unanticipated changes in task constraint (Davids *et al*., 2003). Consequently it emerged that the performer may have adapted their pre-planned anticipated movement pattern caused by the unanticipated change in sprint distance by reducing the FD of the step. The current single subject study provided an initial indication of potentially important mechanisms of adaptation, which may be investigated further to enhance understanding of short-term biomechanical adaptation in maximum velocity sprinting. The observation that the performer adapted their technique as a result of the change in protocol from a closed skill to an open skill provided further argument (Sheppard *et al.*, 2006) against the use of closed skill protocols for the training of field sport performers. With further investigation, open skill protocols may be developed to allow a performer to become familiar with different permutations of a task constraint and to adapt rapidly to changes in those constraints during competition (Sanders *et al*., 2009).

CONCLUSIONS: The study aimed to gain an initial insight into the short-term biomechanical adaptations made when performing maximum velocity sprints of different anticipated and unanticipated sprint distances. The introduction of unanticipated changes in task constraint and a corresponding short-term, individualised biomechanical adaptation highlighted the potential need for coaches to implement protocols that include open skill elements.

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IMPACT PATTERNS IN SOCCER KICK MOTION FOR ELEMENTARY SCHOOL BOYS

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The purpose of this study was to investigate impact patterns and kinematics of the kicking motion in Japanese elementary school boys. The school boys were classified into three groups: good-impact, toe-impact, and poor-impact groups. There were large differences in the ball speed, foot speed, and impact ratio between the good-impact group and the other groups. The good-impact group extended the hip joint largely during the back-swing phase. The college students largely inclined the support leg more than the elementary school boys. The elementary school boys should be taught to increase the range of motion of the kicking leg and to contact the ball with the top of the foot near the foot center of mass, which can be induced by angled approach steps.

KEY WORDS: children, soccer kick, impact pattern, motion analysis.

INTRODUCTION: In elementary school physical education classes, teachers will first observe the motion of children to identify limiting factors. For this task in soccer, teachers should have appropriate information on characteristics of the kicking motion for children because the kick motion of children can differ from that of adults. Some investigations have indicated that ball velocity was affected by impact conditions. Asami and Nolte (1983) reported that the contact point between the foot and ball should be as close as possible to the ankle joint and not on the toe of the foot. The speed of the foot was the most important factor for obtaining a high ball speed, indicating a strong positive correlation between foot speed and ball speed. Although there may be various impact patterns (i.e., effective or ineffective foot contact with a ball), there is little information of kicking motion and impact patterns for the elementary school children. Therefore, the purpose of this study was to investigate impact patterns and kinematics of the kick motion in Japanese elementary school boys with three-dimensional motion analysis techniques.

METHODS: Thirty-three second-grade elementary school boys (age 7 to 8 y) and thirty male college students (age 19 to 31 y) participated in this study. They were asked to kick a soccer ball (20.5cm in diameter and 300g in mass for school boys, 22.0cm and 440g for college students) for maximal ball speed. The kick motions for boys were videotaped using two digital movie cameras (Exilim EX-F1, CASIO Co., Japan) operating at 300Hz and were synchronized with a LED synchronizing system (PH-VX100A, DKH Co., Japan). The kicking motions of the college students were captured with a Vicon T10 system (Vicon Motion Systems, Ltd.) using fourteen cameras operating at 250 Hz.

The school boys were classified into three groups based on the three impact patterns in Figure 1. The good-impact group (n=3) was characterized by plantar flexion at impact and contacting on the top of the foot and near the foot center of mass. The toe-impact group (n=13) contacted the ball with the toes in dorsiflexion. The poor-impact group (n=17) was characterized by plantar flexion at impact but contacting the ball with the foot fingers. The ankle of the kicking leg and three points on the ball surface were digitized at 150 Hz to calculate the speed of the foot and to estimate the center of a ball for the preliminary evaluation. The three-dimensional coordinate data were reconstructed by the DLT method. The kicking motion was separated into pre-impact phase and post-impact phase, which were separately smoothed by a Butterworth digital filter at cutoff frequencies ranging from 7.5 to 12.5 Hz. The pre-impact phase was defined as the phase from the toe-off of the kicking leg to one frame before the ball impact; the post-impact phase was defined as the phase from the ball release to the 10th frame after the release. The impact ratio was defined as the ratio of the ball speed to the foot speed.

The standard motion model of the kick motion for the college students was established by the method of Ae et al. (2007). The relationships among the ball speed, foot speed, and impact ratio were evaluated. Independent t-tests with a significance level of 0.05 were used to test differences between the toe-impact group and the poor impact group.

Good-impact group Toe-impact group Poor-impact group

Figure 1: Three impact patterns of the school children.

RESULTS: Table 1 presents ball speed, foot speed, and impact ratio (ball speed/ foot speed) for three groups of the boys. There was no significant difference in the ball speed, foot speed, or impact ratio between the toe-impact group and poor-impact group. Although we did not statistically test the differences between the good-impact group and the other groups because of small number of the subjects in the good-impact group, the ball speed and impact ratio of the good-impact group were much greater than those of the other groups.

Table 1
Ball speed, foot speed, and impact ratio of three groups of the school boys

	ball speed (m/s)	foot speed (m/s)	impact ratio
Good-impact (n=3)	12.47±1.60	8.95±1.65	1.38±0.14
Toe-impact (n=13)	9.40±2.01	8.33±1.12	1.10±0.18
Poor-impact (n=17)	9.62±2.35	8.41±1.83	1.11±0.17

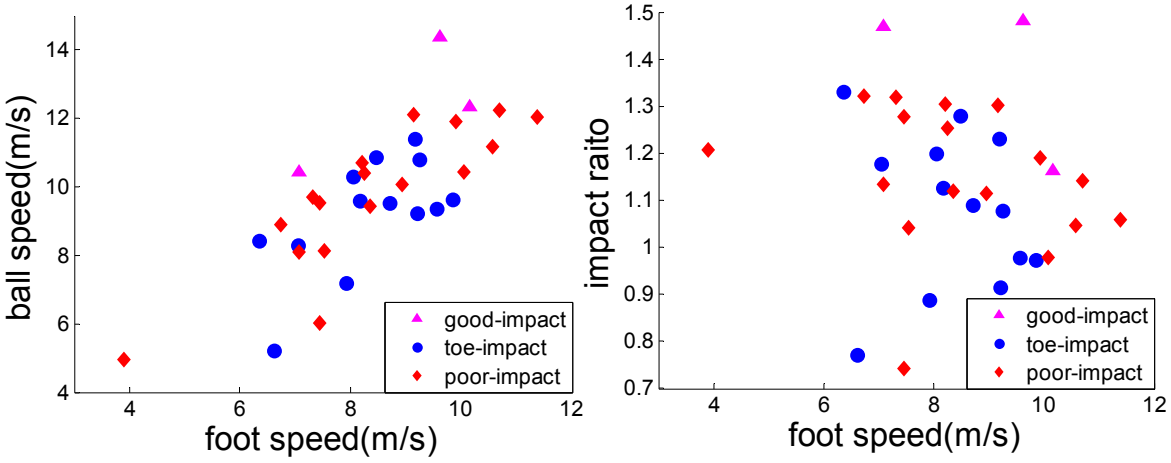

Figure 2: Relationships between foot speed and ball speed, and foot speed and impact ratio.

Figure 2 presents the relationships of the foot speed to the ball speed and impact ratio. There were positive correlations between the foot speed and ball speed in two impact groups (toe-impact: $r=0.650$, $p<0.05$; poor-impact: $r=0.861$, $p<0.01$). There was no significant relationship between the foot speed and impact ratio in the two impact groups. However, after removing the two subjects with the lowest foot speed and impact ratio from the poor-impact group, the poor-impact group has a negative correlation between the foot speed and impact ratio ($r=-0.543$, $p<0.05$).

Figure 3 presents lateral views of the kick motions of three representative subjects from three impact groups and the standard motion of the college students, and Figure 4 presents their view from the back. The boy from the good-impact group exhibited large hip extension and pelvis rotation during the back-swing phase and slight inclining of the support leg before impact; subjects from the other groups showed smaller back-swings and no inclining of the support leg. The students of the standard motion inclined the support leg largely from the angled approach steps and settled the support foot closer to the ball.

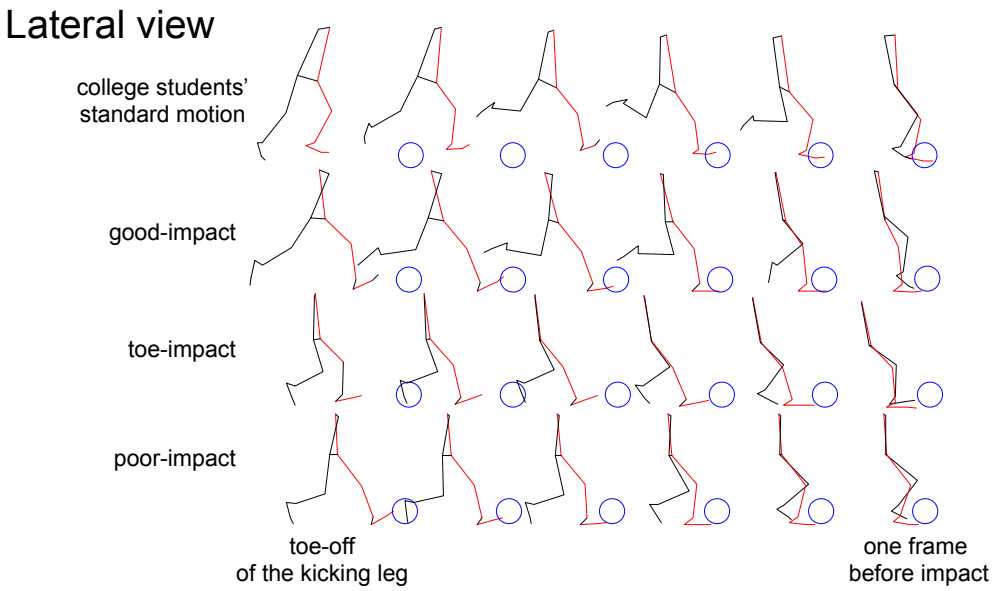

Figure 3: Kick motion of three representative subjects from three impact groups and the standard motion of the college students (lateral view).

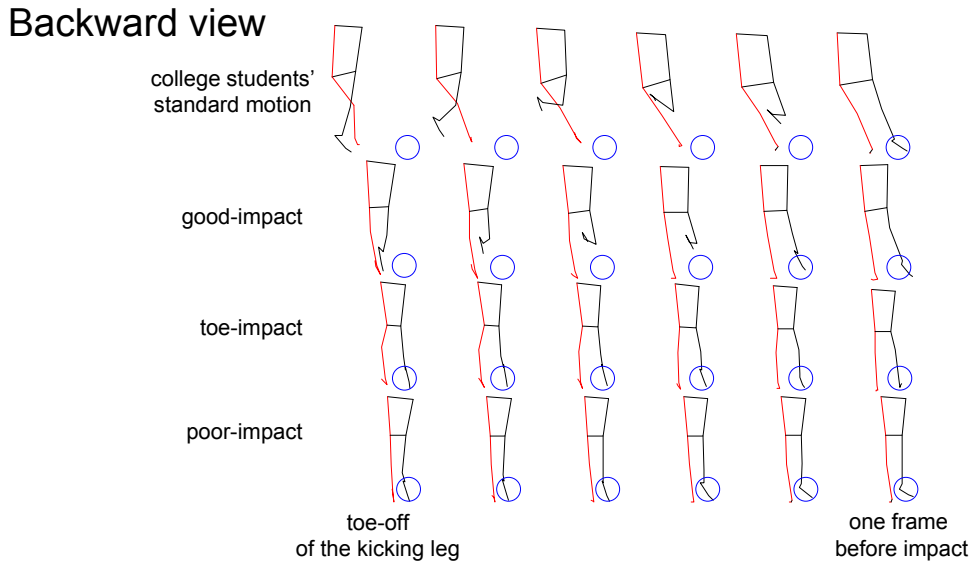

Figure 4: Kick motion of three representative subjects from three impact groups and the standard motion of the college students (backward view).

DISCUSSION: There was a positive relationship between foot speed and ball speed in the kicking motion of the elementary school boys. This result was similar to the case of adult soccer players in a previous study (Asami and Nolte, 1983). However, the negative relationship found between the foot speed and impact ratio in the poor-impact group indicates that the foot speed and impact ratio were conflicting factors for novices in the elementary school boys and suggests that an appropriate impact condition can be a factor in using high foot speed effectively for high ball speed. In teaching school boys the kick motion, it is necessary to pay attention to both swing speed and impact (i.e., ankle joint angle, point of contact of the foot and ball, etc.). The impact ratio differed greatly between the good-impact group and the other groups. Ball et al. (2010) stated that the foot and ball speeds differed significantly between the junior and senior players but the impact ratio was similar in the drop punt kick of Australian football. Their investigation implied that the impact ratio was no longer limiting factor of the ball speed in trained players.

As seen in Figures 3 and 4, the good-impact group extended the hip joint largely and rotated the pelvis during the back-swing phase. These motions were similar to those of the college students' standard motion. Button et al. (2005) indicated that tasks emphasizing maximum

ball velocity resulted in greater range of motion in the lower body joints. By increasing the range of motion of the kicking leg and hip, the good-impact group was able to obtain a higher foot speed than the other groups. Comparing the kicking motions of the college students and the good-impact group, there were some differences in the approach angle, the foot position, and inclining of the support leg. Lees and Nolan (1998) concluded that an angled approach enabled the kicking leg to be tilted in the frontal plane so that the foot could be placed further under a ball, thus making better contact with it. It is inferred from these implications that the high impact ratio of the good impact group may have been induced by slightly inclining of the support leg. Although it is not clear in the present study why the college students inclined the support leg much more than the good-impact group, the extent of inclining the support leg may be an index of the kicking skill development. One possible reason for the large inclining of the support leg seen in the college students is the relationship between the ball diameter and foot length, where the ball diameter was 22.0cm and less than the average foot length of 25.4cm. If the college students did not incline the support leg, the toe of the kicking foot would have hit the ground before impact. For elementary school boys, the ball diameter was 20.5cm and the average foot length was 18.4cm. Therefore, elementary school boys were able to contact the ball near the foot center of mass without largely inclining the support leg.

CONCLUSIONS: The ball speed in the good-impact group exceeded that of the toe-impact group and poor-impact group, and there was a greater difference in the impact ratio. The good-impact group largely extended the hip joint during the back-swing phase. The college students largely inclined the support leg more than did the boys. The elementary school boys should be taught to increase the range of motion of the kick leg and to contact the ball on the top of the foot and near the foot center of mass, which can be induced by angled approach steps.

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