

# BIOMECHANICAL FACTORS OF EFFECTIVE SEOI-NAGE IN JUDO

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The purpose of this study was to compare the seoi-nage techniques between the elite and non-elite judo athletes. The information obtained helps to increase our knowledge on biomechanical factors to determine the effectiveness of seoi-nage. The motion data of the seoi-nage were collected on three male elite judo athletes and seven male student athletes using a three-dimensional motion analysis technique. The velocity generated by the hikite and hip were greater and the angles of pulling and hitting were smaller in the elite judo athletes than the student judo athletes. The comparison of the effects of the velocity and angles of pulling and hitting on the generation of the angular momentum of uke implied that these variables could be indices for coaches to evaluate the effectiveness of the seoi-nage.

**KEY WORDS:** Nage-waza, effectiveness, motion analysis, Judo.

**INTRODUCTION:** In judo, an athlete grips an opponent's "gi", a traditional and special clothes used for judo practice and competition, with hands and pulls or pushes the opponent to lose his/her balance (Kuzushi) and to generate appropriate conditions (Tsukuri and Kake) for a successful throw. Some specific movements are required for a quality nage-waza, which is a challenging task for all judo-kas. The judo-kas needs to move the opponent into an appropriate position by the effective use of opponents' own power (Matsumoto, 1975).

Seoi-nage is one of the most frequently used technique in judo matches by both elite and non-elite judo athletes. The seoi-nage is accomplished by pulling an opponent forward to lose his/her balance, then pick up the body on the back and throw over the shoulder. Recent statistics analysis done by the judo laboratory in the University of Tsukuba, Japan, on the matches of the London olympic games (2012) showed that 54.7% of the matches were won by the nage-waza, followed by penalty (21.7%), the katame-waza (16.5%), and judgment (6.3%), and approximately 20 % of matches determined by the nage-waza were occupied by the seoi-nage. This reveals that the improvement in the seoi-nage technique enhances the judo performance.

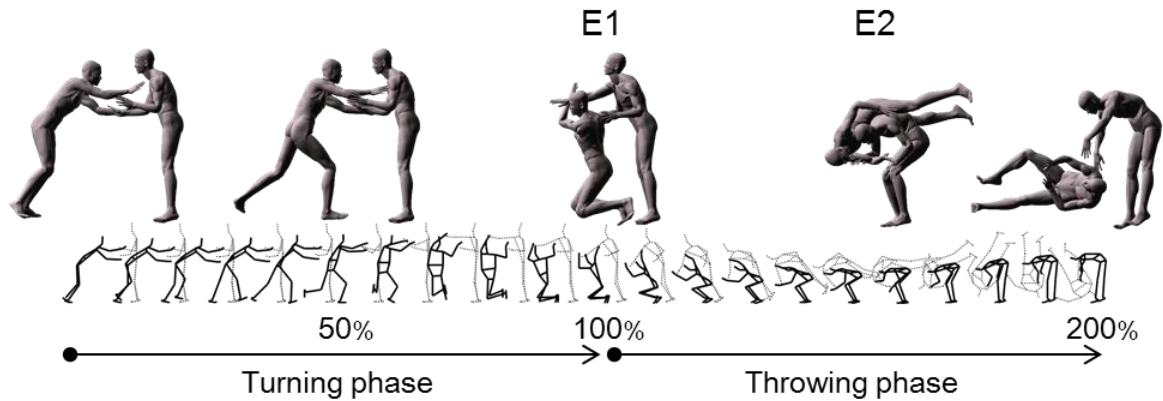
Many coaches usually evaluate and give advices to athletes in the technique training, based on coaches' observation and their experience with less scientific evidence. However, we need to find quantitative criteria to evaluate the level of the seoi-nage technique by investigating biomechanical differences in the seoi-nage technique between elite and non-elite judo athletes. Therefore, the purpose of this study was to compare the seoi-nage techniques between the elite and non-elite judo athletes. The information obtained helps to increase our knowledge on biomechanical factors to determine the effectiveness of seoi-nage.

**METHODS:** The subjects were three male elite judo athletes (medalists in the 2010 world judo championships,  $24.3 \pm 2.1$  years old,  $1.66 \pm 0.05$  m in height,  $72.6 \pm 6.9$  kg in body mass) and seven male collegiate judo athletes ( $20.0 \pm 1.2$  years old,  $1.65 \pm 0.04$  m in height,  $70.6 \pm 5.8$  kg in body mass).

**Data collection:** Three-dimensional coordinate data of the landmarks on the subjects' body performing the seoi-nage in pre-arranged sparring drills (yakusoku-renshu) were collected using 18 cameras of VICON-MX system operating at 250Hz to analyze the three-dimensional kinematics of a tori, a person throwing an opponent, and an uke, an person being thrown by the tori. The subjects wore a specially designed judo clothes which enabled reflective markers attached to the subject to be detected by cameras. The Y axis was defined as the

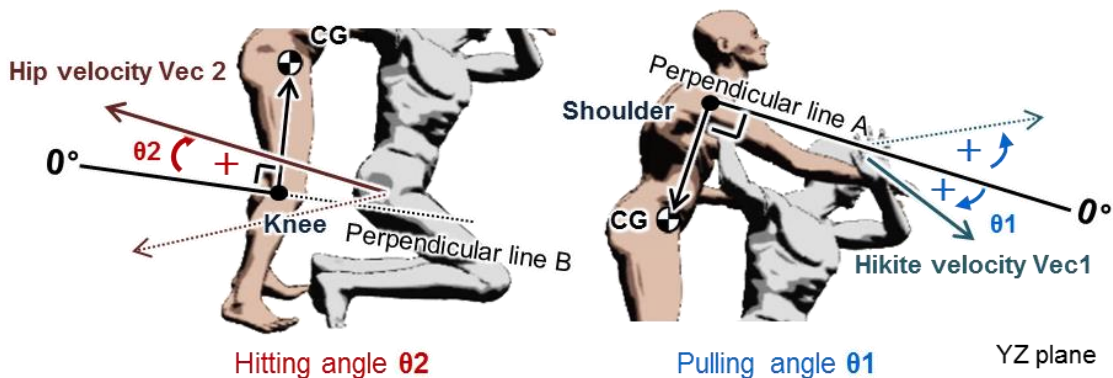
direction of the throwing of the tori, the Z axis as the vertical direction and the X axis as the direction perpendicular to both the Y and Z axes.

**Data analysis:** Three-dimensional coordinate data of the tori and the uke were smoothed by a Butterworth digital filter at cut-off frequencies ranging from 5.8 to 9.3HZ, which were decided by the residual method (Winter, 1990).



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

Figure 1 shows the definition of events and phases of the seoi-nage. Analysis was done from the instant that the tori's pivot foot lifted off the mat for the first forward step to the instant that the uke's part of the body landed on the mat after the completion of the nage-waza. The turning phase was defined from the instant that the pivot foot lifted off to the instant that both feet were in contact with the mat. The throwing phase was defined from the end of the turning phase to the instant that uke's body was in contact with the mat. The data were normalized by the time of each motion phase as 100%. The event 1 (E1 as shown in Figure 1) represents the instant that tori's feet are in contact with the mat and event 2 (E2) is the instant that the legs of the uke are parallel to the mat during the throwing phase.



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

The centers of mass of the tori and the uke were estimated after the body segment parameters for the Japanese athletes (Ae et al., 1996). The angular momentum of the uke about the center of mass and its time derivative as a moment were calculated.

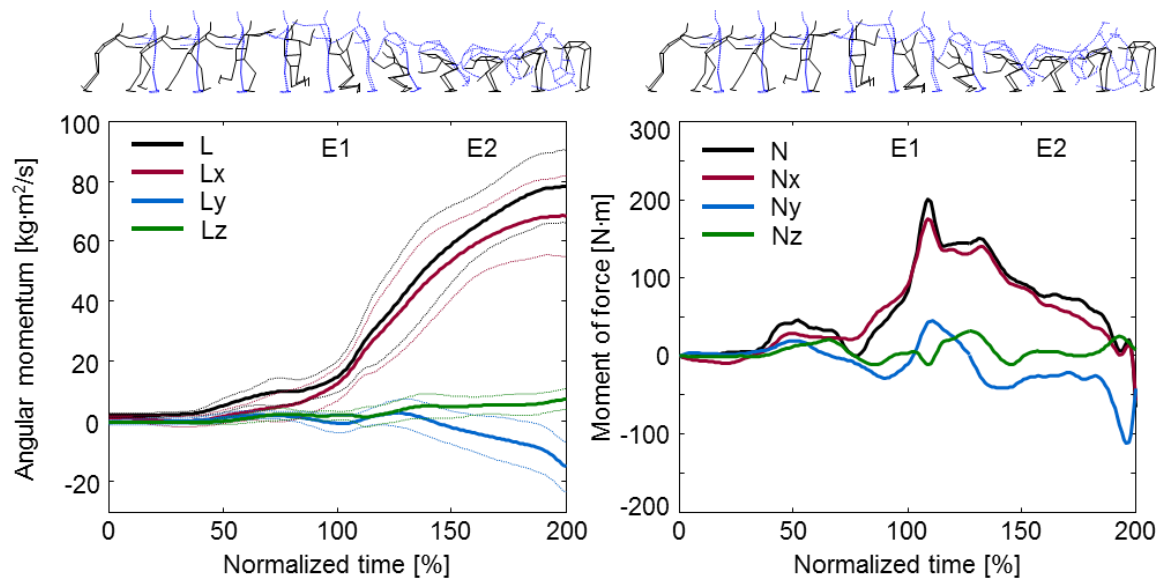
Figure 2 explains definitions of velocity vectors and angles as selected variables. These were used as kinematic criteria to evaluate the effectiveness of the seoi-nage in this study. The velocity vector of the tori's left hand (Vec 1) is referred to as the hikite velocity and Vec 2 is the hip velocity in the sagittal plane.

The Vec 1 and Vec 2 were considered to be indices of the directions of the forces applied to the uke during throwing. The pulling and hitting angles were calculated to evaluate the effectiveness of the seoi-nage. The pulling angle,  $\theta_1$ , is the angle between the direction of

Vec 1 and the line perpendicular to the uke's trunk. The hitting angle,  $\theta_2$ , is the angle between the Vec2 and the line perpendicular to the uke's thigh. The angular velocities of the torso ( $\omega_1$ ) and the thigh ( $\omega_2$ ) of the uke were calculated as indices of the effect of the seoi-nage.

**RESULTS:** Figure 3 shows averaged angular momentum and moment of the uke, the derivative, in the seoi-nage. The transverse (x) angular momentum was the most influential component on the resultant one. Although the resultant and transverse angular momentum of the uke did not show a remarkable increase during the turning phase, it rapidly increased from E1 to E2 in the throwing phase.

The moment in the seoi-nage started increasing rapidly before E1, reached its maximum and gradually decreased towards the end of the motion.



**Figure 3: Averaged angular momentum and moment of the uke in the seoi-nage.**

Table 1 shows comparison of the biomechanical variables between elite and student judo athletes at the events of the seoi-nage. The results demonstrated that the angular momentum in the X-axis at the E1 and E2 of the elite judo athletes (A to C) were greater than those of the student judo athletes. The angular velocity  $\omega_1$  at the E2 of the elite judo athletes was greater than that of the student judo athletes. However, there was no difference in  $\omega_2$  between the elite and students judo athletes. All the elite judo athletes showed smaller mean hitting angle ( $\theta_2$ ) than the student judo athletes.

**Table 1**  
**Comparison of the biomechanical variables between elite and student judo athletes**

	Angular momentum X-axis [kg·m <sup>2</sup> /s]		Velocity YZ plane [m/s]		Pulling & hitting angle YZ plane [deg]		Angular velocity X-axis [rad/s]			
	E1	E2	Hikite	Hip	θ1	θ2	ω1		ω2	
			E1-2	E1-2	E1-2	E1-2	E1	E2	E1	E2
Elite A	16.57	69.82	4.72	1.02	45.6	13.2	2.40	7.12	0.80	8.60
Elite B	21.04	68.01	3.16	1.49	41.1	12.2	3.13	7.78	-0.66	7.31
Elite C	17.58	78.25	3.32	1.41	35.4	15.7	1.59	7.29	1.01	7.32
Students (SD)	9.98 (4.13)	56.29 (5.62)	3.21 (0.62)	1.01 (0.24)	52.3 (10.9)	24.4 (6.4)	1.48 (0.81)	6.09 (1.01)	-0.09 (0.41)	7.63 (1.35)

Although the velocity of the hikite in Elite A was greater than that of the student athletes, Elite B and C were different cases from Elite A. The hip velocities of Elite athletes B and C were greater than that of the student athletes, but not in the case of Elite A. Elite athletes B and C showed smaller mean pulling angle than the student athletes.

**DISCUSSION:** The angular momentum must be generated in order to achieve Ippon, completion of the nage-waza, in the judo. The resultant angular momentum of the uke in seoi-nage increased rapidly while the tori lifted up the uke's body by using his knee extension and trunk flexion. During the throwing phase, the elite judo athletes demonstrated the greater hikite velocity or hip velocity than the student athletes. For effective seoi-nage, the tori needs to apply a force that is eccentric to the center of gravity of the uke with the hikite and hips to generate the moment of the uke. The hikite or hip velocity in the throwing phase may enable us to evaluate technical level of the seoi-nage skill. The elite athletes kept smaller pulling and hitting angles from event E1 to E2.

In order to utilize the force of the tori effectively to generate angular momentum, the pulling and hitting angle by the hikite or hip should be as close as zero degrees, that is perpendicular to the uke's body. The results revealed that the elite athletes were able to adjust their body position so as to apply their force of the hikite and hip to the uke more effectively.

The elite athletes who generated the greater angular momentum about x-axis at event E2 imparted the greater angular velocity of the uke's trunk than the student athletes. To increase the angular velocity of the trunk with large moment of inertia, the elite athlete would have applied great forces at the hikite and hip, which could be inferred by the greater velocity of the hikite and hip at smaller pulling and hitting angles.

**CONCLUSION:** The elite judo-ka pulled the uke with the greater velocity of the hikite and hip and the smaller pulling and hitting angles, which resulted the greater angular velocity at the instant that the uke's body was completely lifted up. The comparison of the effects of the velocity and angles of pulling and hitting on the generation of the angular momentum of the uke implied that these variables could be indices for coaches to evaluate the effectiveness of the seoi-nage.

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