Differences in the Seoi-Nage Skill between Elite and Non-Elite Judo Athlete’s

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Research Article

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Abstract

Background

The present study examined the effects of the seoi-nage skill using expert (i.e., elite) and novice (i.e., non-elite) judo athletes.

Methods

Ten with expert judo athletes and 10 novice judo athletes were instructed to perform seoi-nage skill that consist of three phases (i.e., unbalancing, positioning, and throwing). Kinematic characteristics of the three phases data was collected from an optical motion capture 3D camera, and used to measure the magnitude and direction of the force.

Results

The results indicated that the expert judo athletes showed better performance the rotation and tilt angle characteristics of the shoulder and pelvis, and hip and knee joint flexion-extension angle during seoi-nage skill compared with novice judo athletes. In addition, the shoulder and pelvis of expert judo athletes exhibited together while maintaining the extension of the hip and knee joints to achieve effective sedation than novice judo athletes.

Conclusions

These results suggest that the force and movement control is important for the implementation of optimal the seoi-nage skill.

Introduction

Judo is a modern martial art sport that evolves during the summer Olympic Games. National level players principally use matchmaking techniques (throwing or ground skills) to attain significant movement [1]. Specifically, seoi-nage skill is a form in which an attacker pulls an opponent in various directions and throws the opponent over one's back [1, 2, 3, 4]. To successfully perform seoi-nage skill, players must strongly pull the opponent, shake the center of gravity, and quickly rotate the torso to lift the opponent. Moreover, they should be able to stoop below the opponent's center of gravity for easy lifting. Therefore, seoi-nage involves effective movement of the upper and lower limbs and body. In addition, it is a complicated technique because this complex skill form uses the degrees of freedom of most joints throughout the body [5]. A high level of seoi-nage is related to the attacker's unbalancing (the opponent) and torso's rotational speed [6]. Judo players put more weight on the tilt, and this movement enables fast
rotation of the torso. The throwing motion is faster than that of college judo players. In addition, sufficient pull forward enables faster and more accurate positioning [1].

The unbalancing direction is essential because the positioning and throw process is performed within the unbalancing situation, i.e., with the opponent's center of gravity up and forward. In addition, good unbalancing can be performed faster and more accurately. During precise unbalancing and positioning, the performance speed of seoi-nage appears faster because of the increased amount of frontal momentum of the opponent [7]. Therefore, seoi-nage, unbalancing, positioning, and throwing should be continuously and organically connected and appear as one movement to perform faster and more successfully. This can be regarded as a factor for performing fast and excellent seoi-nage. On performing seoi-nage in judo, the bigger the absolute force than the opponent, the easier the process will be. However, the success or failure of the technique depends on the kinematic variables that appear at each time point of unbalancing, positioning, and throwing [8, 9]. In a study that analyzed seoi-nage for each phase through three-dimensional (3-D) image analysis, the kinematic comparison between elite judo athletes and male college judo athletes was divided into positioning and throwing phases. The angular velocity and center of gravity in the vertical direction were significant in elite judo athletes [1]. In addition, the center of gravity that appeared in each phase (unbalancing, positioning, and throwing) during seoi-nage with four judokas moved forward and upward in the unbalanced positioning and downward in the throwing phase [7]. Ishii and Ae [10] analyzed the angular velocities of three judo athletes and college judo athletes. While the angular velocity of the trunk joint was higher in elite athletes during the rotational phase, the femoral joint angular velocity was similar in both groups. Using 3-D image analysis, prior studies have divided the phases and analyzed them kinetically; however, the kinetic variables have not been analyzed for the magnitude of the force during maximum seoi-nage performance. In seoi-nage, the magnitude of the tilting force is essential because jigging and hanging are performed when the opponent's center of gravity is tilted upward and forward. The magnitude of the pulling force that changes with phase progression is also important. Nonetheless, there have been no attempts to identify the kinematic and magnitude of force characteristics in the unbalanced phase. Therefore, it is difficult to clearly understand the mechanism of performing seoi-nage, and its application to the field is limited. In addition, the measurement of the pulling force using the judo-specialized device measured only the single-axis pulling force, not only the magnitude of the force in each phase (unbalancing, positioning, and throwing) but also the kinematics, and there are no studies that have investigated the variables together.

In this study, the magnitude of the force was measured by hanging a rubber tube for judo training in a judo-specialized device, and the kinematic variables were simultaneously analyzed in three dimensions. In particular, this study distinguishes itself from previous studies in that it measured the force value of seoi-nage using a particular device and analyzed kinematic properties simultaneously. Based on this evidence, we hypothesized that amateur judo players would exhibit greater kinematic deficits than elite judo players during a phase of seoi-nege. Therefore, these findings can be likely used as objective data to enhance the learning effectiveness of judo seoi-nage and to further serve as the basis for accurate training guidelines.
Materials And Methods

Participants

We selected collegiate level of elite judo players (EG, n = 10) (age range: 20–22 years; average age: 20.9 years; men) (Table 1), with an average experience of 7.7 years. In addition, we recruited personnel without injury and a healthy musculoskeletal system (only personnel without serious or acute injuries were selected). As a control group, amateur-judo players (AG, n = 10) were not registered; however, they were selected to participate in sports or national club competitions. Their judo career averaged 4.7 years. Participants were requested to understand the purpose of this study for voluntary participation. The t-test on the height and weight of the experimental and control groups did not display a significant difference in the height ($t=-0.40, p = .696$) and body weight ($t= 1.31, p = .206$) between the groups. The protocol was approved by the Institutional Review Board of Pukyong National University and conformed to the Declaration of Helsinki. Informed consent was obtained from each subject before participation in the experiment.

Table 1
Characteristics of participants (mean ± standard deviation, n = 20)

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Height (cm)</th>
<th>Weight (kg)</th>
<th>Career (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elite-Group (EG)</td>
<td>20.9 (0.88)</td>
<td>173.6 (6.42)</td>
<td>80.8 (14.54)</td>
<td>7.7 (2.54)</td>
</tr>
<tr>
<td>Amateur-Group (AG)</td>
<td>27.5 (2.68)</td>
<td>174.7 (6.00)</td>
<td>73.4 (10.38)</td>
<td>4.7 (2.50)</td>
</tr>
</tbody>
</table>

Apparatus and task

A vector system was used to measure the magnitude and direction of the force. A three-axis load cell sensor was used to measure the magnitude and direction of the force on the Z-axis approximately 9,800 N (in 1 ton), X and Y-axis approximately 4,900 N (in 500 kg), and nonlinearity (1%). The maximum yield load was 150%. While the Z-axis measured the subject in the horizontal direction, the Y-axis and X-axis measured those in vertical and horizontal directions. We measured the magnitude of force appearing in the X, Y, and Z directions and sum of the force vectors at a sampling frequency of 200 Hz (Fig. 1). The rubber tube connected to the judo throw analysis device was held with both hands to perform seoi-nage at maximum speed and force. The baseline was similar for the rubber tube and both arms. The equipment was located 80 cm from the ground, and the distance between the participant and equipment was 150 cm.

We used an optical motion capture camera (Optitrack, Natural Point, Inc. USA) system to analyze the 3-D images recorded during seoi-nage. The subjects' kinematic variables, i.e., shoulder and pelvis rotation angle (counterclockwise rotation + value, clockwise rotation - value), shoulder and pelvis tilt angle
(posterior tilt + value, anterior tilt - value), and hip and knee joint angles (extension + value, flexion - value), were measured using 20 cameras. The motion capture camera's frame rate was 120 frames per second, and reflective markers were positioned on the head, shoulder, hip, knee, ankle, and posterior superior iliac spine to measure the performance. A marker was attached to the seventh cervical spine to distinguish the center of the body and on the lower scapula to differentiate the left and right sides. Before the task, a suit with a marker was attached for the 3-D image analysis. We attached the markers to each position and placed them at baseline to hold the rubber tube connected to the judo throw equipment. Both groups participated in a series of seoi-nages, with two practice attempts. A baseline was set at a distance of 150 cm from the judo throw equipment to identify the performance position. Subsequently, on indicating a ready sign, the participants performed seoi-nage with maximum force and speed. The task involved performing seoi-nage five times, with a 30 s interval between each attempt. The kinematic data measured using the Optitrack motion capture program were digitized by signal cleaning through C motion's 3-D 5V professional, and the quantified data were normalized using MATLAB (The MathWorks Inc., R2015b, Version 8.6, Massachusetts, USA).

**Statistical analyses**

The kinematic characteristic data collected during seoi-nage were classified into four events (Fig. 2). First, the beginning of seoi-nage and first left foot contact time was set as Event 1, following which the left foot rotated and landed, defined as Event 2 (unbalancing phase). Event 3 was set as the point where the shoulder's horizontal rotational angle reached 180° (positioning phase). Event 4 was set as the point when the horizontal rotational angle of the shoulder reached its maximum (throw phase). Event 1 was defined as the motion of stepping forward with the right foot before pulling the judo rubber tube from the stationary position and was excluded from the analysis owing to the absence of pulling motion. The analyzed kinematic variables were the shoulder and pelvis rotation angle (counterclockwise rotation + value, clockwise rotation - value), shoulder and pelvis tilt angle (posterior tilt + value, anterior tilt - value), and hip and knee joint angles (extension: + value, flexion - value). Figure 3 (A - D) depicts the respective definitions of the horizontal rotation angles of the shoulder and pelvis, tilt angles, and hip joint and knee joint flexion angles. In addition, we measured only the horizontal rotation angle of the shoulder and pelvis, tilt (front and back), and the flexion angle of the left hip and knee joints, which is the most important factor in seoi-nage movement. A total of 13 markers were attached to avoid obscuring the 3-D view. Therefore, we limited the difficulty in collecting kinematic data and decided that the motion factor of seoi-nage was sufficient as the factor mentioned above.

[Figure 2 near here]

[Figure 3 near here]

Each event was subjected to a separate independent *t*-test for elite and amateur-judo players. For all analyses, statistical significance was set at a level of 0.05. We performed all analyses using SAS (SAS 9.1.2. software; SAS Institute, Inc., Cary, NC, USA).
Results

Kinematic variables in seoi-nage

In Event 2, the horizontal rotation angle of the shoulder was 129.13° (SD = 20.37) and 138.9° (standard deviation [SD] = 26.12) in EG and AG, respectively ($t$=-2.05, $p$< .05) (top left in Fig. 4). Following Event 3, the angle was 180°. Subsequently, the angle reached the maximum value in Event 4 and demonstrated a significant difference between EG and AG groups (247.4° [SD = 36.69] vs. 208.3° [SD = 18.54]) ($t$= 6.53, $p$ < .01).

[Figure 4 near here]

The anterior and posterior tilting angles of the shoulder (top right in Fig. 4) in Event 2 were −15.13° (SD = 9.61) and −10.42° (SD = 10.25) in EG and AG, respectively ($t$=-2.31, $p$< .05). In Event 3, the angle was −28.65° (SD = 6.40) and −12.14° (SD = 12.66) in EG and AG, respectively ($t$=-8.04, $p$< .01). In Event 4, the tilt angle in EG and AG was significantly different (19.54° [SD = 29.23] vs. 0.62° [SD = 12.01]) ($t$= 4.13, $p$ < .01).

In all events, EG exhibited a larger horizontal rotation angle of the pelvis than AG (bottom left in Fig. 4). In Event 2, the rotation angle in EG and AG was 163.9° (SD = 26.80) and 153.8° (SD = 22.25), respectively ($t$ = 1.99, $p$ < .05). In Event 3, there was a significant difference between EG and AG (205.7° [SD = 9.21] vs. 181.0° [SD = 10.47]) ($t$ = 12.22, $p$ < .01). Moreover, we observed a significant difference between EG and AG in Event 4 (235.4°[SD = 23.97] vs. 194.4° [SD = 15.71]) ($t$ = 9.82, $p$ < .01).

The anterior and posterior tilt angles of the pelvis (bottom right in Fig. 4) were significantly different between the groups ($t$=-2.33, $p$< .05). In Event 3, the tilt angle in EG and AG was −9.91° (SD = 7.58) and −6.72° (SD = 4.90), respectively ($t$=-2.43, $p$< .05). In addition, the tilt angle in Event 4 was 15.13° (SD = 15.92) and −0.74° (SD = 4.90) in EG and AG, respectively ($t$ = 6.54, $p$ < .01).

The angles of flexion (-) and extension (+) of the left hip joint were analyzed when performing seoi-nage (top left in Fig. 5). As a result, in Event 2, EG exhibited an angle of 169.8° (SD = 7.34) and AG demonstrated an angle of 163.3° (SD = 13.25) showed a significant difference between the two groups ($t$ = 2.97, $p$ < .01). In Event 3, EG showed an angle of 156.4° (SD = 10.30), and AG demonstrated an angle of 146.5° (SD = 23.10), and there was a significant difference between the two groups ($t$= 2.70, $p$ < .01). In Event 4, similar to previous results, a significant difference was observed ($t$= 2.26, $p$< .05); EG showed an angle of 136.1° (SD = 14.98), and AG exhibited an angle of 125.0° (SD = 30.64).

[Figure 5 near here]

There were no significant differences in the flexion (-) and extension (+) angles of the right hip joint (top right in Fig. 5) in Event 2 ($t$=-1.40, $p$ = .163). However, there were significant differences between the groups in Events 3 and 4. In Event 3, EG and AG demonstrated an angle of 163.0° (SD = 11.49) and 151.3°
Differences in the flexion (-) and extension (+) angles of the left knee joint (bottom left in Fig. 5) were insignificant in Event 2 (EG, 124.7° [SD = 8.83] vs. AG, 129.8° [SD = 16.03]) \((t = -1.90, p = .06)\). In Event 3, the angle was 124.0° (SD = 10.38) and 120.8° (SD = 29.52) in EG and AG, respectively, without a significant difference between the groups \((t = 0.72, p < .05)\). Moreover, Event 4 did not demonstrate a significant difference \((t = 1.81, p = .074)\) in the angles (EG, 131.3° [SD = 15.21] vs. AG, 121.7° [SD = 33.07]).

In Event 2, the flexion (-) and extension (+) angles of the right knee joint (bottom right in Fig. 5) were significantly different between the groups \((t = 5.44, p < .01)\). In Event 3, EG and AG demonstrated angles of 157.1° (SD = 11.75) and 131.3° (SD = 30.97), respectively \((t = 5.39, p < .01)\). In Event 4, the angle was 165.9° (SD = 9.78) and 132.6° (SD = 33.76) in EG and AG, respectively \((t = 6.57, p < .01)\).

**Kinematic variables during maximum vector sum force expression while performing seoi-nage**

The absolute values of the average maximum force while performing seoi-nage were 341.1 N (SD = 66.69) and 238.3 N (SD = 36.55) for EG and AG, respectively \((t = 6.51, p < .01)\). In addition, the relative values of the average maximum force were significantly different, namely 4.36 N/kg (SD = 1.02) and 3.25 N/kg (SD = 0.49) for EG and AG, respectively \((t = 4.70, p < .01)\). Angles in the vertical direction (up and down) that appeared in the expression of the average maximum vector sum force of the two groups were 6.69° (SD = 4.64) and 2.07° (SD = 5.45) (EG vs. AG), thus indicating significant differences \((t = 3.13, p < .01)\). In addition, angles in the horizontal direction (left, right) were 3.16° (SD = 3.79) and 3.98° (SD = 4.65) (EG vs. AG) \((t = 0.66, p = .512)\), with no significant differences between the groups (Fig. 6).

The horizontal rotation angles of the shoulder while performing seoi-nage were 240.8° (SD = 35.19) and 204.8° (SD = 19.89) for EG and AG, respectively, and these displayed a significant difference \((t = 6.07, p < .01)\). In addition, the shoulder tilt angles were 16.92° (SD = 28.24) and 0.40° (SD = 12.94) in EG and AG, respectively \((t = 3.63, p < .01)\). The horizontal rotation angles of the pelvis were 230.1° (SD = 22.62) and 191.9° (SD = 16.83) for EG and AG, respectively \((t = 9.21, p < .01)\). The tilt angle of the pelvis was 13.22° (SD = 16.02) and −2.44° (SD = 6.75) in EG and AG, respectively, indicating a significant difference between the two groups \((t = 6.16, p < .01)\) (Fig. 7).

The left and right flexion angles of the hip joint when the maximum vector sum force appears when performing the seoi-nage, and the left hip joint angle was 135.7° (SD = 18.00) in EG and 125.8° in AG (SD = 28.00), with a significant difference between the two groups \((t = 2.02, p < .05)\); however, the right hip joint angle was 129.1° for EG (SD = 18.91) and 122.4° for AG (SD = 25.14), and there was no significant difference between the two groups \((t = 1.45, p = .150)\). The left and right flexion angles of the knee joint
were analyzed. The left knee joint angle was 132.3° (SD = 15.22) in EG and 126.8° (SD = 33.93) in AG, indicating no significant difference between the two groups ($t = 0.99, p = .325$); the right knee joint angle was 165.2° (SD = 11.28) in EG and 136.0° (SD = 34.83) in AG, indicating a significant difference between the two groups ($t = 5.36, p < .01$). (Fig. 8).

[Figure 8 near here]

**Discussion And Implications**

The rotation of the shoulder and pelvis plays a significant role in induced seoi-nage performance. If the opponent cannot pull adequately or lacks strength, shoulder and pelvis rotation cannot occur sufficiently. In this study, we separately measured the horizontal rotation angles of the shoulder and pelvis to identify the kinetic characteristics of the torso rotation force. The horizontal rotation angle of the shoulder and pelvis of elite judo players was higher than that of amateur players. In other words, the unbalanced movement was sufficiently performed, thereby resulting in a flexible rotation of the shoulder and pelvis.

Studies by Franchini [11] and colleagues demonstrated that elite judo players display higher body rotation in seoi-nage than amateur-judo players. Therefore, the better the body rotation, the higher is the influence of seoi-nage. However, in Event 2, the horizontal rotation angle of the shoulder was smaller in EG than in AG. It supposedly focused more on tilting upward and pulling toward the body than turning the shoulders. In the overall progress from Event 2 to Event 4, an analysis of the front and back tilt angle of the shoulder and pelvis revealed that the rear tilt was higher in EG than in AG. With seoi-nage progression, the front tilt was significant. Hence, the range from the rear to the front tilt was higher in EG than in AG. In other words, the shoulders of the EG supposedly tilted more backward for unbalancing and positioning than those of the AG and subsequently forward for an effective hang-up operation of seoi-nage.

In contrast, in Event 2, the shoulder displayed a smaller back tilt angle in AG than in EG. Moreover, with the skill progression, the front shoulder tilt was smaller in AG than in EG. Thus, insufficient back shoulder tilt for unbalancing and positioning was absent. Moreover, the front tilt of the shoulder for seoi-nage appeared small, such that differences could be observed according to the induced proficiency. The pelvis and shoulders tilt the same pattern, which is thought to show the difference in movement according to unbalancing and positioning. In other words, appropriate rear flexion of the shoulder and pelvis facilitated pulling the opponent toward the body. The front tilt of the shoulder and pelvis enabled carrying the pulled opponent forward [6, 12, 13, 14, 15]. The shoulder and pelvic tilt range may be related to the inertial force required to position the opponent. The moment of inertia can also vary depending on the induced proficiency and can be a significant kinetic indicator determining the level of seoi-nage. We did not directly measure the moment of inertia. However, the current study results were consistent with those of Ishii [17] and colleagues, who reported on a more significant range of tilt of the shoulder and pelvis from unbalancing to positioning, considering that the size of the shoulder and pelvic inflection range can be inferred. An analysis of the articulation angles of the hip and knee joints demonstrated that the angles were larger in EG than in AG in all events, except in Event 2 for the right hip joint. The hip joint was also higher in EG than in AG because the shoulder and pelvic posterior tilt was higher in EG than in AG in
Events 2 and 3. However, in Event 4, which is a hang phase, the left hip joint was also more extended than the left hip joint, and the front tilt of the shoulder and pelvis was more significant in the EG than in the AG. To summarize, despite the slight curvature of the hip joint, the sizable forward tilt of the shoulder and pelvis occurred because the body was kept parallel to the opponent by pulling the opponent substantially close. Moreover, the heel was lifted to enable the body to lean forward and throw. Owing to the experimental equipment, the hip joint flexion after positioning was not comparable. This is because we measured only the initial stage of the positioning and not the completion of the positioning.

Ishii [17] and colleagues mentioned that a flexibly bent hip joint at the initial point of positioning did not display sufficient angular velocity while performing the actual throw, thereby making it difficult to effectively perform seoi-nage. In addition, early stages of positioning necessitate a certain degree of the extended hip joint angle using sufficient angular velocity [13, 16]. Therefore, the extended hip joint angle in elite judo players can lead to more effective throws than amateur players. In addition, there was no significant difference between the groups; however, the flexion of the right hip joint in Event 2 was higher in EG than in AG. This may be attributed to the close positioning of the right knee to the opponent while lowering his posture during unbalancing, such that the right knee joint could bend naturally.

There was no significant difference in the left knee joint angle between the groups. However, in Event 2, EG tended to be more curved in the initial stage of performing seoi-nage than AG. In Event 4, EG displayed a more advanced knee joint angle than AG. This is because knee joint flexion should appear from unbalancing to the throwing phase. While the posture must be lowered below the opponent's center of gravity, the knee joint extension must appear to lift the latter [9, 17, 18]. In addition, the flexion and extension angles of the right knee joint were more extended in EG than in AG in all events, which is thought to be because the EG lifted or pulled the opponent's center of gravity as much as it tilted and flexed. Moreover, in Event 4, the extension of the left and right knee joints of EG revealed a significant difference. The right knee extension occurred because of the significant rotation of the shoulder and pelvis owing to the nature of seoi-nage. Previous studies have mentioned that the lower right knee extension in the positioning phase while performing seoi-nage did not display sufficient rotation of the shoulders and pelvis [14, 19]. Therefore, EG supposedly performed seoi-nage by sufficiently rotating the shoulder and pelvis.

In addition, flexion angles of the left and right knee joints for both groups demonstrated that the knee joint of EG was more flexed or similar in Event 2 than in Event 3. However, AG was unbalanced. In other words, both knees must be bent at unbalancing and tend to be maintained or slightly extended. Therefore, it is thought that the AG did not perform effective unbalancing and then positioning when performing seoi-nage, which resulted in a minor shoulder and pelvic rotation compared with EG. The horizontal rotation angle and tilt angle of the shoulder in the kinematic characteristics at the point of maximum force development revealed a difference of 36° and 16.52° for EG and AG, respectively, resulting in higher rotation and greater forward tilt. The pelvis rotation and tilt angles were 38.2° and 10.78° for EG and AG, respectively, thus revealing a similar pattern as the shoulder kinematic variables. EG displayed a more extended pattern than AG at the hip and knee joint flexion angles, thus indicating it appeared identical to
the extended pattern required in the positioning phase. The maximal force vector sum was 102.8 N, which was larger in EG than in AG, thereby suggesting that EG was superior to AG in terms of the magnitude of the pulling force. In the kinematic characteristics during the maximum force appearance, the shoulder’s horizontal rotation and tilt angles displayed 36° and 16.52° differences, respectively, compared with EG, indicating that more significant rotation and greater forward tilt were observed. The pelvic rotation and tilt angles also revealed a difference of 38.2° and 10.78° in EG and AG, respectively, thus displaying a pattern similar to the kinematic variables of the shoulder. EG displayed more extension in the hip and knee joint flexion angles than AG, indicating it appeared in a similar pattern as the extension required in the throwing phase. These results suggested that EG was superior to AG in terms of the above-mentioned kinematic characteristics. In summary, the vector sum of forces was more significant in EG than in AG. In addition, EG displayed a greater rate of change in horizontal rotation and the tilt of the shoulder and pelvis than AG. Moreover, it demonstrated flexion and extension patterns of the hip and knee joints that were more effective in throwing.

However, there are limitations to this study. We did not examine the strength characteristics of the right and left arms separately. Therefore, future studies should study the strength characteristics of each arm, in addition to equipment, to generate more useful primary data. Future research should also analyze the force characteristics, kinematic characteristics, and correlations of various judo throwing techniques by using throwing vector equipment to provide more critical primary data in the learning and training methods of the judo throwing technique.

Conclusion

In this study, we found that the horizontal rotation angle of the shoulder and pelvis of elite judo players was higher than amateur players indicating that the unbalanced movement was sufficiently performed, thereby resulting in a flexible rotation of the shoulder and pelvis. Additionally, appropriate rear flexion of the shoulder and pelvis facilitated pulling the opponent toward the body. The front tilt of the shoulder and pelvis allowed for the pulled opponent to be carried forward. Finally, despite the slight curvature of the hip joint, the sizable forward tilt of the shoulder and pelvis was determined to ensure the body was kept parallel to the opponent by pulling the opponent as close as required. Moreover, the heel was lifted to enable the body to lean forward more easily and to throw the opponent. The 3-D force magnitude and kinematic characteristic data from this study can be used as primary basic data to identify force and movement control during seoi-nage.

Declarations

Ethics Approval and Consent to Participate

The research was approved by the Institutional Review Board of Pukyong National University. And informed consent was obtained from each subject before participation in the experiment.
Consent for publication

Not applicable, no individual person's data.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare no conflict of interest.

Funding

None.

Authors’ contributions

SH Choi and YG Song designed the research study. SH and YG collect data and did statistical analysis. All authors wrote the manuscript. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript.

Acknowledgment

None.

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References


**Figures**
After fixing the judo vector equipment to the wall, the judo rubber tube is hung on the load cell hook to perform shoulder throw. The pulling force and direction are measured simultaneously.

**Figure 1**

Vector analysis device

**Figure 2**

Model diagram for each event
Figure 3

The kinematic variant diagram

A) Horizontal angle of rotation of the shoulder and pelvis; B) tilt angle of the shoulder and pelvis; C) angle of flexion-extension of the hip joint; D) angle of flexion-extension of the knee joint
Figure 4

Kinematic variables in seoi-nage (shoulder and pelvis)
Figure 5

Kinematic variables in seoi-nage (hip and knee)
Figure 6

The magnitude of force during maximum force appearance (absolute value, relative value)
Figure 7

Kinematic variables at the time of maximum force appearance (shoulder, pelvis)
Figure 8

Kinematic variables at the time of maximum force appearance (hip, knee)