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Comparison of kicking speed between female and male soccer players

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Abstract

A comparative study of the ball-kicking motion for the instep kick of female and male athletes was conducted by using an optical motion capture system. The results showed that the thigh and shank energies were lower overall for female athletes, and that the average thigh-to-shank energy ratio was significantly lower for female athletes than for male athletes ($p < 0.05$). This suggests that female athletes may have poorer thigh-to-shank energy transfer techniques than do male athletes. Furthermore, a forward dynamics simulation was performed to examine the impact of the vertical force component of the hip joint on the swing velocity. As the vertical translational force increased during a forward swing, the swing velocity also tended to increase. Therefore, accelerating the hip joint of the kicking leg in the vertical direction during the forward swing of the instep motion may be assumed to increase the swing velocity. Such hip acceleration is one of the technical elements that could be improved to increase ball velocity in female athletes.

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Keywords: soccer, female, kicking, speed;

1. Introduction

The technical level of women's football is rising every year. Consequently, there is great demand for improving kicking techniques to enable faster shooting and passing. However, most previous research on kicking

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techniques has focussed on male football players (Lees et al., 2010, Nunome et al., 2006), and little research has been conducted on female football players (Barfieldet al., 2002., Orloff al., 2008, al., Clagg et al., 2009). Moreover, although there are clear differences in skeletal structure, muscle power, and flexibility between female and male athletes (Stølen et al., 2005), the characteristics of kicking techniques in female football players have not been clarified. In the present study, we therefore compared the instep kick motions of female and male athletes by using an optical motion capture system, and clarified the technical characteristics of the motion in female football players. Furthermore, we examined technical factors that contribute to increasing ball velocity.

2. Methods

2.1. Participants and Experimental Procedure

The participants were 26 athletes specializing in soccer at a university with a department of physical education (13 males, 174.3 ± 4.7 cm in height and 66.8 ± 4.9 kg in weight; 13 females, 160.4 ± 4.9 cm in height and 57.1 ± 5.7 kg in weight). The experimental task was to execute a kicking motion in which the ball is caught at the instep (the portion centred on the dorsum of the foot leading to the ankle). Each participant was asked to warm up, and then, with an ad libitum running start, to kick a soccer ball that had been set down towards a goal 10 m away, using the dominant leg at full force. Imaging was performed using 10 infrared cameras (Vicon Motion Systems, Oxford, UK); three-dimensional (3D) coordinate data for each body part (16 anthropometric points with reflective markers attached) during the kicking motion were collected at 250 Hz (Fig. 1). 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). A force platform (Kistler,Winterthur, Switzerland, Type 9287) was installed beside the ball, and the ground reaction force at the point of contact with the supporting leg was measured at a sampling frequency of 1000 Hz.

2.2. Data Analysis and Calculated Parameters

In this study, the following parameters were estimated to analyse differences between females and males. Velocities of the ball and foot velocities of the centre of gravity were calculated. The velocities for hip, knee and ankle joints were calculated respectively. In the present study, the whole body was modelled using a segment model of 15 rigid bodies connected by 14 joints with 3 degrees of motion freedom. A moving coordinate system was set for every degree of motion freedom from the 3D coordinates of each site on the body to calculate the joint angle and joint angular velocity during the kicking motion. Inverse dynamics calculation was adopted for reaction force data to calculate the joint torque. To evaluate the extent to which mechanical energy from the thigh is transferred to the shank, the mechanical energy transfer ratio in the leg was also determined by calculating the thigh and shank energies in the kicking leg (Eq. 1) (Kellis and Katis, 2007). The shank-to-thigh energy ratio was calculated for the point of contact between the kicking leg and the ball, following the point of contact between the support leg and the ground, by dividing the integral value of the shank energy during a later stage by that of the thigh energy. The early stage was defined as the time from the point of contact between the support leg and the ground to the peak thigh energy in the kicking leg, whereas the late stage was defined as the time from the peak thigh energy in the kicking leg to the point of contact between the kicking leg and the ball (Eq. 2).

$$E = U + K \tag{1}$$

Here, E denotes the mechanical energy, where U and K denote the potential and kinetic energy, respectively.

$$\int E_{st} = \frac{E_s}{E_t} \tag{2}$$

Here, E_{st} denotes the shank-to-thigh ratio, where E_s and E_t denote the shank and thigh energies, respectively.

2.3. Forward Dynamics Simulation

In the present study, we evaluated the impact of the vertical translational force of the hip joint for the kicking leg. The right shank, which was used to describe the motion, was modelled as a double pendulum of the knee and hip joints (Fig. 2). From the kinetic data for the kicking leg collected through the optical motion capture system, the equation of motion (Eq. 3, 4) was derived using the multibody dynamics system in MapleSim 6 (Cybernet Systems Co., Ltd.). Furthermore, the equation of motion for the double pendulum model was derived from the Lagrange function, which is composed of kinetic and potential energies. The formula manipulation language Maple 16.01 was used (Cybernet Systems Co., Ltd.) to derive the equations of motion. All joint torques were calculated from the kinetic position data and the inverse dynamics equations of motion; in addition, the position, velocity, and acceleration for all joints were calculated from the joint torques, and the forward dynamics. After investigating the suitability of the kinetic data calculated through a forward dynamics analysis, a forward dynamics simulation was performed using the force data as parameters.

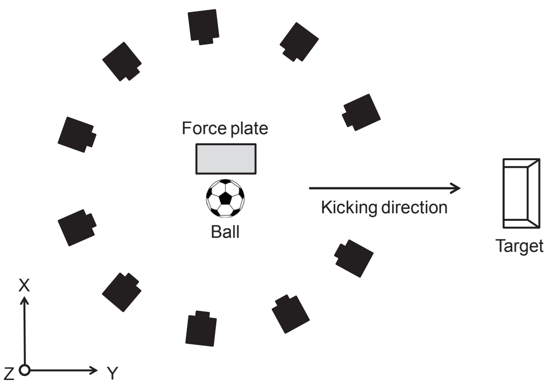

Fig. 1 Experimental setup.

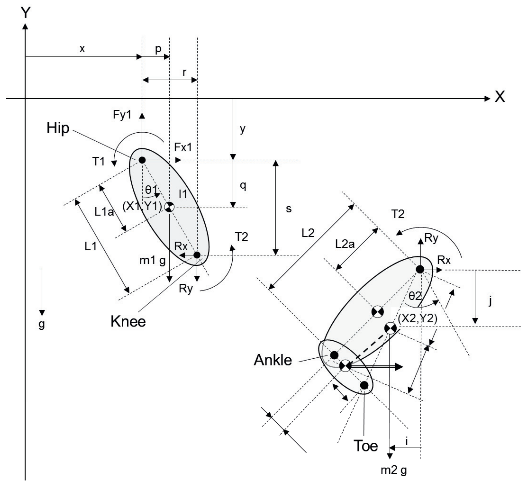

Fig. 2 Two-dimensional double pendulum model.

$$\begin{aligned} V_{foot} &= -\dot{x}(t) - c\dot{\theta}2(t)\sin(\theta1(t)+\theta2(t)) - d\dot{\theta}2(t)\cos(\theta1(t)+\theta2(t)) \\ &\quad - L2a\dot{\theta}1(t)\cos(\theta1(t)+\theta2(t)) - L2a\dot{\theta}2(t)\cos(\theta1(t)+\theta2(t)) \\ &\quad - c\dot{\theta}1(t)\sin(\theta1(t)+\theta2(t)) \\ &\quad - d\dot{\theta}1(t)\cos(\theta1(t)+\theta2(t)) - \dot{\theta}1(t)\cos(\theta1(t))L1 \end{aligned} \tag{3}$$

V_{foot} denotes the foot velocities of the centre of gravity.

$$\begin{aligned} Fz(t) &= MZa - MP\cos(Hs)\,Hv^2 + MP\sin(Hs)Ha + NZa + NA\cos(Hs)\,Hv^2 + NA\sin(Hs)Ha \\ &\quad + NQ\cos(Hs)\cos(Ks)\,Hv + 2NQ\cos(Hs)\cos(Ks)\,HvKv \\ &\quad + NQ\cos(Hs)\cos(Ks)\,Kv^2 - NQ\sin(Hs)\sin(Ks)\,Hv^2 \\ &\quad - 2NQ\sin(Hs)\sin(Ks)\,HvKv - NQ\sin(Hs)\sin(Ks)\,Kv^2 \\ &\quad + NQ\sin(Hs)\cos(Ks)\,Ha + NQ\sin(Hs)\cos(Ks)\,Ka + NQ\cos(Hs)\sin(Ks)\,Ha \\ &\quad + NQ\cos(Hs)\sin(Ks)\,Ka + MG + NG \end{aligned} \tag{4}$$

Fz (*t*) denotes the hip vertical force, *Hs* and *Ks* denotes the hip and knee angle, respectively.

3. Results and Discussion

3.1. Average Velocities of Ball and Centre of Gravity of Foot

The average ball velocity for female athletes (22.0 ± 1.4m/s) was almost identical to the that reported in Orloff et al. (2008) (21.9 ± 3.5 m/s). Furthermore, the average ball velocity for male athletes (26.4 ± 2.0 m/s) was higher than that for male athletes in Orloff et al. (2008) (22.7 ± 3.1 m/s).
The average ball velocity for female athletes was lower than that for male athletes ($p < 0.05$; Fig. 3a).
Various factors affect the ball velocity (e.g. foot velocity, place of impact, stiffness of the foot at point of impact, and mass of the kicking leg). Foot velocity in particular is considered to have the greatest impact on ball velocity. To increase ball velocity, techniques to increase the swing velocity before impact are considered to be important.
The average foot velocity for female athletes (17.2 ± 0.9 m/s) was higher than that reported in Barfield et al. (2002) (16.2 ± 2.3 m/s). The average velocity of the centre of gravity of the foot for male athletes (22.7 ± 3.1 m/s) was higher than that for male athletes in Barfield et al. (2002) (19.7 ± 1.2 m/s). The average foot speed for female athletes was lower than that for male athletes ($p < 0.05$).

3.2. Horizontal Velocities of Hip, Knee, and Ankle Joints in Kicking Leg during Forward Swing

Horizontal velocities of the hip, knee, and ankle joints in a forward swing were examined. For both females and males, the hip joint velocity was the first to show a peak, followed by the knee joint velocity, and lastly the ankle joint velocity (Fig. 3b, c). Thus, for both genders, the proximal-to-distal energy transfer mechanism is apparently at work. Furthermore, the curve that describes the change in horizontal foot velocity in the present study is similar to that of Dörge et al. (2002). This suggests that the same mechanism is at work for the kicking action in both males and females.

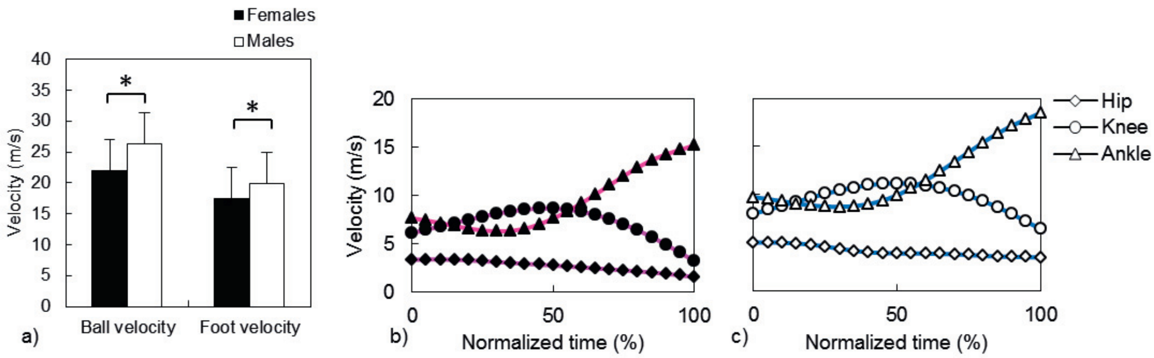

Fig.3 Comparison of velocities for female and male player (a = average ball and foot velocities before impact; b = horizontal velocities of foot, knee, and hip of kicking leg for female players; c = horizontal velocities of foot, knee, and hip of kicking leg for male players).

3.3. Knee and Hip Joint Torques in Kicking Leg

The average peak values for the knee flexion and extension torques as well as the adduction and abduction torques in the forward swing of female athletes were smaller than those of male athletes ($p < 0.05$). Furthermore, the hip flexion and extension torque was the highest among all torques for both males and females (Fig. 4a).
Average peak values for the hip flexion and extension, adduction and abduction, and internal and external rotation torques in the forward swing of female athletes were lower than those of male athletes ($p < 0.05$; Fig. 4b). The hip and knee joint torques are considered to have a large impact on horizontal foot velocity. The difference between the joint torques of the kicking leg for female and male athletes is presumably one factor that contributes to the difference in horizontal foot velocity.

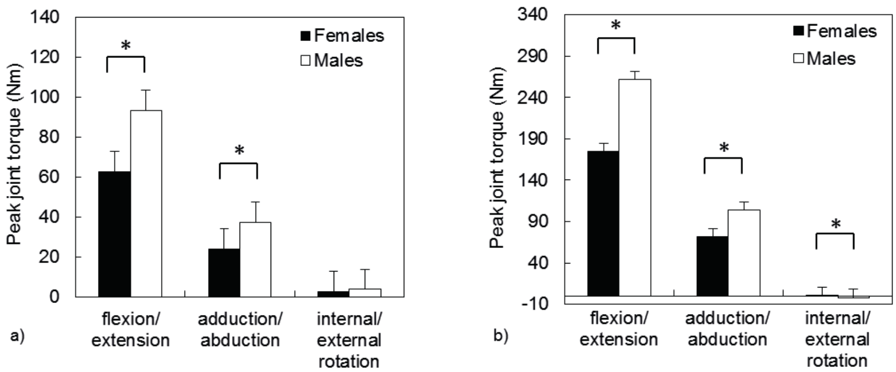

Fig. 4 Comparison of peak knee and hip joint torques of kicking leg for female and male players (a = knee joint torques; b = hip joint torques).

3.4. Thigh and Shank Energies for Kicking Leg

Thigh and shank energies for female athletes are generally lower than those for male athletes. Moreover, in this study, the thigh energy tended to increase by up to around 50% from the point of contact between the support leg and the ground, and to decrease up to the point of ball impact once the peak value was reached (Fig. 5a). The shank energy, on the other hand, tended to increase from the point of contact between the support leg and the ground up to the point of ball impact (Fig. 5b).

To study the energy transfer from the thigh to shank, we plotted the average thigh-to-shank energy ratios (Fig. 5c). The average for female athletes was significantly lower than that for male athletes ($p < 0.05$). This is presumably because the level of thigh-to-shank energy transfer technique in female athletes is lower than that in male athletes. If that is the case, then improving the technical level of thigh-to-shank energy transfer in female athletes may effectively increase their swing velocity.

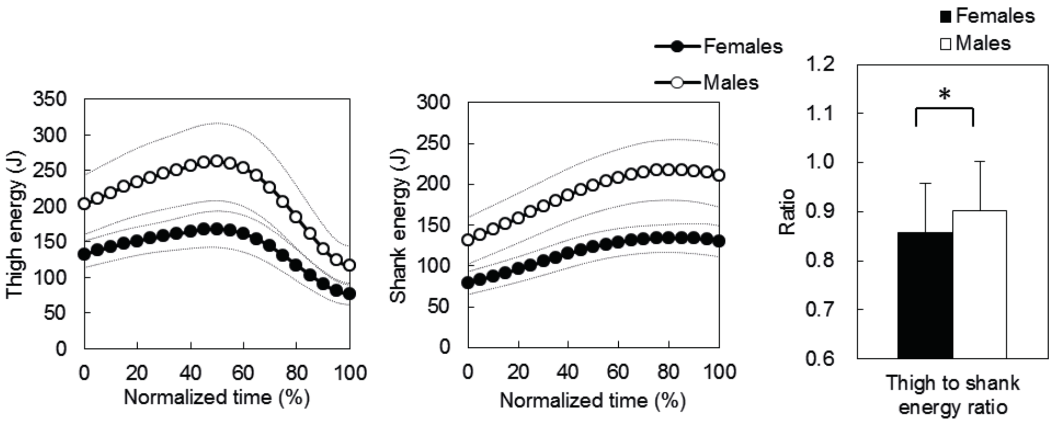

Fig. 5 Energies of thigh and shank in kicking leg for female and male players (a = thigh energy for female and male players; b = shank energy for female and male players; c = thigh-to-shank energy ratios between female and male players).

3.5. Impact of Vertical Force Component of Hip Joint on Swing Velocity

The impact of the vertical force component of the hip joint on the swing velocity was studied using a forward dynamics simulation with force data as parameters. The results indicated similar trends of the ground reaction force, hip and knee joint torques for support leg to those of previous study (Inoue et al., 2012, Ball, 2013). The conventionally calculated vertical force of the hip joint was set as the reference value (0%); cases with a 10% increase or decrease in relation to the reference value (10% or –10%, respectively) were then entered, and the horizontal foot velocity was calculated for each case. Whereas the peak joint force for the 0% cases was 1481.1 N, those for the 10% and –10% cases were 1629.3 and 1333.0 N, respectively (Fig. 6a). The horizontal foot velocities before the ball impact for the 0%, 10%, and –10% cases were 19.2, 19.5, and 19.0 m/s, respectively (Fig. 6b). This indicates a tendency for the swing velocity to increase with increasing vertical force of the hip joint. Hence, extending the support leg at the point of the instep kicking motion and accelerating the hip joint of the kicking leg upwards is likely to increase the swing velocity. Therefore, these changes may constitute key technical adjustments in increasing the ball velocity.

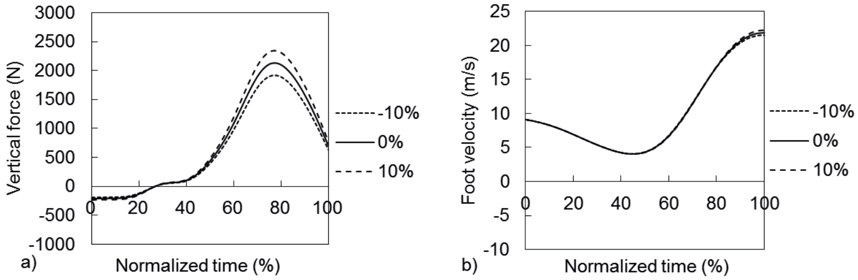

Fig. 6 Simulation data for female and male players (a = hip joint vertical force; b = foot velocity).

4. Conclusion

In this study, we investigated the difference in instep kick ball velocity for female and male athletes. The results showed that the average ball and foot velocities in female athletes were significantly lower than those in male athletes ($p < 0.05$). Furthermore, the average peak values of the knee and hip joint torques for female athletes were also lower than those for male athletes ($p < 0.05$). In addition, thigh and shank energies for female athletes were overall lower than those for male athletes. The average thigh-to-shank energy ratio in female athletes was significantly lower than that in male athletes, suggesting that female athletes may have poorer thigh-to-shank energy transfer techniques than do male athletes. We think that to increase the foot velocity of the kicking leg in female athletes, investigating the factors that improve thigh-to-shank energy transfer techniques is important. Furthermore, accelerating the hip joint of the kicking leg upwards during a forward swing, which is assumed to increase the swing velocity, may constitute a key technical improvement that increases ball velocity. We suggest that for female athletes who have less physical power than their male counterparts, improvement of thigh-to-shank energy transfer techniques and techniques to accelerate the hip joint of the kicking leg upwards will be crucial for generating higher ball velocity. Finally, a 2D analysis system was used in the present study. Although 2D analysis is able to represent the essence of the motion, 3D analysis would be beneficial for the practical use. One of the challenges in the future will be to extend this system to a 3D analysis system.

References

Lees, A., Asai, T., Andersen, T.B., Nunome, H. and Sterzing, T., 2010. The Biomechanics of Kicking in Soccer: A Review, *Journal of Sports Sciences*, *28(8)*, 805-817.

Nunome, H., Lake, M., Georgakis, A. and Stergioulas, L.K., 2006. Impact phase kinematics of instep kicking in soccer, *Journal of Sports Sciences*, *24(1)*, 11-22.

Barfield, W.R., Kirkendall, D.T. and Yu, B., 2002. Kinematics Instep Kicking Differences between Elite Female and Male Soccer Players, *Journal of Sports Science and Medicine*, 1, 72-79.

Orloff, H., Sumida, B., Chow, J., Habibi, L., Fujino, A. and Kramer, B., 2008. Ground Reaction Forces and Kinematics of Plant Leg Position During Instep Kicking in Male and Female Collegiate Soccer Players, *Sports Biomechanics*, *7(2)*, 238-247.

Clagg, S. E., Warnock, A., and Thomas, J. S., 2009. Kinetic analyses of maximal effort soccer kicks in female collegiate athletes, *Sports Biomechanics*, *8(2)*, 141–153.

Stølen, T., Chamari, K., Castagna, C., and Wisløff, U., 2005. Physiology of soccer, *Sports Medicine*, *25(6)*, 501-536.

Kellis, E., & Katis, A. 2007. Biomechanical characteristics and determinants of instep soccer kick, *Journal of Sports Science and Medicine*, *6*, 154–165.

Winter D. A., 2004. Biomechanics and motor control of human movement. 3rd ed., John Wiley & Sons, Hoboken (NJ).

Dörge, H.C., Bull-Andersen, T.B., Sørensen, H. and Simonsen, E.B., 2002. Biomechanical Differences in Soccer Kicking with the Preferred and the Non-preferred Leg, *Journal of Sports Sciences*, *20*, 293-299.

Ball, K., 2013. Loading and performance of the support leg in kicking. Journal of Science & Medicine in Sport, *16(5)*, 455-462.

Inoue, K., Nunome, H., Sterzing, T., Hironari, S., Ikegami, Y. 2012. Kinetic analysis of the support leg in kicking. in Proceedings of the 30th conference of the international society of biomechanics in sports, Bradshaw E, Burnett A, Hume P, editors, Melbourne, Australian Catholic University, 21-24.