COMPARISON OF SUCCESS AND FAILURE IN SOCCER VOLLEY KICKING

Shusei Sugi[1], Hiroyuki Nunome[2], Yuji Tamura[2] and Shariman Ismail[1]

Graduate School of Sports and Health Science, Fukuoka University, Fukuoka, Japan[1]
Faculty of Sports and Health Science, Fukuoka University, Fukuoka, Japan[2]

The purpose of this study was to describe kinematic variables that can distinguish between successful (straight to the goal) and failed (over the goal) soccer volley kicking. To mimic the situation of the volley kicking, the ball was set on a paper pipe. The kicking motions of both successful and failed trials were captured from ten male university soccer players using an optical motion capture system at 500 Hz. As a result, foot–ball impact points on the ball in failed trials were concentrated around the bottom part of the ball, and the kicking motion in failed trials were characterized as: 1) smaller hip internal rotation during the back-swing, 2) more upright foot posture at ball impact and 3) more downward leg swing just before ball impact. Furthermore, it was suggested that there were several patterns of failed trials depending on the subjects.

KEYWORDS: kicking leg, joint angular motion, failure trials, coaching cues

INTRODUCTION: Volley kicking; striking 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 for generating fast, accurate shots during a match. Sugi et al. (2016) clarified the three-dimensional joint kinematics of soccer volley kicking at various ball heights (25 cm, 50 cm and 75 cm) and succeeded in extracting several unique motions required for the volley kicking. In addition, they applied the procedure of Sprigings et al. (1994) to detect the contribution of lower body segment rotations to the velocity of foot centre of gravity (foot CG), thereby showing instantaneous trends in the contribution of each segment rotation (2019).
In the 2018 FIFA World Cup in Russia, of all 169 goals, 38 goals (accounts for 22.5%) were scored by volley kicking. From the video footage of all shots, the authors classified ball hitting height of volley kicking into three categories: below the knee (low), above the knee and below the waist (middle), and above the waist (high). On target percentage of low, middle and high volley kicks were 18.0%, 9.4%, and 3.0%, respectively, indicating that the difficulty to make a shot on target increases as the ball height increases.
A number of biomechanical researches have been conducted for soccer kicking (Nunome et al. 2002, Inoue et al. 2014), however, most of these previous studies regarding soccer kicking, failed trials were excluded from the data set and only successful trials were extracted for further analysis. In general, it can be assumed that inadequate techniques used for kicking can discriminate between successful and failed outcomes. However, it is still unknown how players failed soccer kicking.
From our survey of the 2018 FIFA World Cup in Russia, volley kicking to a high ball was extracted as the most difficult task having only 3% of shots on target. We also found that the most common failed pattern of this volley kicking was to launch the ball over the crossbar (53%). These data indicate that the most common failed pattern of volley kicking is kicking over the crossbar using high volley kicking. To identify the factors behind the failure of this technique would provide more insightful information for coaches and players to refine this kicking technique.
Therefore, the purpose of this study was to describe kinematic differences between successful and failed soccer high volley kicking. Regarding this aim, we set two hypotheses: successful shots would show 1) larger trunk lean angle and 2) larger hip internal rotation during back swing.

METHODS: Ten experienced male university soccer players (age = 21.5 ± 0.9 yrs; height = 171.7 ± 1.5 cm; mass = 64.7 ± 4.2 kg; career = 14.7 ± 1.4 yrs) volunteered to participate in this study. To mimic the situation of soccer volley kicking in the laboratory, the ball was set on light weight paper pipes (placed 7 m away from the goal) with 75 cm heights. The participants were

asked to conduct a volley kicking towards a goal 7 m ahead using their preferred leg (all right). Their kicking trials were captured by an 8 cameras optical motion capture system (Vicon Nexus; Vicon Motion Systems, Oxford, UK) at 500 Hz. According to the model of Sugi et al. (2019), 8 reflective markers were placed on the ball and 23 reflective markers were placed on both sides of the subject's lower body.
The successful volley kicking in this study were defined as the two fastest ball speeds among the attempts where the kicked ball flew without bound to the goal centre. On the other hand, the failed volley kicking was defined as the two largest launch angles among the attempts in which the kicked ball was over the goal height.
From the three-dimensional coordinates, kicking leg: 1) knee flexion/extension angle, 2) hip internal/external rotation angle, 3) hip abduction angle and 4) height of foot CG, 5) pelvis lean angle, 6) pelvis transverse rotation angle, and support leg: 7) knee flexion/extension.
In addition, foot orientation (kicking side) was calculated from the heel to toe vector and the horizontal axis (Nunome et al. 2018). Attack angle (before the impact) was calculated from the foot CG swing vector and the face vector (Ishii et al. 2009). Impact point was calculated from the distance from the centre of the ball to the contact point (position of foot CG at ball impact). Based on the report by Shinkai et al. (2009), the ball impact was defined as one frame (2 ms) before the reflective markers attached to the ball moves forward.
A paired T-test was used to compare ball and foot kinematics between successful and failed trials just before, during and after ball impact (Table 1). The differences in time-series average joint angle changes (Figure 2) were assessed across the kicking phase (0%: toe-off to 100%: ball impact) with a statistical parametric mapping (1D SPM) paired T-test (Pataky, 2012). The criterion for statistical significance was set at $P < 0.05$.

RESULTS: Table 1 shows the average value of ball and foot kinematics just before, during and after ball impact. Initial ball velocities of successful and failed trials were: 20.2 ± 2.0 m/s and 18.1 ± 2.2 m/s, respectively. The successful trials produced significantly faster ball velocity than that of the failed trials ($P = 0.003$). the failed trials significantly launched the ball higher (19.5 ± 3.0°) than that of successful trials (4.5 ± 1.9°, $P = 0.000$).
Figure 1 shows the distribution of foot–ball contact point computed as the position of foot CG on the ball at the moment of ball impact. It was found that the failed trials apparently hit lower part of the ball than the successful trials.

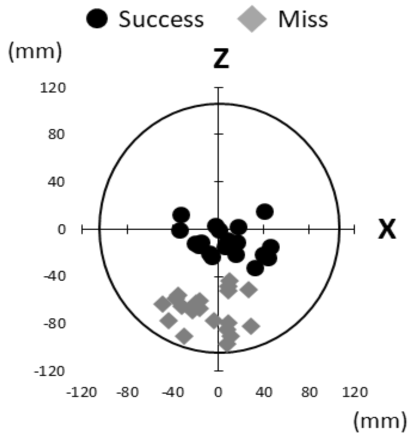

Figure 1: Foot-Ball contact point.

Table 1: Summarized foot and kinematics around ball impact.

	Success	Miss	P value
a. Initial ball velocity (m/s)	20.2 ± 2.0	18.1 ± 2.2	.003
b. Foot CG velocity (m/s)	14.4 ± 3.3	15.4 ± 3.5	.008
c. Ball foot contact rate	1.41 ± 0.35	1.19 ± 0.33	.001
d. Foot orientation (deg.)	30.9 ± 7.4	34.0 ± 6.5	.029
e. Attack angle (deg.)	31.0 ± 3.3	34.0 ± 3.0	.008
f. Impact point (mm)	27.2 ± 14.5	61.2 ± 14.2	.000

Figure 2 shows the comparison of ensemble average changes of successful and failed trails for six joint motions. Significant difference was only found in hip internal/external rotation motion (Figure 2-b) while there were no significant differences in other joint motions. The 1D SPM T-test revealed significant differences in this axial hip motion from 0 to 62% of the time, indicating that the failed trials were characterized by significantly smaller hip internal rotation during the back-swing phase.

DISCUSSION: Successful trials had significantly faster initial ball velocity instead of faster, however, the foot CG velocity was faster in the failed trials (Table 1). This apparent discrepancy can be explained due to a different manner of foot contact on the ball between the success and failed trials. Regarding the foot orientation, the smaller angle indicates more horizontal (less upright) posture of the foot towards ball impact. For the successful trials, this angle was significantly smaller than that of the failed trials. In addition, the attack angle of the foot was significantly smaller in the successful trials than that of the failed trials, suggesting that a successful volley kicking requires to swing the kicking leg as horizontal as possible while keeping the horizontally foot posture. On the other hand, to strike the lower part of ball is a feasible condition to launch the ball over the goal as is generally seen in a failed volley kicking. As shown in Figure 1, it was confirmed that the failed trials apparently hit the off-centre, lower part of ball, which may also account for slower ball velocity observed in the failed trials.

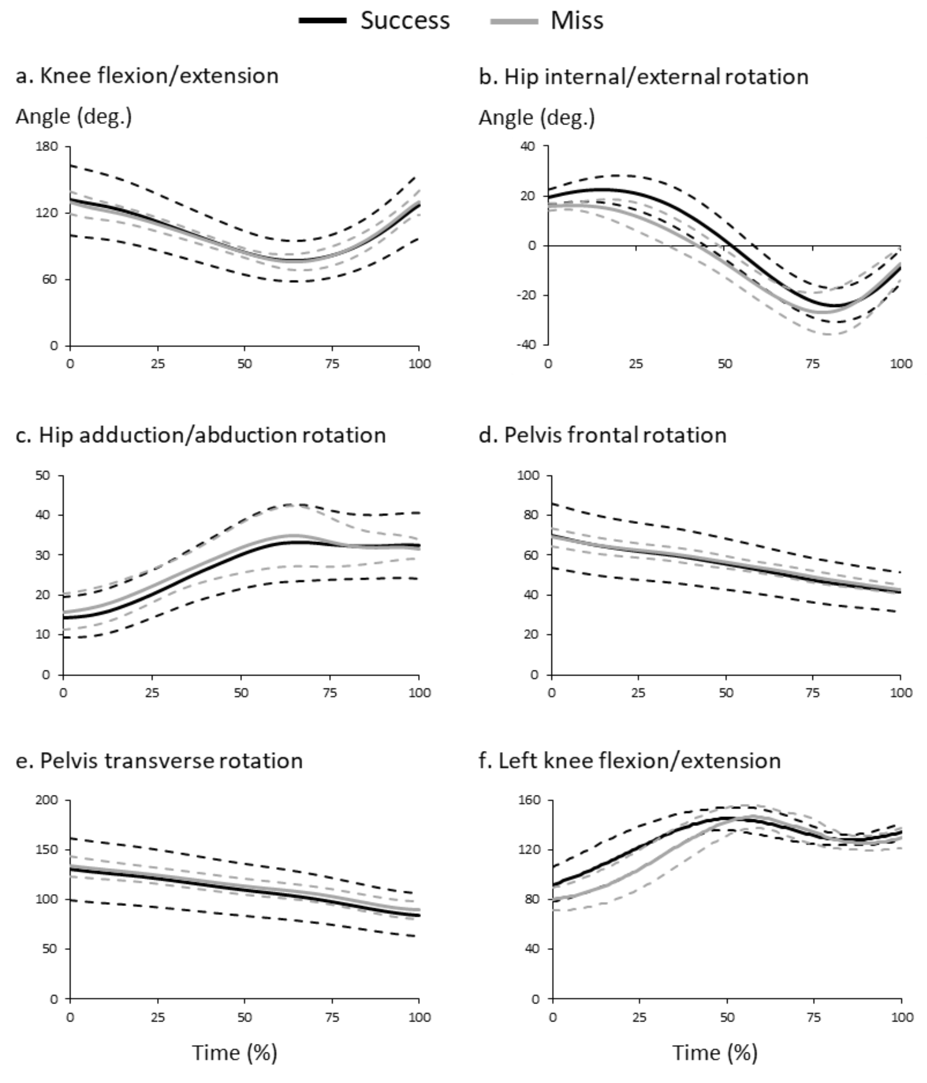

Figure 2: Comparison of ensemble average changes of seven joint motions between successful and failed trials. The time was normalized to 100% using the definition of Nunome et al. (2002).

Sugi et al. (2019) quantified how lower body segment rotations contribute to the foot CG velocity in soccer volley kicking. They clarified that a) knee flexion, b) hip internal rotation and c) pelvis clockwise rotation within the frontal plane were main contributors to produce the upward foot CG velocity. In this study, we found that the hip internal rotation was significantly restrained during the back-swing phase in the failed trials. This finding is in line with the study of Sugi et al. (2019) and strongly supported our second hypothesis. From practical perspectives, appropriate hip internal rotation during the back-swing phase is an important point for successful volley kicks and can be used as a coaching cue in the field. However, as there were no significant changes for the other joint motion in volley kicking, our first hypothesis was not supported.

In this study, we found that high volley kicking has several unique, individual patterns of failure. Figure 3-a shows the changes of pelvis frontal rotation of subject A. Two trials were shown for each of the successful and failed trials (total 4 trials). There is a clear trend for this subject; insufficient lean angle of the pelvis was observed in the failed trials. Thus, insufficient pelvis lean motion may explain lowered kicking leg trajectory in his failed trials. On the other hand, Figure 3-b shows the changes of support leg (left) knee flexion/extension angle of subject B. In the case of this subject, the knee extension angle was apparently smaller in his failed trials. This may account for his lower kicking leg trajectory in the failed trials.

From the comparison of the time series joint angular motions between successful and failed trials, the 1D SPM extracted a significant difference only in hip internal rotation motion. However, there were unique failed patterns for each subject. These may be categorized into several patterns, as shown in Figure 3. This finding may imply there are varied, individualized cause other than insufficient hip internal rotation to induce failed high volley kicking.

In this study, we used an experimental design using a placed ball and exclusion of opponent. This could be a limitation to interpret the findings of this study. Further studies apply more realistic condition such as flying ball should be warranted.

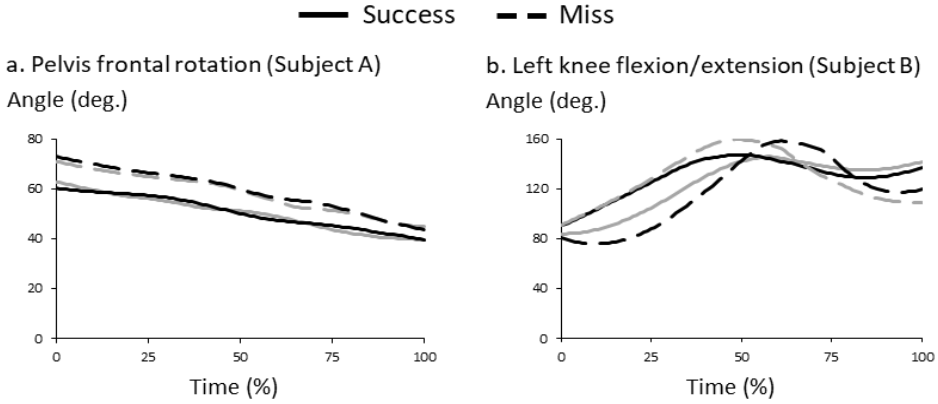

Figure 3: Examples of individualized pattern of failure seen in two subjects.

CONCLUSION: In this study, an attempt was made to clarify the differences between successful and failed soccer high volley kicking from the viewpoint of kinematics. In contrast to our hypothesis, only hip internal rotation motion was showed significant difference between the two kicking outcome conditions. The failed trials hit the lower part of ball than the successful trials, due to the larger downward leg swing immediately before ball impact. Moreover, several personalized failed patterns were observed, suggesting the cause of failure partially depends on individuals.

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