# KINEMATIC COMPARISON OF THE SEOI-NAGE TECHNIQUE BETWEEN ELITE AND COLLEGE JUDO ATHLETES

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The purposes of the present study were to compare the biomechanics parameters of seoi-nage between elite and college judo athletes and to produce the standard motion models of elite and college judo athletes. The motion data of the seoi-nage were collected on three male elite judo athletes and nine male student judo athletes using a three-dimensional motion analysis technique and compared. The results demonstrated that the elite judo athletes flexed the knee of the pivot leg and showed less shoulder rotation angle during the latter half of seoi-nage than the college judo athletes. The present study also revealed that the standard motion model seemed to be valid to represent the characteristics of groups' motions.

**KEY WORDS:** standard motion, motion analysis, martial arts, Judo throwing technique.

**INTRODUCTION:** Technical factors determining sport performance have been frequently assessed by using the knowledge of biomechanics. Until now, however, no biomechanical bases that allow us to utilize for coaching of judo have been established. Therefore, many judo coaches still evaluate the performance on the basis of their own subjective feeling, observation and experiences. In addition, one of the essential tasks of coaches is to provide an appropriate model technique as a reference. However, this approach has some limitations: there is motion variability in a model technique attributed to performers' property; there is no firm or valid base for the model technique of judo throwing; in order to improve coaching methods for judo-throwing, we need to establish some objective biomechanical measures that reflect skill levels and prepare appropriate motion models that include important biomechanical factors of high-level judo throwing.
A judo athlete has to move into a position where the technique can be performed effectively, and has to move the opponent into an appropriate position where it is easy to throw in a fast and smooth manner (Matsumoto, 1975). In addition, investigations by Ishii et al. (2016, 2017) indicated that the relative forward centre of mass (CM) velocity contributed to performing a successful seoi-nage (shoulder throwing), one of nage-waza (throwing) techniques, by comparing its biomechanics between elite and college judo athletes. However, the previous study has not discussed the kinematics that reflect the skill levels of seoi-nage. Therefore, the primary objective of the present study was to compare the selected biomechanics parameters of seoi-nage between elite and college judo athletes.
Ae, Muraki, Koyama and Fujii (2007) proposed a method to produce a standard motion model as an averaged motion pattern of skilled performers. Although the use of the standard motion model is expected to be effective in coaching judo techniques, the averaged motion patterns might not reflect crucial biomechanical characteristics of seoi-nage especially in elite athletes. Therefore, the second objective of this study was to produce standard motion models of seoi-nage for elite and college judo athletes and compare their biomechanical parameters between both groups.

**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 nine male college judo athletes (20.0 ± 1.2 years; 1.65 ± 0.05 m; 70.0 ± 7.2 kg). The college athletes currently compete 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 specially designed judo gear 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 seoi-nage move rated highest by the coaches was chosen as a best trial for motion analysis.

The anterior-posterior (Y) axis is 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 5.8 to 9.3 Hz, as determined by the residual method (Winter, 2009).

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 in Figure 1) represents the instant that the tori's pivot foot was lifted off for the first forward step, which was identified as the instant that the toe marker reached 0.02 m higher than the standing position, and Event 2 (E2) represents the instant that the pivot foot came in contact with the mat, as confirmed by the ground reaction force data. Event 3 (E3) denotes the instant that both of the tori's feet are in contact with the mat. Three-dimensional coordinate data of reflective markers for tori and uke were normalised by the time of each motion phase and participant's height, and averaged to produce the standard motion model (Ae et al., 2007). In this study the focus was on the turning phase.

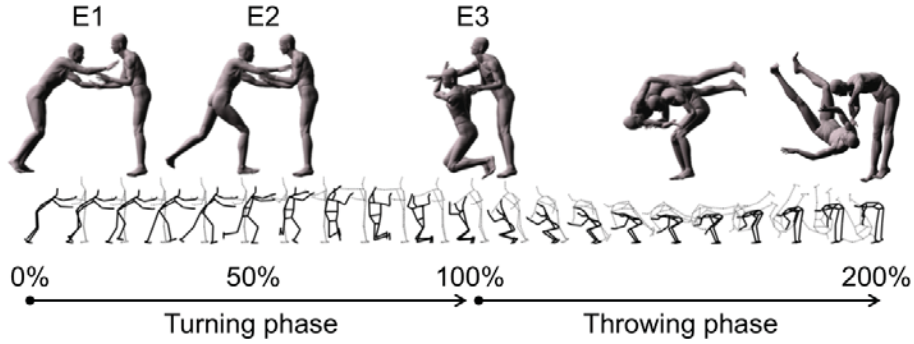


**Figure 1: The events and phases of seoi-nage.**

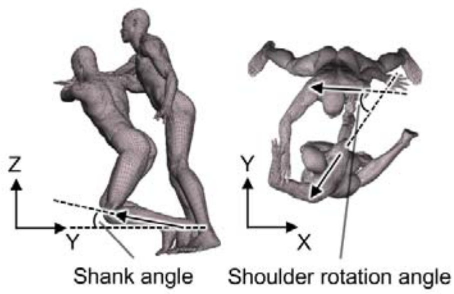


**Figure 2: Illustration of selected variables.**

To compare the kinematics for both groups, the knee joint angle of the pivot leg was calculated using a joint coordinate system described by Suzuki et al. (2014). The shoulder rotation angle between a vector from the right to left side of tori's shoulder and a vector from the left to right side of uke's shoulder on the horizontal plane (Figure 2). For example, a large shoulder rotation angle indicate that tori's torso have rotated relative to the uke. The shank angle of the swing leg was the angle between a vector from the ankle to the knee of tori's swing leg and the horizontal axis on the Y-Z plane.

The Mann-Whitney U test from non-parametric statistics was conducted to test differences between the two groups in the knee joint angle of the pivot leg, the shoulder rotation angle and the shank angle of the swing leg. Effect size was calculated using *r* proposed by Cohen (1988). The effect size was assessed as trivial (<0.1), small (0.1-0.3), medium (0.3-0.5), large (0.5-) (Cohen, 1988). MATLAB and its statistics toolbox (The MathWorks Inc., R2015b, Version 8.6, Massachusetts, USA) were used for calculation, and the level of significance was set at 5%.

**RESULTS:** Table 1 shows the knee joint angle of the pivot leg, the shoulder rotation angle and the shank angle of the swing leg for the tori for both groups. Although there was no significant difference in the knee joint angle of the pivot leg at the 50% mark between the two groups, the shoulder rotation angle tended to be smaller in the elite athletes than in the college athletes ($p$ = 0.065, $r$ = 0.53). The shoulder rotation angle at the 65% mark and the shank angle of the swing leg at the 100% mark were significantly smaller in the elite athletes compared with the college athletes. There was no significant difference in the shoulder rotation angle at the 100% mark between the two groups. The knee flexion angle of the pivot leg at the 65% and 100% mark was significantly larger in the elite athletes compared with the college athletes.
The knee flexion angle of the pivot leg, the shoulder rotation angle and the shank angle for the standard motion model of elite and college athletes were similar to the medians for each group.

**Table 1**
**The knee joint angle of the pivot leg, shoulder rotation angle and the shank angle of the swing leg for the tori.**

| | Median | | | | Standard motion | |
|---|---|---|---|---|---|---|
| | Elite | College | *P* | ES | Elite | College |
| 50% mark | | | | | | |
| Knee joint angle of pivot leg | 42.7 (4.8) | 33.9 (6.7) | 0.096 | M (0.48) | 43.1 | 33.7 |
| Shoulder rotation angle | 7.9 (5.0) | 24.4 (14.2) | 0.065 | L (0.53) | 4.9 | 24.1 |
| 65% mark | | | | | | |
| Knee joint angle of pivot leg | 66.3 (11.5) | 50.3 (5.3) | 0.042* | L (0.59) | 66.5 | 50.7 |
| Shoulder rotation angle | 19.8 (16.2) | 40.1 (21.3) | 0.027* | L (0.64) | 18.9 | 42.7 |
| 100% mark | | | | | | |
| Knee joint angle of pivot leg | 114.6 (11.0) | 82.7 (8.2) | 0.016* | L (0.69) | 109.4 | 80.5 |
| Shoulder rotation angle | 113.3 (35.3) | 106.9 (11.0) | 1.000 | T (0.00) | 99.4 | 107.6 |
| Shank angle of swing leg | 2.9 (11.8) | 25.0 (8.0) | 0.027* | L (0.64) | 5.1 | 24.7 |

*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-).

**DISCUSSION:** Understanding joint kinematics specific to judo is crucial in coaching judo throwing techniques. However, there is little information on biomechanics of judo throwing techniques performed by elite judo athletes. Therefore, we compared the kinematics of the seoi-nage motions performed by elite and college judo athletes, and that of the standard motion models for two groups. We found differences in the knee joint angle of the pivot leg at the 65% and 100% mark, the shoulder rotation angle at the 65% mark and the shank angle of the swing leg 100% mark in the seoi-nage motion between two groups. However, there were no significant differences in the shoulder rotation angle at the 100% between two groups.
The previous study (Ishii et al., 2017) demonstrated that the college athletes landed their pivot leg with the knee more extended and stiffened than the elite athletes, which may have caused a large decrease in the forward velocity of the body in the turning phase. Their results suggested that the forward velocity of the body was important to seoi-nage, and soft landing of the pivot foot as the elite athletes performed, should be advised. The results of the present study supported the finding of the precious study. The large knee flexion angle observed at 50% and 65% mark in the turning phase may help the athletes to maintain the relative forward velocity. The smaller shoulder rotation angle may contribute to delay the defensive response of the opponent, which may be specific biomechanical characteristics of seoi-nage in the elite judo athletes.

There would be some controversy that the standard motion does not reflect crucial characteristics of the motion for elite or skilled performers because it is merely an averaged motion. The present study, however, demonstrated that the selected biomechanical parameters for the standard motion model were similar to the median values of the elite athletes' data. This indicates that the standard model in this study can be a representative motion model of skilled performers. Therefore, coaches can provide an appropriate motion pattern to athletes using the standard motion model in this study, as exemplified. In future study, we need to investigate effects of coaching programs using the standard motion model of seoi-nage for non-elite judo athletes to improve their techniques.

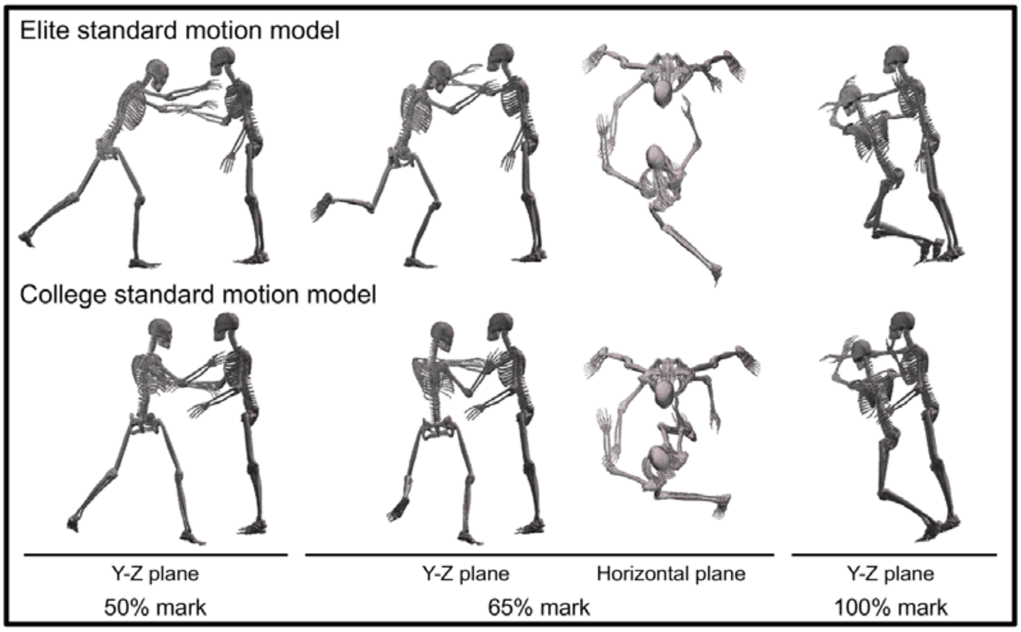


**Figure 2: The standard motion models of the elite and college athletes.**

**CONCLUSIONS:** Our study demonstrated that the elite judo athletes flexed the knee of the pivot leg and showed less shoulder rotation angle during the latter half of seoi-nage than the college judo athletes. The present study revealed that the standard motion model seemed to valid to represent groups' motions. In future, the standard motion model method would provide judo coaching for non-elite athletes with one of appropriate motion models.

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