THE CENTRE OF MASS KINEMATICS FOR ELITE WOMEN JUDO ATHLETES IN SEOI-NAGE

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The purpose of this study was to investigate kinematics of the whole body centre of mass (COM) in seoi-nage performed by elite and collegiate women judo athletes. Three-dimensional coordinate data were captured using a Vicon-Mx system with 18 cameras operating at 250 Hz as 3 women elite judo athletes and 6 women college level judo athletes performed seoi-nage. No difference was found in motion time of the turning phase in seoi-nage between the two groups, indicating that motion time may not be a factor to determine the skill level of seoi-nage. The maximum Y relative velocity of the COM in seoi-nage was much greater in the elite women judo athletes than the collegiate judo athletes, which implied that the relative forward velocity of the COM would be an index to evaluate the skill level of seoi-nage for women judo athletes.

KEY WORDS: motion analysis, martial arts, Judo throwing technique, sex differences

INTRODUCTION: International Judo Federation (IJF) held the first World Women Judo Championships in 1980, which 27 countries and regions participated. Since then, the population of women judo athletes has been continuing to grow, and 120 countries and regions joined the world championships held in 2015. However, there is limited biomechanical information on judo throwing techniques of women in high performance level, compared with men's judo.

The investigations by Ishii et al (2014, 2015) demonstrated some biomechanical characteristics of seoi-nage in elite men judo athletes by comparing with that of college judo athletes. Because of sex differences in physique, muscle strength and power, there will be differences in throwing techniques between men and women judo athletes and even in women elite judo athletes. It is inferred that the differences would make coaching and teaching methods for women change.

Therefore, the purpose of this study was to investigate kinematics of the whole body centre of mass (COM) in seoi-nage performed by elite and collegiate women judo athletes. The hypothesis in this study is that the forward COM velocity in the turning phase of seoi-nage will be greater in elite judo athletes than college judo athletes.

METHODS: The participants were three women elite judo athletes who were champions in the World Judo Championships on senior or junior levels (age, 23.3 ± 4.7 years; height, 1.57 ± 0.00 m; body mass, 54.1 ± 6.2 kg) and six female collegiate judo athletes (21.5 ± 4.5 years; 1.60 ± 0.04 m; 58.7 ± 11.2 kg). The collegiate athletes currently compete at the Japanese collegiate level which requires advanced judo skills.

Three-dimensional coordinate data of 94 reflective markers on the participants' body (47 markers each) were collected with 18 cameras using a VICON-MX system operating at 250 Hz during the experimental session simulating pre-arranged sparring drills (yakusoku-renshu) of seoi-nage. Seoi-nage is accomplished by making the opponent off-balance by pulling in various directions, then putting the opponent's body on one's back and throwing the opponent over the shoulder. In the measurement, the participants rated their own performance on a scale of 1 to 5 (1 = poor, 2 = below average, 3 = average, 4 = good, 5 = excellent). They were asked to repeat seoi-nage until five trials rated 4 or 5 had been captured successfully. In addition, five experienced coaches rated the participants' performance using the same evaluation scale. The seoi-nage move rated highest by the coaches for each subject was chosen as the best trial for motion analysis.

The Y axis was defined as the direction of throwing uke, a person being thrown, by the tori, a person throwing an opponent, the Z axis as the vertical direction and the X axis as the direction perpendicular to both the Y and Z axes. Three-dimensional coordinate data of the tori and uke were smoothed by a Butterworth digital filter at cut-off frequencies ranging from 4.8 to 9.8 Hz, which were determined by the residual method (Winter, 1990).
The turning phase started when the pivot foot (right foot for a right-handed athlete) lifted off and ended when both feet were in contact with the mat. The throwing phase was defined from the end of the turning phase to the instant that a part of the uke's body was in contact with the mat. Event 1 (E1) represented the instant that the tori's pivot foot lifted off from the mat for the first forward step and Event 2 (E2) was the instant that the pivot foot was in contact with the mat. Event 3 (E3) denotes the instant that both of the tori's feet were in contact with the mat and Event 4 (E4) is the instant that the uke's body part was in contact with the mat, for taking a protective motion called ukemi. Analysis was performed between E1 and E4 (completion of nage-waza). The kinematic data on COM were normalised by the time of each motion phase. The coordinate data for one left-handed athlete was treated as a right-handed one by mirroring their data.
The motion phase time between the events were obtained as an index of the quickness of seoi-nage. The COM of the tori and uke were estimated after the body segment parameters for Japanese athletes (Ae, 1996). Three-dimensional COM velocity was obtained by differentiating the displacement of the COM with respect to time, and relative COM velocity (Vrel) of the tori to the uke was calculated.

RESULTS: There were no differences in the motion phase times of the early phase (E1-E2) and whole turning phase (E1-E3) between elite and collegiate level athletes, as shown in Figure 1. The motion phase time of the late phase (E2-E3) was shorter in the collegiate level athletes than in the elite athletes.

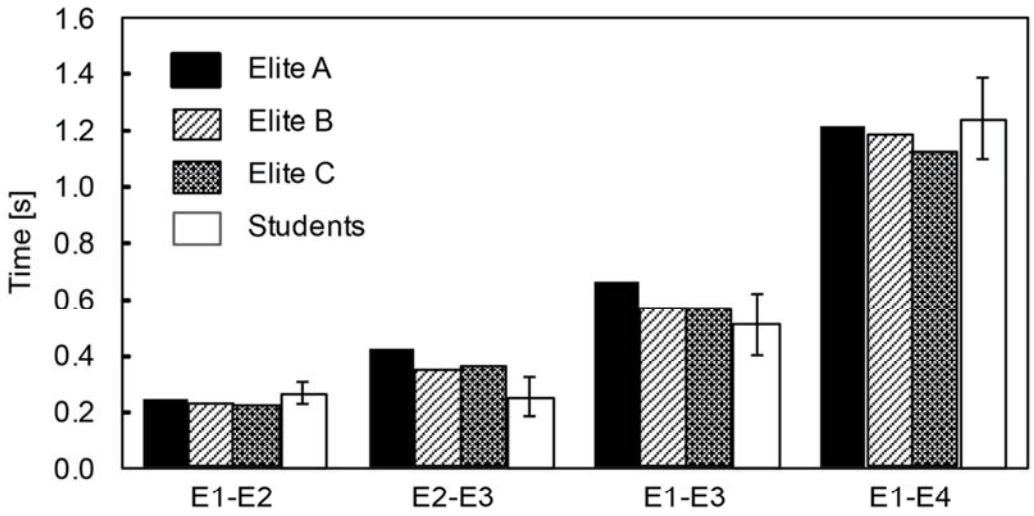

Figure 1: Motion phase times for the tori in seoi-nage.

Figure 2 shows changes in velocity of the COM of the tori for both groups. The solid lines indicate the COM velocity of elite athletes and broken line shows the average velocity of the college athletes with a standard deviation range in a dotted line. The left column demonstrates the absolute velocity of the COM and the right one is the relative velocity. The tori's X component of the absolute and relative velocity of the COM was small throughout seoi-nage in both groups. The Y absolute velocity gradually increased in the college athletes from the beginning of the turning phase to the 50% time of the turning phase, and then gradually decreased. The Y absolute velocity of the elite athlete B and C showed no remarkable increase and that of elite athlete A was negative until the 50% mark, and then

those kept to increase until approximately 130% mark. The Y relative velocity was larger in the college athletes than in the elite athletes until the 70% mark. However, that of the elite athletes rapidly increased and was larger than that of the college athletes from the 80% to the 150% mark. The difference in the Y relative velocity between both groups was larger than that of the Y absolute velocity.

The Z absolute velocity rapidly decreased in the elite athletes from the 60% to 100% mark and then rapidly increased to 150% mark. Furthermore, the downward absolute and relative velocities in the elite athletes tended to be larger from the 80% to the 110% mark than those of the college athletes.

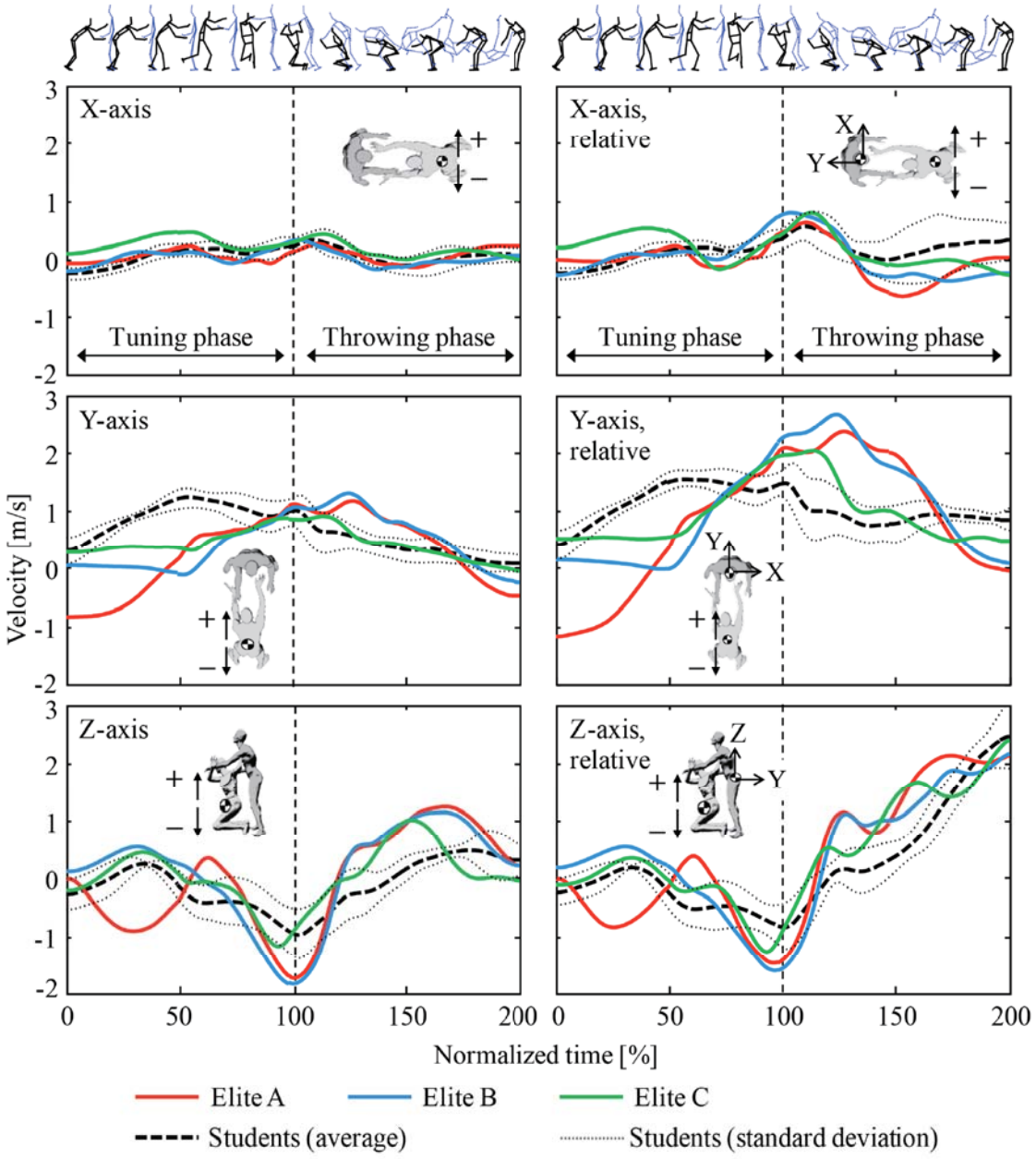

Figure 2: Changes in velocity of the whole body centre of mass for the tori in seoi-nage.

DISCUSSION: At a glance, there were no clear differences between both groups in the motion phase times and the COM velocity. The small differences in the present study would

be resulted from small technical differences between the both groups, since the college athletes in the present study were not novices and competing in high-level Japanese varsity competitions. However, in order to identify some features of elite women judo athletes, it is necessary for us to read and analyse the small differences in the data deeply and closely.
The elite athletes drove themselves toward the uke more quickly during the turning phase and this forward movement would enable elite athletes to complete seoi-nage before the opponent responded for defence. This result is similar to the finding obtained in the investigation of Ishii et al (2015) that the elite men athletes indicated a greater maximum relative COM velocity in the kuzushi-tsukuri phase. However, the pattern of the relative COM velocity change in the elite women athletes was differed from that in the elite men athletes. The previous investigation reported that the Y relative COM velocity in the elite men athletes exceeded that of the college men athletes around 60% mark in the tuning phase, while the present study demonstrated that the COM velocity of the elite women athletes exceeded that of the college women athletes around 80% mark. The difference in the COM kinematics may be attributed by their lower strength and power in women, which may cause difficulty in generating a high COM velocity in the early phase of seoi-nage.
The maximum Z COM velocity during the turning phase seems to be an important factor for high skilled seoi-nage. The large downward velocity of the COM results in a large downward displacement of the body during the turning phase, which may allow the judo athlete to raise and rotate the opponent effectively during the throwing phase. However, two of the three elite athletes, A and B, showed faster downward velocity of the COM in the turning phase than the college athletes (Figure 2). We speculate from the present results that the improvement in both forward and downward propulsive motion will help judo athletes to rotate an opponent effectively in seoi-nage. There was no difference in the motion phase time of the turning phase between the both groups. The similar result was obtained in men judo athletes (Ishii, 2015). The present results suggest that coaches need to pay more attention to the forward driving toward the uke in the latter half of the kuzushi-tsukuri phase rather than the whole motion time.

CONCLUSIONS: Compared with the college athletes, the elite women judo athletes indicated a greater maximum Y relative COM velocity in seoi-nage. The forward relative COM velocity is likely to be an important factor which determine the skill level of seoi-nage, suggesting that coaches should pay more attention to the relative velocity of the tori to the uke for the evaluation of seoi-nage skill in women judo athletes.

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