THE EFFECTS OF LIFTING THE ROTATIONAL AXIS ON SWING SPEED OF THE INSTEP KICK IN SOCCER

Shin-ichi Inoue, Tomoki Ito[1], Yasuhiro Sueyoshi[2], Raphael K. O'Donoghue[3] and Masayuki Mochinaga
Saga University,Saga,Saga,Japan
[1]Kurume University,Kurume,Fukuoka,Japan
[2]Kagoshima University,Kagoshima,Kagoshima,Japan
[3]Fukuoka University,Fukuoka,Fukuoka,Japan

This study was conducted to investigate the hypothesis that expert soccer players lifted the trochanter major rotational axis of the swing leg faster before impact to increase the speed of the swing leg. This movement pattern is referred to as "lifting the rotational axis of the swing leg". To examine this hypothesis, an experiment and computer simulation was carried out. The results were as follows: (1) Experts were found to lift the rotational axis of the swing leg to a greater degree than novices. (2) Computer simulations of the swing leg, developed by combining data of torque patterns data of the thigh and the leg from the novices with kinematic data of the trochanter major from the expert group, resulted in a slight increase in swing speed. When the kinematic data from the most accomplished expert alone was used, a remarkable increase in swing speed was seen. These results suggest the movement pattern such as lifting the rotational axis of the swing leg was useful in increasing the swing speed.

KEY WORDS: soccer, instep kick, swing speed, rotational axis, computer simulation

INTRODUCTION: In soccer it is important to strike the ball accurately and with speed. To achieve this, soccer players often use the Instep Kick. Generally, in order to kick the ball harder, greater foot velocity needed. Ohta (1998) reported that experts swung their swing leg with upward velocity of center of gravity at greater speed, in an experiment comparing the Instep Kick of novices and experts. Accordingly, the hypothesis of this study proposed that experts would lift the rotational axis of their swing leg (trochanter major) faster than would novices. The first purpose of this study was to examine this hypothesis by comparing the Instep Kick skill of a novice group to that of an expert group. The second purpose of the study was to examine the relationship between the movement of rotational axis and swing velocity of the foot in the Instep Kick. Subsequently, computer simulation of the swing leg was performed, by using torque pattern data of the thigh and the leg from each novice. Kinematic data of the rotational axis from experts was used to examine whether or not the swing velocity of each novice was improved by these simulations.

METHODS: The subjects were 18 male expert soccer players who had played for at least 7 years, and 8 male novice players. The Instep Kick of each subject was recorded by high-speed video camera (250Hz) from a sagittal plane. Each body landmark was translated to coordinates on a computer, from which the kinematic data of the hip and the knee joints of the swing leg were obtained by using the "Mathematica Ver.3.0" program. The dynamical parameter was that of Chandler et al. (1975). The period of time from the landing of pivot foot to the ball impact of the swing leg was defined as swing phase.

RESULTS: Figure 1 illustrates the means for the horizontal and vertical displacements of trochanter major for the novice group and the expert group. Time bases were normalized to 100% of the swing phase.
The horizontal displacement of experts' data was slightly greater than that of novices'. However, the shape of the graph was similar. In contrast, a remarkable difference was seen between the novices' and experts' vertical displacement. The characteristic of the novices' pattern is a continuous descent of trochanter major to a point of 80 percent of the whole movement time, followed by a slight ascent. On the other hand, experts' descent of the trochanter major stopped at the 30 percent of whole movement time point, where it remained

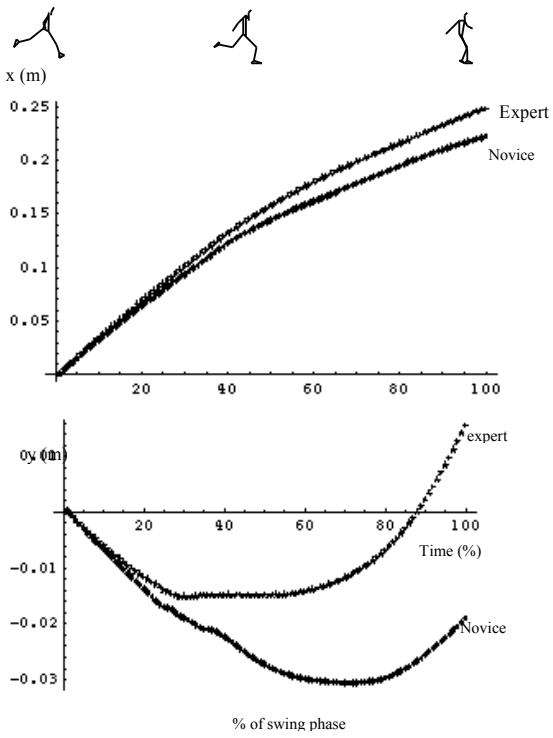


Figure 1 - Displacement of rotational axis on expert and novice group. Above: horizontal component; Below: vertical component.

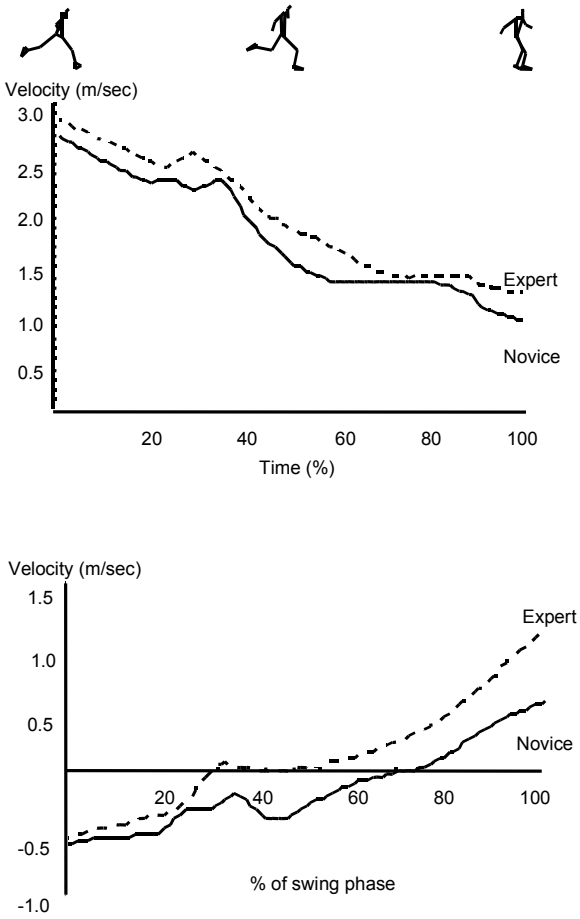


Figure 2 - Velocity of rotational axis on expert and novice group. Above: horizontal component; Below: vertical component.

for some time, followed by an ascent from the 50 percent of whole movement time point.

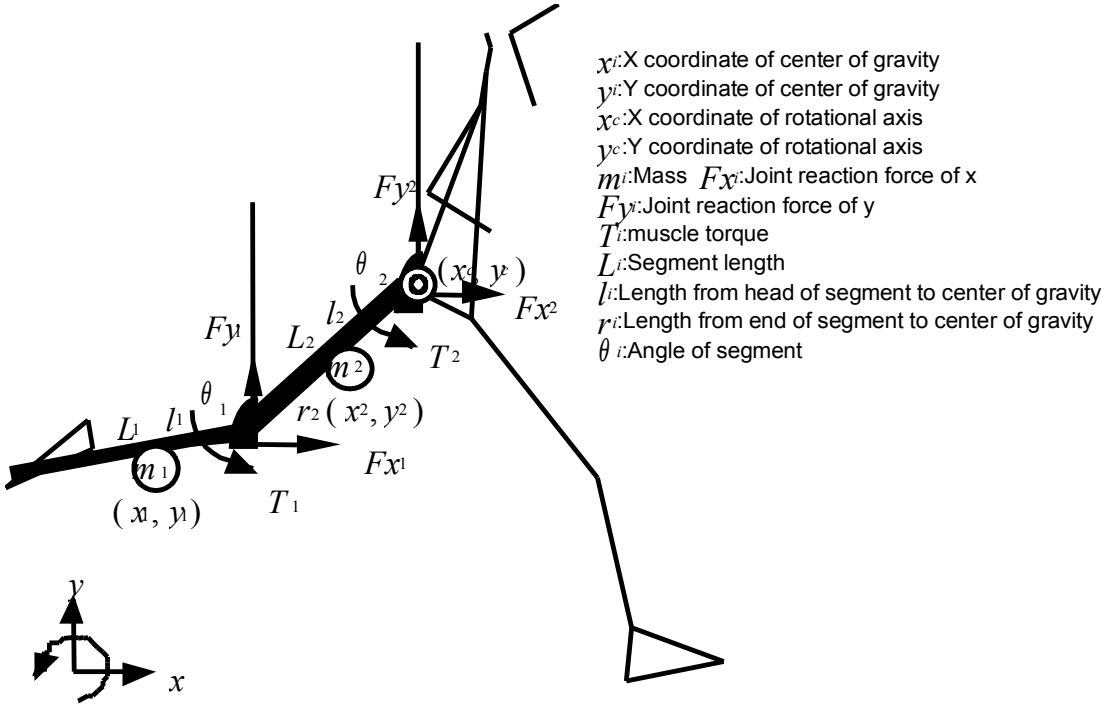
Figure 2 illustrates the mean horizontal and vertical velocity of trochanter major of novices and experts. The horizontal velocity of experts was slightly faster than that of novices. On the other hand, the vertical velocity of both subjects showed deceleration from the landing point for a period of time. By comparison, experts showed an increase in velocity from the early part of the swing phase to the latter phase.

These results indicate that, compared with novices, the experts lifted their rotational axis from the middle phase of the forward swing in the Instep Kick.

Simulations. Figure 3 shows a model of the Instep Kick and the equation of motion built by the model. This model consists of segment representing thigh and combined shank with foot, and representing each torque which is assumed to be generated on the hip joint and knee joint.

There are two Input values for this simulation. One is for muscle torque of novice subjects exerted on the hip and knee joints, and the other is kinematic data on the rotational axis (trochanter major) of the expert subjects. Two sets of rotational axis data are used for this simulation, one is the average data of the expert group (simulation1), and the other is the data of a subject who accomplished the fastest swing speed among all subjects (simulation2). Figure 4 shows the displacement and velocity of horizontal and vertical axis on the rotational axis, which is used for two simulations. The initial angle value and angular velocity for each segment of each novice subjects was used, and the motion of equation was solved numerically by these initial conditions. The method of solution for this motion of equation as the differential equation is the Runge-Kutta method.

Figure3 - Swing model for simulation and equation of motion.



$$m_i \cdot \ddot{x}_i = Fx_i - Fx_{i-1} \qquad (Fx_0 = 0)$$

$$m_i \cdot \ddot{y}_i = Fy_i - Fy_{i-1} - m_i g \qquad (Fy_0 = 0)$$

$$I_i \cdot \ddot{\theta}_i = Fx_{i-1} \cdot r_{i-1} \cdot \cos\theta_i + Fy_{i-1} \cdot r_{i-1} \cdot \sin\theta_i + Fx_i \cdot l_i \cdot \cos\theta_i + Fy_i \cdot l_i \cdot \sin\theta_i + T_i - T_{i-1} \qquad (r_0 = 0)$$

$$x_i = -L_{i+1} \cdot \sin\theta_{i+1} - l_i \cdot \sin\theta_i + x_c$$

$$y_i = L_{i+1} \cdot \cos\theta_{i+1} + l_i \cdot \cos\theta_i + y_c \qquad (L_3 = 0)$$

Figure 3 - Swing model for simulation and equation of motion.

Results of simulations. Figure 4 shows the result of a simulation done on a novice subject (B.K.).The top graph is the displacement of the rotational axis, and bottom graph is the liner velocity.

At impact, the slowest swing was the actual swing, the second slowest was simulation 1 which used the average data of the expert subjects group, and simulation 2 which used the data of elite subject showing the fastest swing speed.

Table 1 shows the actual swing velocity at impact for each novice subject and the results of two simulations. According to each average velocity data, actual swing velocity was 17.41m/s, simulation 1 was 17.95m/s, which was slightly faster than the actual swing. Simulation 2 was 20.53m/s, which was much faster than the actual swing.

These results indicate that even though generated muscle torque in hip and knee joint are the same, the movement of rotational axis significantly influences the foot swing velocity. And since the velocity lifting the rotational axis in simulation 1 is faster than in simulation 2, it can be expected that lifting the rotational axis with greater speed before impact is necessary to improve the swing velocity.

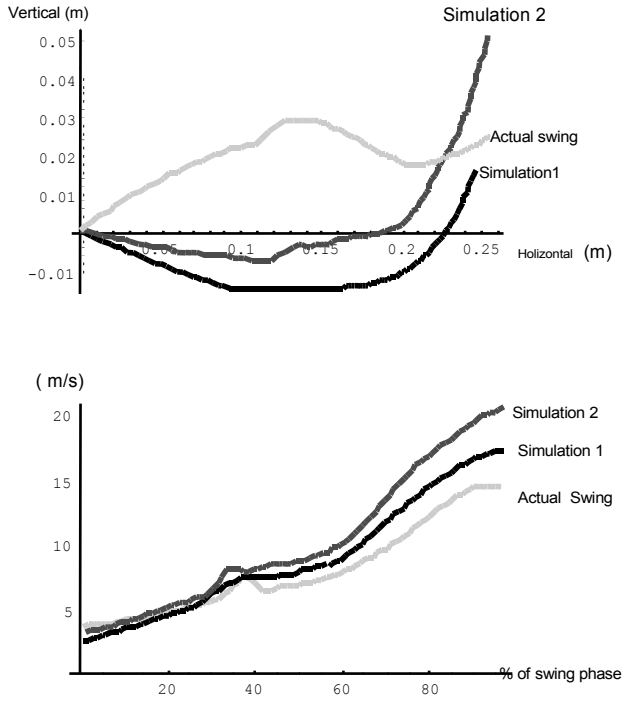


Figure 4 – Above: Displacement of rotational axis for actual swing of Subject B. K. and used in Simulation 1 and 2; Below: Linear velocity of foot on actual swing (B. K.) and calculated by each simulation.

Table 1 Liner Velocity of Foot at Impact on Actual Swing for Each Novices and Calculated by Each Simulations (m/sec)

Subject	Actual Swing	Simulation 1	Simulation 2
S. I.	17.75	18.70	21.22
U. R.	19.39	18.62	21.08
B. K.	14.45	17.27	20.23
S. K.	17.73	17.92	20.64
A. M.	17.66	17.35	19.61
T. K.	16.52	15.00	17.50
N. G.	17.76	18.08	20.38
M. S.	17.98	20.62	23.54
Mean (S.D.)	17.41 (1.42)	17.95 (1.59)	20.53 (1.69)

DISCUSSION: According to the hypothesis, when compared with novices, experts lifted the trochanter major of swing leg faster before impact. When observing expert players on T.V. etc. they appear to jump upward after kicking the ball. Also the result of simulation suggests that lifting the rotational axis of the swing leg was useful in increasing the swing speed. In general, the instruction method of the Instep Kick does not stress the importance of lifting the rotational axis, but it is necessary to emphasize this movement skill in order to increase the swing speed.

REFERENCES:

Chandler, R.F., Clauser C.E., Mcconville J.T., Reynolds H.M., & Young J.W. (1975). *Investigation of Inertial Properties of the Human Body.* U.S.: Government Printting Office, pp.

68-95.
Ohta, N. (1998). *Biomechanics Approach on the Instep Kick*. Unpublished Master's thesis of Faculty of Culture and Education, Saga University.