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Analysis of the Force Characteristics of Seoi-nage based on the Performance Height of Elite Male Judo Athletes

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Abstract

Seoi-nage is a representative technique frequently used in judo. Therefore, it is essential to identify how seoi-nage force characteristics change under various conditions. This study aimed to determine the differences in the force characteristics at different performance heights of elite male judo athletes. Twenty elite male judo athletes participated in the study. They were asked to perform seoi-nage at different heights (80 cm and 60 cm) using a rubber band as a practice situation. Data were collected by a force-measurement device with a rubber band connected to the device. The time variables, force value magnitude, force value rate, and force value angle in the vertical/horizontal planes were calculated and compared at 80 cm and 60 cm. There were significant differences in the force magnitude and the force vector vertical angle at 80 cm and 60 cm ($p<.05$). The force magnitude was greater at 60 cm than at 80 cm height. The force vector vertical angle was greater at 60 cm than at 80 cm height. In conclusion, seoi-nage at 80 cm height requires less force than at 60 cm; hence, judo players should perform the seoi-nage throw placing their center of mass lower than that of an opponent. Practicing seoi-nage repeatedly at 60 cm height under the training conditions is recommended. Seoi-nage at 60 cm height can be considered an effective training method for increasing the ability to handle difficult opponents.

Key words: judo, seoi-nage, force characteristics, force vector, performance height

Introduction

Judo is a sport involving sparring in which the athlete is required to act instantaneously, reflecting the opponent's move and responding to their technique. In judo, various techniques, such as *nage-waza* performed in a standing position and *ne-waza* performed in a supine position, are applied according to the given position. Between the two techniques, the athlete performs *nage-waza* by lowering or tilting the opponent's center of mass (COM) using his trunk as a lever to carry their opponent on the back or by turning him over while using the force as efficiently as possible. It is an important technique that accounts for 60% of all attack moves in judo. Among the *nage-waza* techniques performed in a standing position, *seoi-nage* is the most well-known and frequently used, which

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includes *morote-seoi-nage* (using both arms) and *ippon-seoi-nage* (using one arm), as well as *kata-eri-seoi-nage* and *seoi-otoshi*, while *morote-seoi-nage* is generally referred to as *seoi-nage* (Kim, 2000; Kim et al., 2002).

Performance of *seoi-nage* is broadly divided into three phases. The first is *kuzashi*—a move used to destabilize the opponent's balance through pulling or pushing; the second is *tsukuri*, a move to make the opponent lose their balance or increase the COM to make it easier to throw him subsequently; the last is *kake* in connection with *tsukuri* (Blais et al., 2007). Here, the most important phase to ensure the successful performance of *seoi-nage* is *kuzashi* because this move allows effective implementation of the subsequent move presuming the balance of the opponent has been adequately lost (Kim & Yoon, 2003).

Previous studies on successful *kuzashi* during *seoi-nage* were as follows: Yilmaz (2015) measured the force of pulling by both hands during *seoi-nage* in 40 elite judo athletes and showed that the athletes applied a greater force on the hand pulling the sleeve than the one pulling the collar, irrespective of the dominant hand in performing *morote-seoi-nage*. Nowoisky (2008) also analyzed the force of pulling during *seoi-nage* in elite judo athletes and reported that the force increased as the time up to the point of maximum force decreased in performing *kuzashi*. These results were indicative of the greatest emphasis placed on the move to lift the opponent's arm in *kuzashi*, while the time at which the force is applied is as important as the simple magnitude of force. In addition, Hassmann et al. (2010) made a direct measurement of the pulling force in judo athletes by attaching a load cell to their garment, and the results indicated an increase in the maximum pulling force with a decrease in the overall time of the move, which lent support to the findings of previous studies.

As previously mentioned, the *seoi-nage* technique is complete as *kuzashi* is performed, immediately followed by *tsukuri* and *kake*, for which the rotation of the trunk, the force of the feet pressing against the ground and the perfect balance of the movements of all segments are the prerequisites. In a diversity of previous studies, therefore, kinematic devices (infrared camera, force plate, etc.) were used to analyse the force applied by the athlete on the ground during *tsukuri* and *kake* and the kinematic variables of the trunk and lower limbs (Kim, 2011; Kim & Kim, 1991; Kim et al., 2002), while most studies divided the *seoi-nage* technique into the rotation phase (*kuzashi-tsukuri*) and the *nage-waza* phase (completed through *kake-nage-waza*) to analyze the time taken by each phase as well as the rate related to the COM (Ishii et al., 2018). The results of these studies showed that the ratio for the time of the rotation and *nage-waza* phases was 50:50, while the *kuzashi* and *tsukuri* phase was reported to be as important as the *nage-waza* phase, and that the change of COM was generally faster on the left-right plane than the front-back plane so that the importance of the front to back and top to bottom movements was highlighted.

As can be seen, continuous efforts have been made to improve the *seoi-nage* technique in judo, and previous studies have concurrently suggested the need for an in-depth discussion on the pulling force in terms of both direction and magnitude during *kuzashi* for an athlete to accomplish a successful performance of *seoi-nage* to the highest level. The previous studies have analyzed the force or the rate on its own without considering the force direction in *kuzashi* and neglecting to evaluate the force magnitude while performing that technique. Therefore, a study examining the direction of tilting or pulling of the opponent by judo athletes and the force magnitude upon such moves in varying conditions (*morote-seoi-nage* and *ippon-seoi-nage*, with a change of performance height) is needed in the actual performance of *seoi-nage* for the improvement of this technique.

Thus, the purpose of this study was to conduct an in-depth analysis of the magnitude and direction of the force applied at the *kuzashi* and *tsukuri-kake* phases in *seoi-nage* using a vector measuring device developed for *nage-waza* in Kil et al. (2018). Identifying the differences in the force characteristics between

morote-seoi-nage and *ippon-seoi-nage* could provide basic data for improving future training and feedback.

Methods

Participants

The participants in this study were twenty judo athletes of the national team at the Jakarta Palembang 2018 (age: 24.50±3.45 yrs., height: 176.65±7.20 cm, body mass: 92.55±24.67 kg, career: 11.90±3.26 yrs.). All participants voluntarily agreed to participate and their movements were measured accordingly.

Experimental Procedures and Analytical Methods

The technique was divided into the two most widely used moves *morote-seoi-nage* and *ippon-seoi-nage,* to examine the *seoi-nage* technique of judo athletes under varying conditions. The heights of 80 cm and 60 cm (the most frequently observed in the actual training) were applied to identify the differences in *seoi-nage* that may arise due to the opponent's height. Here, to minimize the extrinsic factors of the opponent during *seoi-nage*, the rubber band used in the actual training (*seoi-nage* practice) was attached to a vector-measuring device for *nage-waza* for the experiment (Figure 1). In addition, the athletes applied the most frequently used move in actual practice settings; they held a point on the rubber band 10 cm from the tip to perform the technique, and each move was tried five times.

The measuring device used in this study is shown in Figure 2. The device used a 3-axis load cell sensor as a force vector-measuring module. The 3-axis load cell was the LCXYZ-T001 of A&D Korea, with the vertical (Z) axis allowing approximately 1 ton of weight to be measured and the horizontal (X and Y) axes allowing approximately 500 kg of weight to be measured. The device also exhibited 1% nonlinearity and 150% maximum yield load. The data collected using the vector measuring device for *nage-waza* were categorized into a *kuzashi* phase (Phase 1: Event 1 –Event 2) and a *tsukuri-kake* phase (Phase 2: Event 2 –Event 3). The data of the two phases were analyzed with respect to the time taken by each phase at each time point, the force magnitude (sum of the force vectors), the rate of force, and the upper and lower angles and left and right angles of force vector (Figure 3). The upper and lower angles and left and right angles of force vector were defined as the angles on the YZ plane and XZ plane, respectively. The magnitude of force was normalized based on weight, and the rate of force was estimated by differentiating the force magnitude by time. The direction of the force vector was defined as a + value on the left and a – value on the right of the X-axis (left to right, frontal axis) as the athlete faced the device and as a + value on the top and a – value on the bottom of the Y-axis (top to bottom, vertical axis), while for the Z-axis (sagittal axis), the direction of the rubber band pulled by the athlete was set as a + value (Kil et al., 2018, Figure 4).

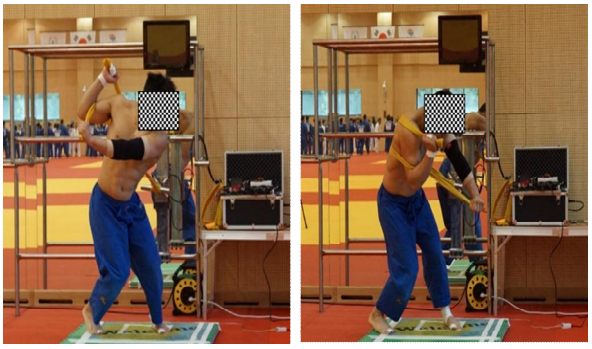

Figure 1. *Sample of seoi-nage*

Figure 2. *Force vector equipment (left) and sensor of vector equipment (right)*

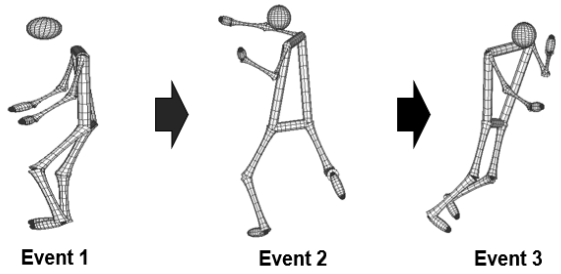

Figure 3. *Definition of event*

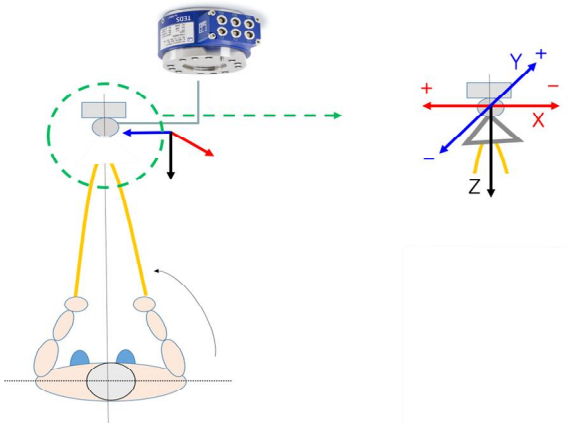

Figure 4. *Definition of measuring equipment axis*

Statistical Analysis

A paired t-test was performed on each variable (time, magnitude of force, rate of force, the upper and lower angles, and left and right angles of the force vector) to investigate how the force and direction vary in performing judo *seoi-nage* under different conditions (*morote-seoi-nage* and *ippon-seoi-nage*, with a change of performance height), using the SPSS 25.0 program. The level of significance was set at α=.05.

Results

In this study, the differences in performing *seoi-nage* by the national team elite judo athletes were determined according to the performance height. We analyzed the variables (time, force magnitude, force rate, and the upper and lower angles and left and right angles of the force vector) according to performance height (80cm, 60cm) of the two most widely used techniques in judo *morote-seoi-nage* and *ippon-seoi-nage*.

Phase Time in *morote-seoi-nage* and *ippon-seoi-nage* according to the Performance Height

This study examined each phase time in *morote-seoi-nage* and *ippon-seoi-nage* according to performance height, and no significant variation was found across all phases (Table 1, p>.05).

Table 1. *Comparison of time variables between 80cm and 60cm*

Type	Phase	Height	Time Duration (sec)
Morote-seoi-nage	Kuzashi (Phase 1)	80cm	0.27±0.08
		60cm	0.32±0.12
		t(p)	-1.82(0.08)
	Tsukuri-Kake (Phase 2)	80cm	0.48±0.08
		60cm	0.52±0.11
		t(p)	-1.36(0.18)
Ippon-seoi-nage	Kuzashi (Phase 1)	80cm	0.27±0.12
		60cm	0.28±0.12
		t(p)	-0.28(0.78)
	Tsukuri-Kake (Phase 2)	80cm	0.50±0.11
		60cm	0.53±0.12
		t(p)	-0.97(0.34)

*Indicates significant difference between 80cm and 60cm (p<.05)

Time-Dependent Magnitude of Force and Rate of Force in *morote-seoi-nage* and *ippon-seoi-nage* according to the Performance Height

This study examined the time-dependent magnitude of force and the rate of force in *morote-seoi-nage* and

ippon-seoi-nage according to the performance height, and the result showed a significant difference in the force magnitude at the *kuzashi* time-point (Event 2) in the *morote-seoi-nage* between 80cm and 60cm at 1.87±0.32 N/kg and 2.18±0.42 N/kg, respectively ($p<.05$). The rate of force, on the other hand, displayed no significant variation (Table 2, $p>.05$).

Time-Dependent Upper and Lower Angles and Left and Right Angles of the Force Vector in the *morote-seoi-nage* and *ippon-seoi-nage* according to the Performance Height

This study examined the time-dependent upper and lower angles and left and right angles of the force vector

Table 2. *Comparison of force variables between 80cm and 60cm*

Type	Phase	Height	Force (N/kg)	Power (N/sec)
Morote-seoi-nage	Kuzashi (Event 2)	80cm	1.87±0.32	3.44±0.93
		60cm	2.18±0.42	3.34±1.01
		t(p)	**-2.60(0.01)***	0.32(0.75)
	Tsukuri-Kake (Event 3)	80cm	5.05±1.17	4.56±0.78
		60cm	5.02±1.26	4.14±0.77
		t(p)	0.09(0.93)	1.71(0.10)
Ippon-seoi-nage	Kuzashi (Event 2)	80cm	1.71±0.32	3.48±1.59
		60cm	1.95±0.50	3.41±1.18
		t(p)	-1.76(0.09)	0.15(0.89)
	Tsukuri-Kake (Event 3)	80cm	4.48±0.98	3.96±0.81
		60cm	4.45±1.10	3.69±1.00
		t(p)	0.11(0.91)	0.93(0.36)

*Indicates significant difference between 80cm and 60cm ($p<.05$)

Table 3. *Comparison of force vector variables between 80cm and 60cm*

Type	Event	Height	Sagittal Angle (deg.)	Frontal Angle (deg.)
Morote-seoi-nage	Kuzashi (Event 2)	80cm	39.00±6.29	23.02±5.81
		60cm	43.16±7.95	22.38±6.63
		t(p)	-1.83(0.08)	0.32(0.75)
	Tsukuri-Kake (Event 3)	80cm	15.08±8.47	14.47±4.50
		60cm	22.80±9.40	14.76±6.03
		t(p)	**-2.73(0.01)***	-0.18(0.86)
Ippon-seoi-nage	Kuzashi (Event 2)	80cm	39.04±8.13	21.00±6.49
		60cm	44.69±8.08	22.03±7.15
		t(p)	**-2.21(0.03)***	-0.48(0.64)
	Tsukuri-Kake (Event 3)	80cm	15.67±7.66	13.68±4.59
		60cm	23.35±8.65	15.34±4.39
		t(p)	**-2.98(0.01)***	-1.17(0.25)

*Indicates significant difference between 80cm and 60cm ($p<.05$)

in *morote-seoi-nage* and *ippon-seoi-nage* according to performance height. The result showed a significant difference in the upper and lower angles of the force vector at the *tsukuri-kake* time-point (Event 3) in *morote-seoi-nage* between 80 cm and 60 cm at 15.08±8.47° and 22.80±9.40°, respectively ($p<.05$). Significant differences between 80 cm and 60 cm were also found in the upper and lower angles of the force vector in the *ippon-seoi-nage* as follows: 39.04±8.13°and 44.69±8.08° at the *kuzashi* time-point (Event 2) and 15.67±7.66° and 23.35±8.65° at the *tsukuri-kake* time-point (Event 3) ($p<.05$). In contrast, the left and right angles of force vector displayed no significant variation across all time points (Table 3, $p>.05$).

Discussion

In this study, the change of the force characteristics during *seoi-nage* performed by elite male judo athletes of the national team was observed while changing the performance height. The analysis of the results provided basic data for future training and feedback. In judo, *seoi-nage* is one of the most widely used techniques accounting for up to 60% of all attack moves, whereby the athlete makes the opponent lose their balance or tilts the COM of the opponent using his trunk as the lever to carry him on the back or turn him over with the flow of his movement. Hence, it is essential to determine the force's magnitude and direction characteristics according to the opponent's position (*morote-seoi-nage* and *ippon-seoi-nage*, with a change of performance height).

Our results showed that, while no significant variation in time was found across all phases of the *morote-seoi-nage* and *ippon-seoi-nage* techniques (Table 1, $p>.05$), an overall shorter period of time was observed at the 80 cm height position than at 60 cm (at the time points of *kuzashi* and *tsukuri-kake)* and the force value of *morote-seoi-nage* was lower during *kuzashi* at 80 cm than at 60 cm (Table 2, $p<.05$). This result coincided with the general characteristics of the *seoi-nage* technique as in an actual game, it is easier to turn over the opponent if his COM is high and reduce the relative effort on *kuzashi*, creating conditions for performing *tsukuri-kake* in the lower direction. The effort on *kuzashi* increases if the opponent's COM is low, thus making it more difficult to lose; hence, driving the athlete to focus more on *kuzashi* than *tsukuri-kake*. A previous study reported that, at the moment of *kuzashi* in *seoi-nage*, it is important to align one's COM with the opponent's COM. At that time the athlete should lower his body as much as possible, trying to achieve a lower COM than that of the opponent, which is essential for *tsukuri-kake* (Kim, 2001; Kim et al., 2002). Our study results demonstrated that the technique is performed with less force at the height of 80 cm than at 60 cm, which is regarded as a relatively low COM height compared to their opponent (Table 2, $p>.05$). This could be considered quantitative evidence for the practical application of lower posture in an actual game as the athlete would use efficient force to perform the *seoi-nage* technique. For *ippon-seoi-nage*, likewise, no significant variation was found, but based on the trend of decreased force in *kuzashi* at 80 cm compared with 60 cm, the ability to control one's COM in line with the opponent's COM is crucial irrespective of which *seoi-nage* technique is being performed.

Furthermore, regarding the upper and lower angles of force vector in *morote-seoi-nage* and *ippon-seoi-nage*, significant differences were observed for *tsukuri-kake* in *morote-seoi-nage* and for both *kuzashi* and *tsukuri-kake* in *ippon-seoi-nage* (Table 3, $p<.05$). In a previous study, it was highlighted that the possibility of successful performance increased as the vertical displacement (upper to lower movement at *kuzashi*) in *seoi-nage* increased (Ishii et al., 2017). In this study, likewise, the upper angle was higher at 60 cm than at 80 cm, as the onset of the technique is in a high position at 80 cm, and the resistance of the rubber band is low; hence, a high level of performance is not required. However, at 60 cm, the onset of the technique

is relatively low, so the upper angle should be increasingly demand a higher level of effort during the *seoi-nage* performance. Lastly, the left and right angles of the force vector displayed no significant variation in *morote-seoi-nage* and *ippon-seoi-nage* (Table 3, $p>.05$), which might be due to the experience of the participants, being able to adequately match and maintain their COM in line with the opponent's COM. Therefore, the left and right angles of the force vector should be a target variable in the training of judo athletes outside the national team, whose techniques are yet to reach completion. In that scenario, the applied strategy would notably enhance athletes' performance.

In conclusion, our study identified how the characteristics of the *morote-seoi-nage* and *ippon-seoi-nage* techniques change according to performance height changes. Our results might be seemed that *morote-seoi-nage* and *ippon-seoi-nage* performance at 80 cm height is more efficient and effective than at 60 cm height. However, the time and force were higher at 60 cm than at 80 cm, and the upper and lower angles of the force vector in *kuzashi* were higher; hence, the training *seoi-nage* could be repeatedly practiced on an opponent with a lower COM and at 60 cm height. This type of repeated practice is anticipated to assist athletes in performing *seoi-nage* successfully by exerting a strong instantaneous force and increasing the angles in *kuzashi* against an opponent with a lower COM that otherwise poses difficulties in performing the technique.

Conclusion

This study aimed to identify the force characteristics during *seoi-nage* in elite male judo athletes of the national team and conduct an in-depth analysis to provide the basic data for future training and feedback. The study results showed that, in both *morote-seoi-nage* and *ippon-seoi-nage*, the 80 cm height condition led to lower levels of time and force for performing efficient moves. The ultimate goal, however, is for the athletes to execute a high level of performance as fluently as possible in an actual training setting. It has, thus, been determined, based on the findings of this study, that the repeated practice of *seoi-nage* at the height of 60 cm or below during training would be a suitable method to improve the athletes' abilities against an opponent with a lower COM that poses difficulties in performing the technique. It is also suggested that future studies investigate the kinematic factors that reflect the athlete performing the technique in consideration of such variables as actual body angles and muscle activities while varying the conditions of the opponent to take into account that judo is a sport involving sparring.

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