Kinematic analysis of the ball impact in female soccer players

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Abstract

In recent years, the number of female soccer players has been increasing worldwide; however, few studies have investigated the kicking technique of female players. Accordingly, this study used 3 high-speed video cameras (1000 fps) to compare the ball velocity, foot velocity, repulsion ratio, and angular displacement at ball impact of the instep kick and inside kick in female and male soccer players to identify the mechanical and technical characteristics of female players at ball impact. For both kicks, the ball velocity, foot velocity immediately prior to impact, and average repulsion ratio were smaller for the female players than for the male players. For both males and females, there tended to be a lower repulsion ratio the further the impact point was from the centre of gravity of the foot. The mechanical properties of the ankle joint in female players during the instep kick may involve slightly lower dynamic stiffness than that of the male players. In addition, the lower dynamic stiffness of the ankle joint in female players is believed to have a comparatively greater effect on the instep kick, suggesting that impacting the ball with the centre of gravity of the foot is even more important.

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1. Introduction

A number of studies have investigated the interaction between the ball and the foot during ball impact (Dörge \textit{et al.} [1]; Shinkai \textit{et al.} [2]). However, in the majority case, researches were done for male soccer players; studies on the kicking action of female soccer players are scarce (Barfield \textit{et al.} [3]; Clagg \textit{et al.} [4]). Accordingly, this study was designed to compare the ball impact kinematics between female and male soccer players to extract the mechanical and technical characteristics of female players.

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2. Methods

The subjects included 17 male soccer players with at least 10 years of soccer experience (height: 172.0 ± 4.4 cm, weight: 65.7 ± 4.8 kg) and 17 female soccer players with at least 5 years of soccer experience (height: 161.4 ± 4.5 cm, weight: 56.0 ± 3.4 kg), totalling 34 athletes specializing in soccer at a university with a department of physical education. The goals and content of the experiment were explained to the subjects beforehand and their consent was obtained. For collection of data, hemispherical markers (diameter ~1 cm) were attached to each subject at 13 locations: 4 on the leg (knee, lateral malleolus, medial malleolus, and the midpoint between the knee and the lateral malleolus), 5 on the side of the foot (toe tip, head of the fifth metatarsal, midpoint between the head of the fifth metatarsal and the base of the fifth metatarsal, midpoint between the base of the fifth metatarsal and the heel, and the heel) and 4 on the top of the foot (toe tip, head of the third metatarsal, midpoint between the head of the third metatarsal and the base of the third metatarsal, and cuneiform bone). The subjects were instructed to kick a placed soccer ball (FIFA-approved size 5 ball, weight: 430 g, pressure: 900 hp; Adidas, Herzogenaurach, Germany) with the dominant foot at full strength towards the goal (height: 2.44 m, width: 7.32 m). The kicking techniques used were the instep kick (a kicking action involving the instep) and the inside kick (a kicking action that scoops the ball with the inside surface of the foot, performed while the ankle is flexed), each of which was conducted 10 times (Figure 1). The test kicks were recorded by 3 high-speed video cameras (FASTCAM 1024 PCI model 100KC, speed: 1000 fps, exposure time: 1/5000 s, resolution: 1024 × 1024 pixels; Photron, Tokyo, Japan). A camera was installed on the right side (on the side of the kicking leg) and another was installed on the right-rear side with respect to the kicking direction, which recorded data synchronously (Figure 2). The third camera was set up normal to the swing plane of the kicking foot, and was used to measure the horizontal velocity of the foot.

The three-dimensional motion of the ankle was measured using the direct linear transformation (DLT) method (Abdel-Aziz and Karara, 1971 [5]).

This study calculated the average foot velocity, the ball velocity, and the angular displacement. The ball velocity is defined as the average of five frames after the ball is taken off from the foot, and the foot velocity was calculated one frame before the foot touches the ball. In addition, the difference between maximum and minimum displacement of foot joint during the foot contact with the ball was defined as the angular displacement. Descriptive statistics were used to determine means and standard deviations. A two-way analysis of variance was performed to determine gender and kick difference.
3. Results and Discussion

3.1. Comparison of male and female players

Fig. 3. Comparison of kicking parameters for female and male players [a = ball velocity; b = foot velocity; c = coefficient of restitution; d = reduced mass]. The bars and asterisks represent significant differences between males and females (p < .05); significant differences between kicks are not shown on the graphs.

The average ball velocity for the instep kick of the female players was $22.0 \pm 2.6$ m/s and $19.0 \pm 2.1$ m/s for the inside kick, compared to male players scoring $26.6 \pm 2.6$ m/s for the instep kick and $21.9 \pm 2.0$ m/s for the inside kick (Figure 3(a)). Thus, the average ball velocity of the female players was 17% lower than the male players for the instep kick and 13% lower for the inside kick, both of which were significantly different (p < 0.05). The average ball velocity for the instep kick of the male players was roughly 1.9 m/s higher than that (24.7 ± 2.5 m/s) reported for male players in Dörge et al., and the average inside kick of the male players was roughly 1.5 m/s lower than that (23.4 ± 1.7 m/s) reported for male players by Nunome et al. [6].

For the female players, the average foot velocity immediately prior to impact was $18.0 \pm 1.8$ m/s for the instep kick and $14.0 \pm 1.3$ m/s for the inside kick (Figure 3(b)). One reason for this difference might be that compared to the swing of the inside kick, the extension action of the leg in the swing of the instep kick is easier. In this study, the average foot velocity of the instep kick for the female players was roughly 1.8 m/s higher than that (16.2 ± 2.3 m/s) for female players reported by Barfield et al.. Compared to the female subjects in the present study, those of Barfield et al. are inferred to be excellent players, although this effect is considered to have been small. In the present study, the foot velocity of the female players immediately prior to impact was roughly 12% lower than the males for the instep kick and roughly 10% lower for the inside kick, both of which were significantly different (p < 0.05). These results are thought to be reflective of gender differences in physical characteristics such as leg extension power, as well as differences in swing technique.

The average repulsion ratio of the instep kick was $1.23 \pm 0.16$ for the female players and $1.31 \pm 0.18$ for the male players, a 6% lower value for the female players that was significantly different (p < 0.05; Figure 3(c)). The average repulsion ratio reported for the male players in Kellis et al. [7] had a slightly higher average value of $1.40 \pm 0.12$. The significant difference in repulsion ratios for the instep kick between males and females in the present study may have been due to the locking of the ankle joint of the female players at impact being less than that of the male players.

The average value of the inside kick was slightly lower for the female players than for male players ($1.37 \pm 0.14$ vs. $1.41 \pm 0.16$, respectively), although the difference was not significant. Comparing this average value to that for the instep kick, the repulsion ratio of the inside kick had a tendency to be larger. However, this analysis compared only the average values of the instep kick and the inside kick, and differences in ball impact location are expected to have a large effect on the repulsion ratio.
Consequently, an investigation of the relationship between repulsion ratio and ball impact location would be valuable.

3.2. Relationship between the repulsion ratio and the impact point

The repulsion ratio near the centre of gravity for the instep kick was ~1.35 for the female players (the y-intercept of the quadratic regression curve), which was slightly lower than ~1.45 for the male players (Figure 4(a), (b)). The angular displacement (flexion and extension) for the female players also tended to become larger than for the male players the further the impact point was from the centre of gravity of the foot (Figure 5(a), (b)). In terms of mechanical characteristics at impact, these results suggest that the ankles of the female players exhibited both a lower mass and lower dynamic stiffness than did the male players. The repulsion ratio in the vicinity of the centre of gravity at impact was ~1.144 (the y-intercept of the quadratic regression curve) for the female players, slightly less than ~1.149 for the male players (Figure 4(c), (d)). Furthermore, this tendency remained despite a decrease in the repulsion ratio the further the impact point was from the centre of gravity of the foot. The overall average repulsion ratio for
the female players was not significantly different from that for the male players. In addition, the relationship between angular displacement (external rotation) and impact point for the female players had a similar trend to that of the male players, and no marked gender differences were seen (Figure 5(c), (d)).

![Graphs showing relationship between impact distance and angular displacement for male and female players.]

From these results, it can be inferred that kicking technique has a greater effect than the mechanical properties of the ankle joint on the tendency for a lower repulsion ratio at impact among the female players compared to the male players.

Looking at the overall relationship between impact distance and repulsion ratio for the instep and inside kicks of the male and female players, for all of the test kicks, a trend was seen for the repulsion ratio to be higher near the centre of gravity of the foot and to decrease with increasing distance. This may be due to the increasing moment around the centre of gravity that arises with increasing distance from the centre of gravity of the foot, and therefore, a lower amount of energy is transmitted to the translational motion of the ball. Consequently, it is conceivable that for both male and female players and for both the instep and inside kicks, impacting the ball at the centre of gravity of the foot is an important technical point, as it increases the repulsion ratio.
4. Conclusion

In this study, 3 high-speed video cameras (1000 fps) were used to compare ball velocity, foot velocity, repulsion ratio, and angular displacement at ball impact of the instep kick and inside kick of female and male soccer players in an attempt to elucidate the mechanical and technical characteristics of female players at ball impact.

For the instep and inside kicks, the ball velocity, foot velocity immediately prior to impact, and average repulsion ratio were smaller for the female players than for the male players. For both kicks for males and females, there tended to be a lower repulsion ratio the further the impact point was from the centre of gravity of the foot. The mechanical properties of the ankle joint of female players during the instep kick may involve slightly lower dynamic stiffness than that of the male players. In addition, the lower dynamic stiffness of the ankle joint of female players is believed to have a comparatively greater effect on the instep kick, suggesting that acquisition of the technique of impacting the ball with the centre of gravity of the foot is even more important. This study analyzed only the moment of ball impact, and to investigate gender differences in more detail, it will be necessary to analyze the entire kicking action. Moreover, a future challenge is to perform not only kinematic studies of gender differences, but also kinetic studies.

References


