COMPARISON OF SEOI-NAGE TECHNIQUE FOR JUDO ATHLETES OF DIFFERENT SKILL LEVELS

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The purpose of the present study was to compare the biomechanics parameters of seoi-nage in judo between highly skilled judo athletes and skilled ones. The motion data of the seoi-nage were collected on three male elite judo athletes and sixteen male student judo athletes using a three-dimensional motion analysis technique. This study found that the anterior-posterior component of the ankle and hip peak velocity of the tori in turning phase were significantly larger in the highly skilled group than the skilled group. In addition, the peak velocities of the ankle and hip were significantly correlated to the peak angular momentum of the tori. The results suggested that it would be useful for judo coaches to pay a greater attention to linear velocity of the lower extremities to evaluate the seoi-nage skill than the knee extension.

KEYWORDS: Nage-waza, seoi-nage, motion analysis, angular momentum.

INTRODUCTION: A well-designed training program is crucial to enhance judo performance. Because judo as one of the martial arts requires all-round physical abilities due to its characteristics, coaches have strived to develop comprehensive programs for maximizing the performance of their judo athletes. They have also been asked to design a time-efficient and individualised training program based on the properties of judo athletes.

According to statistical analysis done on the Rio de Janeiro Olympics Games in 2016 and the world judo championships in Baku, the Republic of Azerbaijan in 2018, judo athletes were most likely to acquire points with seoi-nage techniques in the matches (Judo scientific research team of the All Japan Judo Federation, unpublished data, 2018). Some reports in the last 30 years of high-ranked international tournaments indicated that many judo athletes in the world employed seoi-nage techniques during competitions (Nakamura, Tanabe, Nanjo, Narazaki & Shigeoka, 2002), suggesting that seoi-nage would be the most widely used and effective techniques for point acquisition in high-level judo matches.

In order to provide appropriate instruction and program for seoi-nage skill development to the athletes, coaches need a thorough understanding of the kinematics of seoi-nage. Therefore, our research group has been trying to visualize its biomechanical characteristics that differentiate the skill levels using the standard motion model so that coaches will be able to improve their observation skills to evaluate its performance properly. Ishii et al (2018) reported there was a positive linear correlation between the peak angular momentum of uke (opponent) and that of tori (thrower) during the throw in the high-level judo athletes, indicating that highly-skilled judo athletes were able to produce greater angular momenta of themselves and transfer that to the uke efficiently. It has been said in coaching judo that the knee extension in the seoi-nage motion is strongly associated with the seoi-nage performance. However, the result demonstrated the peak value of the knee extension torque during the execution was not significantly correlated to the peak of the angular momenta during the motion. The results suggest that coaches may not be able to evaluate the skill of seoi-nage by only observing the knee motion and that kinematics of the body parts in the seoi-nage still remains to be elucidated. Therefore, we aimed to compare kinematic variables of the body parts of tori in the seoi-nage motion for highly skilled judo athletes with that of skilled ones and to identify kinematic variables relating to seoi-nage skill levels.

METHODS: The participants were three male elite judo athletes who were medallists in the 2010 World Judo Championships (age, 24.3 ± 2.1 years; height, 1.66 ± 0.05 m; body mass, 72.6 ± 6.9 kg) and sixteen male college judo athletes (19.7 ± 1.7 years; 1.66 ± 0.04 m; 69.1 ± 6.5 kg). In the time of the data collection, the college athletes actively competed at the Japanese collegiate level, which requires advanced judo skills.

Three-dimensional coordinate data for 94 reflective markers on the participants' body were captured with 18 cameras of a VICON-MX system (VICON Motion Systems, Ltd., Oxford, UK) operating at 250 Hz for the tori (the person throwing an opponent) and the uke (the person being thrown by the tori) while they performed seoi-nage in pre-arranged sparring drills. The participants wore judo gear designed to improve visibility of the markers (Ishii et al, 2018) and performed seoi-nage as close as possible to that in their usual sparring drills.

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 trial rated highest by the coaches was chosen as the best trial for motion analysis.

The anterior-posterior (Y) axis was defined as the directional line from the tori to the uke in the starting position, the vertical (Z) axis as the vertical direction, and the medial-lateral (X) axis as the direction perpendicular to both the Y and Z axes. The range covered by motion capture cameras was 2.5 m in the X axis, 4 m in the Y axis and 3 m in the Z axis.

Three-dimensional coordinate data of the tori and uke were smoothed by a Butterworth digital filter at a cut-off frequency ranging from 4.8 to 9.3 Hz, as determined by the residual method (Winter, 2009). When a marker could not be tracked by obstruction (e.g. uke's body), the 3D marker trajectory data were virtually estimated from adjacent three markers.

We analysed the seoi-nage motion from the time when the pivot foot of the tori (the right foot for a right-handed athlete) lifted off to the time when a part of the uke's body was in contact with the mat. The turning phase was defined from the instant when the pivot foot left the floor to the instant when the tori's knee joint reached maximum flexion angle. Data were normalised by duration of the turning phase. In this study, we focused on the turning phase of seoi-nage.

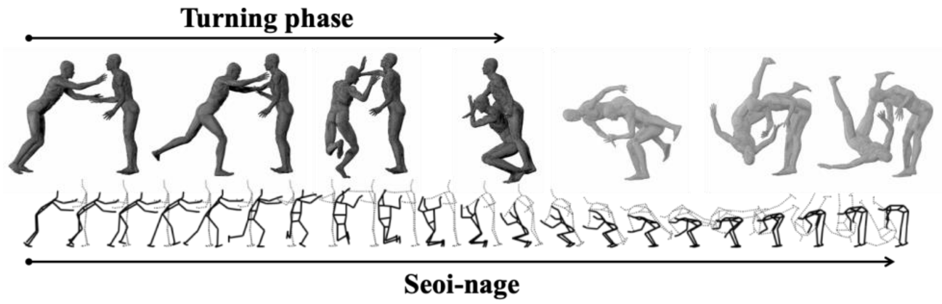

Figure 1: The turning phase of seoi-nage.

The centre of mass (COM) of the tori was estimated after body segment parameters for the Japanese athletes (Ae et al., 1996). The angular momentum of the tori about the whole body COM was calculated by Dapena's (1978) method. We normalized the angular momentum of the whole body by the square of body height and the body mass of the participant after Hinrichs (1987). Therefore, the unit of normalized angular momentum was indicated by (s^{-1}). Based on the magnitude of the angular momentum of the uke in seoi-nage, we selected the top and bottom six participants and assigned them the highly skilled and skilled groups, respectively.

The Mann-Whitney U test from non-parametric statistics was conducted to test differences between the two groups in the peak angular momentum of the tori and the peak velocity of joints (ankle, hip, shoulder and hand of the swing leg) in the anterior-posterior (A-P) direction of the tori during the turning phase. The velocity vector in the anterior direction represented as a positive value in this study. Effect size (Cohen, 1988) was calculated as trivial (<0.1), small (0.1-0.3), medium (0.3-0.5), large (0.5+). In addition, the correlation coefficients between the peak angular momentum of the tori and the peak velocity of joints in the turning phase were calculated. In seoi-nage, the throwers use the upper extremities to apply forces on the uke in the posterior direction by a pulling motion, whereas they use lower extremities to produce the force to the anterior direction by a pushing motion. Therefore, we focused on the peak negative velocities of the upper extremities and the peak positive velocities of the lower extremities for the analysis. MATLAB and its statistics toolbox (The MathWorks Inc., R2017b, Version 8.6, Massachusetts, USA) were used for all calculation, and the level of significance was set at 5%.

RESULTS: Table 1 shows the kinematic variables of both groups. The peak angular momentum of the tori in seoi-nage was significantly greater in the highly skilled group than the skilled group (p = 0.045, ES = 0.58). Although there was no significant difference in the

Table 1: The kinematic variables of highly skilled and skilled judo athletes.

	Median			
	Highly skilled	skilled	*P*	ES
Peak angular momentum of the tori (s^{-1}) †	0.22 (0.01)	0.19 (0.02)	0.045*	L (0.58)
A-P velocity of joint of the tori in the turning phase				
Peak ankle velocity (m/s)	7.98 (0.51)	6.51 (0.82)	0.031*	L (0.62)
Peak hip velocity (m/s)	3.29 (0.38)	2.28 (0.21)	0.031*	L (0.62)
Peak shoulder velocity (m/s)	-0.64 (0.16)	-0.38 (0.28)	0.936	T (0.02)
Peak hand velocity (m/s)	-2.37 (0.05)	-2.28 (0.47)	0.936	T (0.02)

Notes: Median (quartile deviation); *, significant;
ES, Effect size: T, trivial (<0.1); S, small (0.1-0.3); M, medium (0.3-0.5); L, large (0.5+).
†, Peak angular momentum data was normalized by the square of the body height and weight.

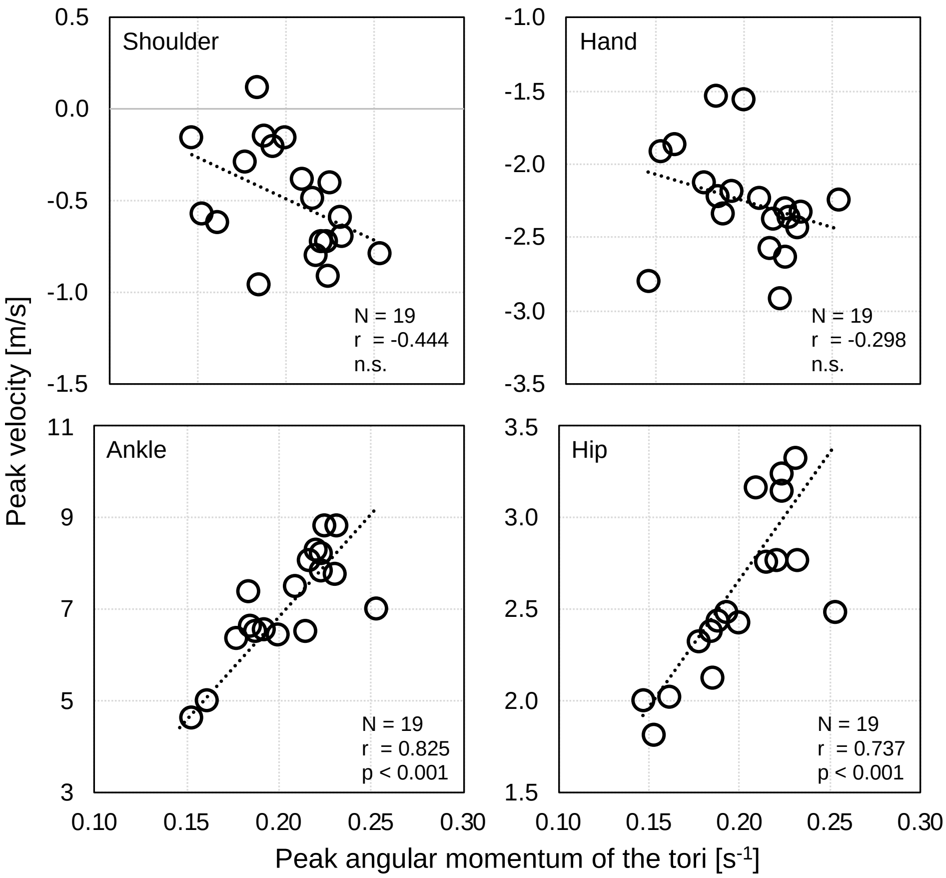

Figure 2: Relationship between normalized angular momentum of the tori and the peak velocity of the ankle, hip, shoulder and hand in the turning phase.

A-P component of peak velocities of the shoulder and hand of the tori in the turning phase between the two groups, A-P component of the peak ankle and hip velocity of the tori was significantly larger in the highly skilled group than in the skilled group (P = 0.031 and P = 0.031 respectively). We found a positive correlation between the peak of normalized angular momentum of the tori in the turning phase and the peak ankle and hip velocity of the tori in the tuning phase (r = 0.825, P < 0.001 and r = 0.737, P < 0.001 respectively) (Figure 2).

DISCUSSION: We compared the kinematics of the seoi-nage motions performed by judo athletes of different skill levels. The present study demonstrated that the angular momentum of the tori in the highly-skilled group was significantly greater than that in the skilled group. In the throwing phase of the seoi-nage, judo athletes apply the forces to the uke using the pulling motion of the upper extremities and the pushing motion of the lower extremities so as to generate the angular momentum of the uke. The present study suggests that highly-skilled athletes may increase the angular momentum of uke by transferring their greater angular momentum to the uke. We also found that the anterior-posterior component of the peak ankle and hip velocities of the tori in the turning phase were significantly larger in the highly-skilled group than those in the skilled group, indicating that the lower extremities velocities of the tori towards the uke may distinguish highly-skilled judo athletes from skilled ones. In addition, the positive correlation between the peak angular momentum of the tori and peak ankle and hip velocities of tori in the turning phase may indicate that both highly-skilled and skilled athletes utilize the linear motion to generate the angular momentum of the tori. Seoi-nage is usually preferred by judo athletes of short stature. We speculate that the morphological factor may allow short judo athletes to utilize the more pushing force of the lower extremities than the pulling force of the upper extremities to generate the greater angular momentum of the uke. Most elite judo athletes and coaches are likely to believe that the knee extension torque in the throwing phase is the most critical contributor to the seoi-nage performance. However, the previous result (Ishii et al., 2018) did not support the anecdotal statement.

CONCLUSION: This study found that the peak angular momentum of the tori and the anterior-posterior component of the ankle and hip velocity of the tori in the turning phase were significantly larger in the highly skilled group than in the skilled group. The present result suggest that we need to pay greater attention to the linear velocity of the lower extremities to evaluate the seoi-nage skill.

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