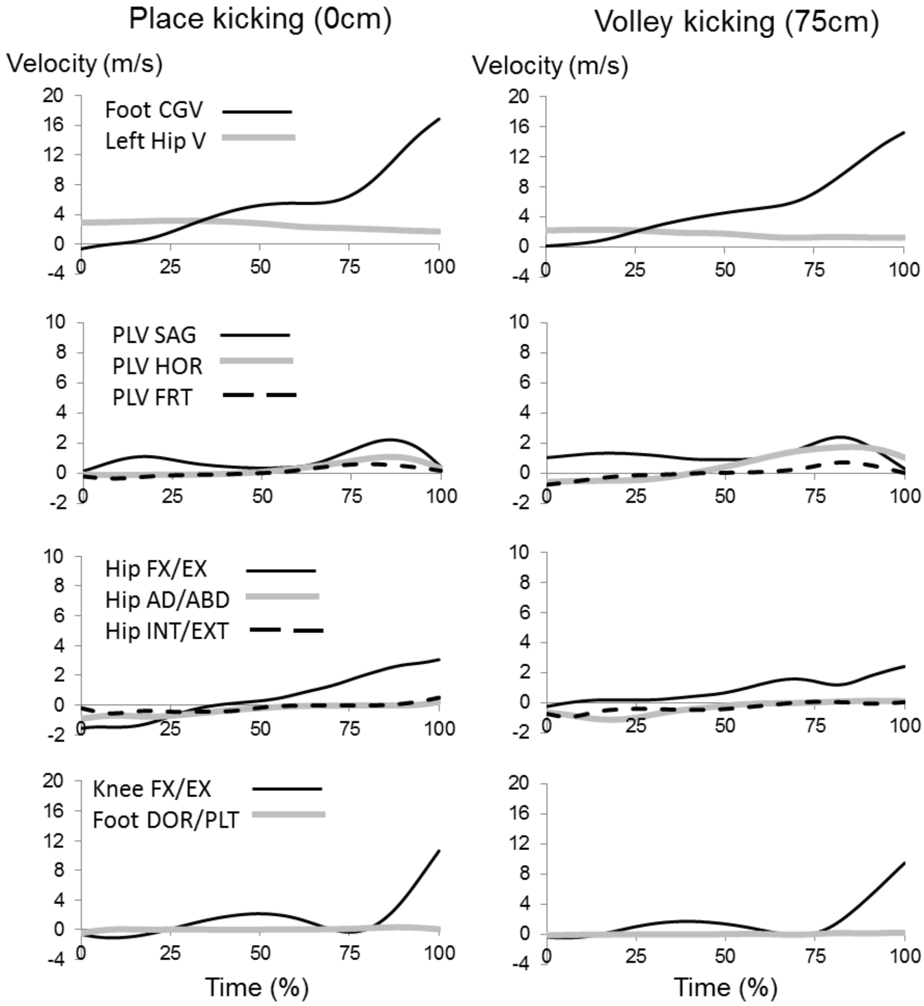

Figure 1. Ensemble average changes of individual contributions to forward foot velocity provided by linear hip (left) velocity, pelvis and kicking leg segment

Figure 1 shows the average changes of the fCG forward velocity (top panel) and individual contributions produced by the left hip linear velocity and the kicking leg rotations. For easy interpretation, the average changes of two most distant conditions (0 cm and 75 cm) were compared. For both conditions, there is a consistent trend on how the foot forward velocity produced. As shown in the figure, the knee extension was the main contributor (bottom panel), followed by the hip flexion (3rd panel) and the pelvis sagittal rotation (2nd panel) while the contribution of the foot segment was small to be negligible (bottom panel). A marked difference was, however, observed for the contribution of the pelvis horizontal rotation in the high volley kicking condition. This motion showed a comparable contribution to that of the pelvis sagittal rotation (2nd panel).

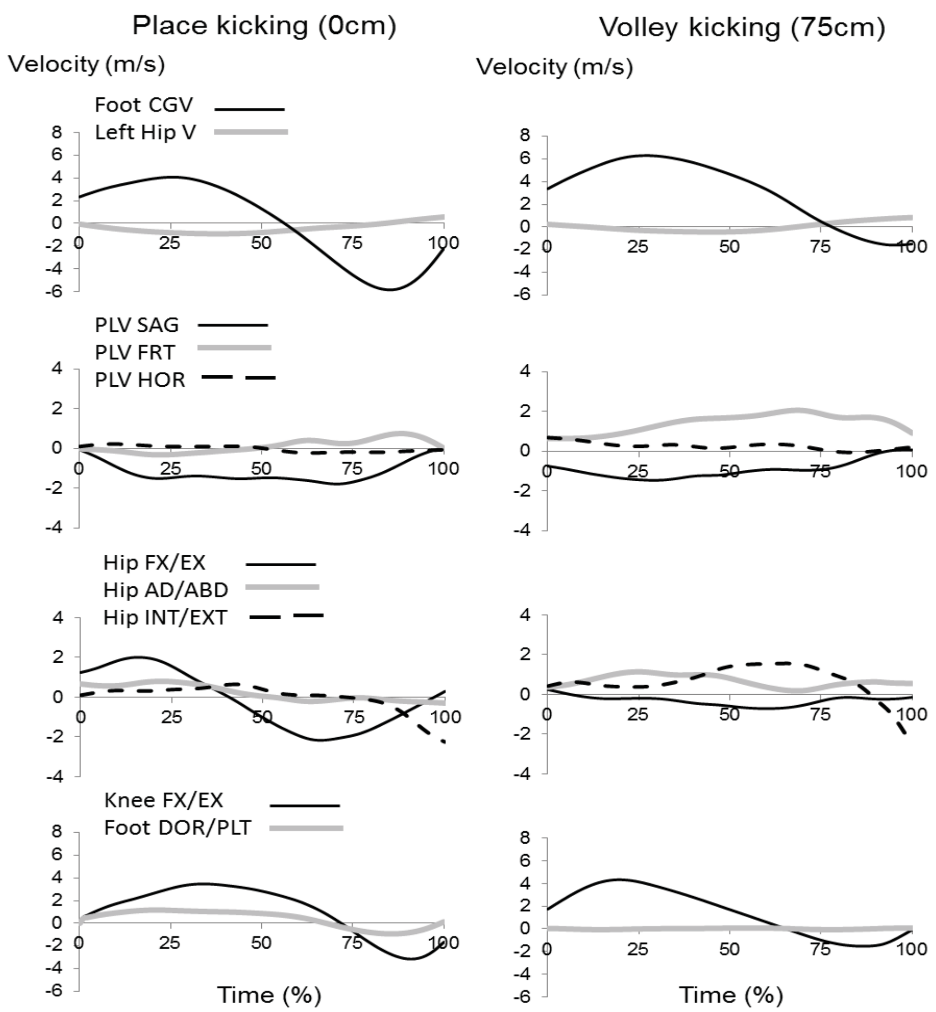

Figure 2. Ensemble average changes of individual contributions to vertical foot velocity provided by linear hip (left) velocity and kicking leg segment rotations.

Figure 2 shows the average changes of the vertical component of fCG velocity and the individual contributions. Similar to Figure 1, the two most distant conditions (0 cm and 75 cm) were compared in the figure for easy interpretation. In contrast to the forward component of fCG velocity production, there are apparent differences between the two conditions for the upward fCG velocity production. In the high volley kicking condition (75 cm), substantially larger upward fCG velocity appeared with distinctively longer duration (see top panel). In the place kicking (0 cm), the knee flexion (bottom panel) and the hip flexion (3rd panel) are most likely responsible to produce the upward fCG velocity. In contrast, there are several unique contributors in the high volley kicking condition. The pelvis frontal rotation (2nd panel), the hip abduction and internal rotation (3rd panel) showed apparent contributions in producing the upward fCG velocity.

DISCUSSION: The purpose of this study was to illustrate kinematic contribution of kicking leg and pelvis rotational motions in producing foot velocity during soccer volley kicking.

Compared with the place kicking (0cm), the high volley kicking (75cm) showed unique segmental contributions on the forward and upward fCG velocity production. Sugi et al (2016a) systematically investigated how soccer players adapt their kicking motion to different ball heights (25cm, 50cm and 75cm). They succeeded in extracting the following unique motions: 1) more flexed knee angle, 2) larger range of hip joint internal/external rotation, 3) larger pelvis lean angle and 4) larger range of pelvis horizontal plane rotation. Moreover, these motions were systematically emphasized with an increase of ball heights.
To explore the essential roles of these characteristic motions seen in the high volley kicking, an attempt was made to clarify the contributions of the lower body segment rotations in producing fCG velocity using the procedure of Sprigings et al (1994). As Sugi et al (2016b) reported that soccer players need to rise the foot in higher position for succesfull volley kicking, the contributions on the vertical fCG velocity was computed as well as the forwad component. These results strongly endorsed the suggestions made by Sugi et al (2016a). For the forward fCG velocity, we demonstrated an apparent contribution of the pelvis rotation within the horizontal plane in the high volley kicking. When players raise the foot to almost same height of the pelvis, the players come to have a feasible posture to effectively increase the foot forward velocity using the horizontal rotation of the pelvis. This may be a feasible strategy to effectively increase the foot forward velocity in high volley kicking.
For the upward fCG velocity, we also succeeded in clarifying the essential roles of the two motions: larger range of hip joint internal rotation and larger pelvis lean. These motions showed distant contributions to the upward fCG velocity in the high volley kicking. Sugi et al (2016a) suggested that an emphasized hip axial rotation (corresponds to the hip internal rotation) seen in volley kicking enables players to align their lower leg configuration horizontally to the ball launching direction. In this posture, players can fully utilize their planar motions to increase the foot velocity. Thus, these unique motions form another reasonable strategy to increase the foot forward velocity in high volley kicking.

CONCLUSION: We succeeded in illustrating unique segmental contributions of pelvis and kicking leg to produce foot velocity in soccer volley kicing. To achieve higher foot position required for the volley kicking, players exhibited larger upward foot velocity utilizing 1) the pelvis frontal rotation and 2) the hip internal rotation. These motions allowed players to align to utilize their planar pelvis and lower leg motions to increase forward foot velocity. Also typical foot high posture in the volley kicking allowed players to utilize the plevis horizontal rotation for producing the foot forward velocity. This may explain why that motion was emphasized in soccer volley kicking. These findings most likely support practical implications suggested by Sugi et al (2016a, 2016b).

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