COMPARISON OF KINETICS OF THE LEG JOINTS IN SEOI-NAGE BETWEEN ELITE AND COLLEGE JUDO ATHLETES

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The purpose of the present study was to identify biomechanical factors that could be used for the evaluation of seoi-nage technique by comparing the techniques of elite and college-level 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 qualitatively compared. This study found that the peaks of the knee flexion torque, knee negative power, hip extension torque and hip positive/negative power on the swing leg of elite athletes was much greater than those of the college athletes. These indicated that the knee and hip joint contributed to the mechanical energy absorption of the tori's body in the early phase and generated the positive power in the throwing phase.

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

INTRODUCTION: To achieve high sport performance, athletes, coaches and teams first have to identify limiting factors of performance and design effective training programs. In addition to coaches' observation of athletes in competition and/or practice, they also often utilize various objective measures to properly evaluate athletes' physical fitness such as strength, power, anaerobic and aerobic abilities, agility, speed, and flexibility.
Technical factors of sport performance have been frequently assessed by using the knowledge of biomechanics. Until now, however, no objective biomechanical parameters that allow us to evaluate levels of judo technique have been established, and therefore many judo coaches still analyse judo performance based on only their subjective observation and experience.
Seoi-nage of judo is one of nage-waza (throwing) techniques that is frequently performed during practices and matches. It is accomplished by making an opponent off-balance with pulling in various directions, then putting the opponent's body on your back and throwing over the shoulder. A statistics analysis on judo in the London Olympic Games (2012) showed that 54.7% of the matches were won with nage-waza, and approximately 20% of the matches determined by nage-waza were occupied by seoi-nage (The judo laboratory in the University of Tsukuba, Japan, 2012). We are able to advance the scientific evidence-based judo coaching by identifying the biomechanical parameters that reflects the level of seoi-nage technique. Therefore, the purpose of this research was to perform a descriptive study of select kinematic and kinetic factors that could be used for the evaluation of seoi-nage technique by comparing the techniques of elite and college-level judo athletes.

METHODS: The subjects were three male elite judo athletes (medalists in the 2010 world judo championships, 24.3 ± 2.1 years old, 1.66 ± 0.05 m in height, 72.6 ± 6.9 kg in body mass) and nine male collegiate judo athletes (20.0 ± 1.2 years old, 1.65 ± 0.05 m in height, 70.0 ± 7.2 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 for a tori (athlete throwing an opponent) and a uke (athlete being thrown by an opponent). The subjects wore a specially designed judo gear that allowed visualization of forty-seven reflective markers to create a fifteen linked segment model. The subjects were instructed to execute seoi-nage as close to

that of their usual sparring drills as possible. 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 5.2 to 10.0HZ, which were decided by the residual method (Winter, 1990).

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 left from 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 left from to the instant that either foot was in contact with a force platform.

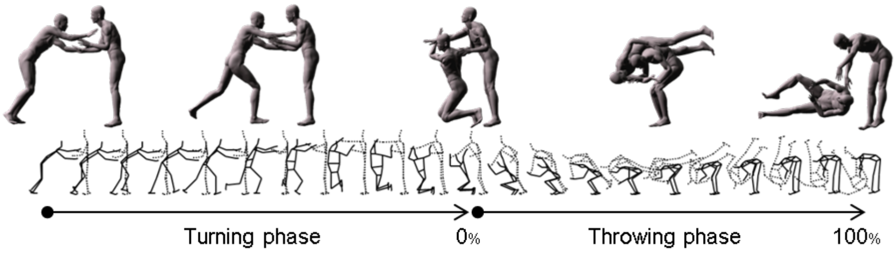

Figure 1: The events and phases of the seoi-nage.

The throwing phase was defined from the end of the turning phase to the instant that the uke's body was in contact with the mat. The time-series data were normalized by the time of each motion phase as 100%. The centres of masses (COM) of the tori and uke were estimated using after the body segment parameters for the Japanese athletes (Ae, 1996). Three components of the COM velocity were calculated by differentiating the displacement of the COM. The joint torque of the pivot and swing legs was calculated using an inverse dynamics approach with a three-rigid-segment model consisting of the foot, shank, and thigh of the pivot and swing legs. The equations of motion for these segments were solved from the distal to the proximal segments by using the ground reaction forces as input for the foot segment. These dependent variables were qualitatively compared across the two skill levels.

RESULTS: The Y component of COM velocity for the elite athletes at the beginning of the throwing phase was 1.21 ~ 1.30 m/s, whereas the mean ± sd COM velocity for the student athletes was 0.89 ± 0.39 m/s. The Z component of COM velocity for the elite athletes at the beginning of the throwing phase was -1.11 ~ -1.44 m/s, whereas the mean ± sd COM velocity for the student athletes was -0.88 ± 0.34 m/s.

Figure 2 shows changes in the joint angular velocity (top), joint torque (middle), and joint power (bottom) of the knee flexion/extension (left column) and the hip flexion/extension (right column) for the elite judo athletes and the mean data for the student athletes during the throwing phase. Table I shows difference in the kinematic and kinetic variables between elite and students athletes. Rapid knee flexion of the pivot and swing legs occurred at the beginning of the throwing phase, followed by knee extension which was resulted from the large extension torque in the first half of the throwing phase. The peak knee extension angular velocities of the pivot and swing legs were apparently greater in the elite athletes than those of the student athletes. The peak knee extension torques of the pivot and swing legs were apparently larger in the elite B and C (pivot leg: 2.40 ~ 2.43 Nm/kg, swing leg: 2.80 ~ 3.42 Nm/kg) than those of the student athletes (pivot leg: 1.70 ± 0.38 Nm/kg, swing leg: 1.87 ± 0.57 Nm/kg). The peak knee flexion torque of the swing leg was apparently larger in the elite athletes than that of the student athletes, while there was little apparent difference in that of the pivot leg between the two groups. The negative knee torque power of the pivot and swing legs were found from 0% to 20% time, followed by the positive torque power from 20% to 50% time and negative torque power in the latter half of the throwing phase. The knee negative peak power of the swing leg after 30% time was apparently larger in the elite

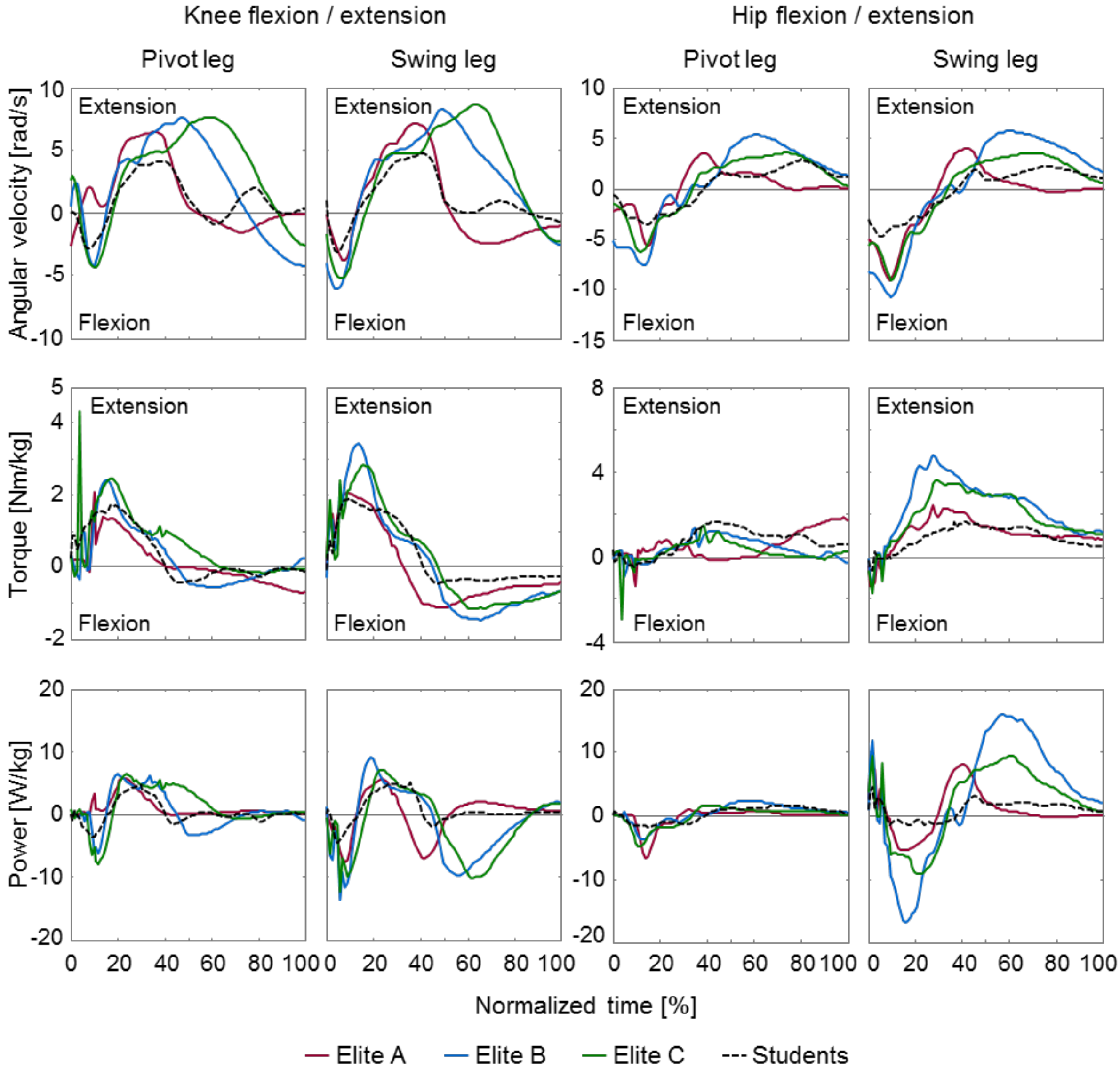

Figure 2: Joint angular velocities (top), joint torques (middle), and joint torque power (bottom) of the knee and hip of the pivot and swing legs for elite and students athletes during the throwing phase of seoi-nage.

Table I. Difference in the kinematic and kinetic variables between elite and students athletes.

	Elite A	Elite B	Elite C	Students (M ± SD, n=7)
Peak angular velocity (rad/s)				
Knee of pivot leg	6.4	7.5	7.5	4.0 ± 1.8
Knee of swing leg	7.0	8.2	8.6	4.7 ± 3.0
Hip of pivot leg	-5.7	-7.6	-6.3	-3.6 ± 1.2
Hip of swing leg	-9.0	-10.7	-9.1	-4.9 ± 4.5
Peak extension torque (Nm/kg)				
Hip of swing leg	2.42	4.80	3.53	1.60 ± 0.83
Peak flexion torque				
Knee of swing leg	-1.14	-1.49	-1.19	-0.50 ± 0.75
Peak positive torque power (W/kg)				
Hip of swing leg	7.99	15.73	9.19	3.12 ± 3.46
Peak negative torque power (W/kg)				
Knee of swing leg	-6.96	-9.69	-10.20	-1.95 ± 4.10
Hip of swing leg	-5.47	-16.98	-9.38	-1.72 ± 2.52

athletes than that of student athletes. The large extension torque was observed only in the swing leg during the throwing phase. The peak hip flexion angular velocities of the pivot and swing legs and the peak hip extension torque of the swing leg were apparently greater in the elite athletes than those of the student athletes. The negative hip torque power of the swing leg was found in the elite athletes during the first half of the throwing phase, followed by the positive hip torque power in the second half of the throwing phase. The peak hip positive/negative power of the swing leg were apparently larger in the elite athletes than those in the student athletes. There was a likely difference in the joint power of the swing leg between the elite and student athletes.

DISCUSSION: Ishii and Ae (2014) reported that the elite judo athletes showed greater velocities of the hikite and the hip from 0% to 50% time during the throwing phase than the student judo athletes. In addition, they estimated that the direction of applied force to the uke by the hikite and the hip of the tori was different in the two groups. Based on the previous investigations and judo textbooks, we hypothesized that the torques of the knee extension and the hip flexion at the beginning of the throwing phase would be greater in the elite judo athletes than the student judo athletes. However, the hypothesis were not confirmed in the present study.

The COM velocities in the Y and Z components were apparently larger in the elite athletes than those of the student athletes. The negative power was exerted in the knee joint from 0% to 20% time, and the positive power was exerted from 20% to 50% time in the throwing phase. These results indicate that the knee joint contributed to the mechanical energy absorption of tori's body in the early phase and generated the positive power in the throwing phase, which would help the tori to change the direction of the applied force and to apply the force to the uke effectively. The hip flexion/extension of the swing leg exerted the negative and positive power, indicating that the hip of the swing leg contributed to absorb the mechanical energy, especially the rotational energy, of the tori's body.

Many elite judo athletes and coaches who are good at seoi-nage agree that knee and hip play an important role in seoi-nage. However, a few high skilled athletes have pointed out trunk forward rotation or inclination by hip flexion as an important parameter for high skilled seoi-nage. Our kinetic results revealed that the hip joint exerted the extension torque to absorb the applied force during the early throwing phase. The elite athletes may not recognize the importance of the hip flexion in the seoi-nage.

We found apparently large differences in the joint torque of knee and hip extension especially on the swing leg between the elite and student judo athletes. The observations in this initial study should be confirmed by future studies and also examined as interventions to explore the training applications of these results.

CONCLUSION: This study found that the peaks of the knee flexion torque, knee negative power, hip extension torque and hip positive/negative power on the swing leg of elite athletes was much greater than those of the college athletes. These indicated that the knee and hip joint contributed to the mechanical energy absorption of the tori's body in the early phase and generated the positive power in the throwing phase.

REFERENCES:

Ae, M. (1996). Body segment inertia parameters for Japanese children and athletes (in Japanese). *Japanese Journal of Sports Sciences*, 15, 155-162.

Ishii, T. and Ae, M. (2014). Biomechanical factors of effective seoi-nage in judo. 32th international conference on biomechanics in sports (2014), ISBS – Conference Proceedings Archive (online), available from < https://ojs.ub.uni-konstanz.de/cpa/article/view/6035/5516 >, (accessed 2015-01-21).

Judo Laboratory, University of Tsukuba (2012). Statistical analysis on winning points in Judo in the London Olympic Games. Personal communication.

Winter, D.A. (2009) Biomechanics and motor control of human movement (4th ed.). *John Wiley & Sons*: New Jersey, pp. 70-73.