# Influence of lower-limb muscle power-related variables on the *ippon-seoi-nage* of elite judokas

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# Influence of lower-limb muscle power-related variables on the *ippon-seoi-nage* of elite judokas

**Abstract**

This study investigated the influence of the lower-limb extension mechanical variables (strength variables) on the *ippon-seoi-nage* kinematic variables (technical variables) in elite judokas. Additionally, we studied the effect of performing *ippon-seoi-nage* with lower-limb flexion-extension action *vs.* without it, on the technical and strength variables, as well as on their relationship. Twenty-four male elite judokas were classified in two groups depending on the type of *ippon-seoi-nage* performed, i.e., with lower-limb flexion-extension action or without it. Mechanical outputs from an incremental loaded countermovement jump test were assessed, as well as kinematic variables transferred to the *uke* (person who is thrown) during an *ippon-seoi-nage* technique test. The strength parameters did not positively correlate with the technical ones, showing no transference between the variables studied. Furthermore, the judokas that performed the *ippon-seoi-nage* with lower-limb flexion-extension action presented lower times in the execution of the technique than the group that did not perform this action. Therefore, the transference from strength parameters to the performance of *ippon-seoi-nage* is not yet explained, even when considering different technical styles.

**Keywords:** *judo, ippon-seoi-nage, lower-limb muscle power.*

## Introduction

Judo is a grappling combat sport characterized by high-intensity intermittent efforts (Degoutte et al., 2003). The main goal of a judoka is either to throw the adversary on his back, hold him down on his back for 20 s, apply a joint lock or a strangulation technique (Miarka et al., 2014). To achieve this goal, the judoka must apply different judo techniques. These complex skills are categorized according to whether they are employed on the ground or standing, as well as according to how the body segments are used (Abalde-Amoedo & Pino-Juste, 2016; Gomes et al., 2017). In this regard, the *ippon-seoi-nage* is one of the throwing techniques most used in judo (Carratalá et al., 2009; Ishii, Ae, Suzuki, et al., 2018). Accordingly, it is the most analysed technique in the scientific literature (L. Blais et al., 2007; Imamura et al., 2006; Ishii, Ae, Suzuki, et al., 2018).

Descriptive kinematic analysis of judo throws can explain the motor skills used by athletes in order to improve the technical learning process (Gomes et al., 2017). Some authors have analysed judo techniques from a biomechanical perspective using tridimensional analysis via camera systems (L. Blais et al., 2007; Imamura et al., 2006; Ishii, Ae, Suzuki, et al., 2018). However, these results should be interpreted with caution due to the reduced size of the sample in most of the studies ($n < 10$), although it was of high quality. It is also worth noting that the camera systems used were highly expensive, not portable and recorded at a 250 Hz sampling rate, which is insufficient to analyse a technique performance of ~1.2 s. Moreover, considering that judokas should move high loads (the opponent's body mass), it is important to focus on the *uke*'s (person who is thrown) mechanical parameters, in addition to those related to the *tori* (person who throws). Indeed, the velocity and acceleration that *tori* is able to transmit to unbalance *uke* and throw is a fundamental parameter (Imamura et al., 2006), and not only *tori*'s capacity to move his own body at high speed before colliding with *uke*. To date, only four studies analysed the *seoi-nage* kinematic parameters from this perspective (Almeida et al., 2018; Almeida et al., 2021; Imamura et al., 2006; Ishii & Michiyoshi, 2014). Additionally, although the lower-limb flexion-extension action has been considered a fundamental parameter in the performance of *ippon-seoi-nage* (Laurent Blais & Trilles, 2004; Ishii & Ae, 2015; Ishii, Ae, Koshida, et al., 2018), only one study analysed the influence of strength parameters on the technical performance displaying no association between them (Almeida et al., 2018). Finally, no study endeavoured to explore the influence of the type of *ippon-seoi-nage* on this relationship, as well as the differences between the 2 main *ippon-seoi-nage* styles.

Therefore, the primary aim of this study was to analyse the influence of the lower-limb extension mechanical variables on the *ippon-seoi-nage* kinematic variables in elite judokas. Additionally, we aimed to compare the effect of *ippon-seoi-nage* style (with lower-limb flexion-extension action *vs.* without it) on the kinematic variables of the technique, on the lower-limb mechanical variables, as well as on their relationship. We hypothesized that: (1) the lower-limb mechanical variables would positively correlate with the *ippon-seoi-nage* kinematic variables and (2) this association would be stronger in the group that performed the *ippon-seoi-nage* with lower-limb flexion-extension action; furthermore, (3) the *ippon-seoi-nage* kinematic variables would improve when the technique includes a lower-limb flexion-extension action.

## Materials and methods

### *Experimental approach to the problem*

We employed a cross-sectional design to assess the relationship between the *ippon-seoi-nage* kinematic variables and the lower-limb mechanical variables in elite judokas (McKay et al., 2022). Furthermore, we compared the effect of performing *ippon-seoi-nage* with two different styles (i.e., with lower-limb flexion-extension action *vs.* without it) on the *ippon-seoi-nage* kinematic variables, on the lower-limb mechanical variables and on their relationship. Participants were classified in two groups depending on the type of *ippon-seoi-nage* performed, i.e., with lower-limb flexion-extension action ($n$ = 14) or without it ($n$ = 10).

### *Subjects*

Twenty-four male elite judokas (McKay et al., 2022) from the High-Performance Centre of Valencia (age: 22.04 ± 3.18 years; body mass: 84.54 ± 19.17 kg; height: 179.36 ± 9.84 cm; fat percentage: 11.83 ± 3.28%; relative one repetition maximum [1RM] in the half squat: 1.86 ± 0.27 $kg.kg^{-1}$ of body mass) participated in this study. All participants had experience in the loaded countermovement jump, as well as in the specific protocol used in this study. They had been practicing judo for at least 10 years and all had attained the rank of black belt (from first to third Dan). All participants had been medallists in the junior or senior National Championships in Spain, Dominican Republic, or Georgia; eight of them in junior or senior European Cups; four in Continental Opens; one in Grand Prix; two in junior Continental Championships; and one in junior World Championships. All participants self-reported no chronic diseases or recent injuries that might compromise performance.

Participants were instructed to avoid any strenuous exercise for a minimum of two days preceding the testing sessions. They were informed about the study protocol and signed a written informed consent form prior to investigation. The study protocol was approved by the university Institutional Review Board (approval number 453/CEIH/2017) and was carried out in accordance with the Declaration of Helsinki.

***Procedures***

*Countermovement jump test*

After a 10-min standardized warm-up (jogging, dynamic stretching, joint mobility exercises, unloaded countermovement jumps, and 5 countermovement jumps loaded with 20 kg), participants undertook an incremental loaded countermovement jump test. The protocol consisted of 2 repetitions per each loading condition (20, 40, 60 and 80 kg), separated by 1 min of rest between repetitions with the same load and 3 min between each loading condition. A complete description of the countermovement jump technique can be found elsewhere (Almeida et al., 2018). The test was performed in a Smith machine (Multipower Fitness Line, Peroga, Murcia, Spain) with a linear velocity transducer (T-Force System, Ergotech, Murcia, Spain) at 1000 Hz sampling rate attached to the bar. The peak velocity and the mean propulsive velocity of each jump were recorded. The repetition with the highest peak velocity of each load was selected and used for analysis. The relationship between load displaced and peak velocity was established through a linear regression (load-velocity relationship) and subsequently the peak velocity associated to the load displacement equivalent to the 25, 50, 75 and 100% of the judoka's body mass was calculated. The 1RM was considered as the absolute load linked to a mean propulsive velocity of 0.33 $m \cdot s^{-1}$ obtained from the individual load-velocity relationship (Conceição et al., 2016; Loturco et al., 2016). Afterwards, the 1RM relative to body mass (kg·kg$^{-1}$ BM) was calculated. Test-retest reliability of this test has been previously reported (García-Ramos et al., 2017). Simultaneously, Samozino's method (Samozino et al., 2008) was used to assess the mechanical outputs under the above mentioned four individual loading conditions, plus a loading condition of 0.2 kg (free jump with a plastic bar to maintain the same body position). For this, countermovement jump height was estimated from the flight time collected by an infrared platform (Optojump, Microgate, Bolzano, Italy) at a 1000 Hz sampling rate. All jumps were monitored to ensure that the assumptions of the flight-time method were met (Linthorne, 2001). The highest of the 2 jumps was selected and used for analysis. The countermovement jump height with 0.2 kg was considered the jumping performance. The mean values of force and velocity at each loading condition were calculated from the equations proposed by Samozino et al. (2008) and validated for the countermovement jump (Jiménez-Reyes et al., 2017). Test-retest reliability of this test has been previously reported (Jiménez-Reyes et al., 2017). Afterwards, these mean values were used to assess the current force-velocity relationship and the associated maximum theoretical force ($F_0$, force-axis intercept), velocity ($V_0$, velocity-axis intercept) and power ($P_{max}= F_0 \cdot V_0/4$) values through a linear regression. A specific spreadsheet based on the equations proposed by Samozino et al. (2008) for squat jump and validated for the countermovement jump by Jiménez-Reyes et al. (2017) was used for all calculations (Morin & Samozino, 2017). The data were checked to ensure they met the assumptions of least squares regressions before fitting any relationship.

*Ippon-seoi-nage test*

Participants performed a specific warm-up (5 *ippon-seoi-nage* repetitions) to prepare for the technique test. During the warm-up and the technique test, participants used a dummy as an *uke* (57 kg of mass) to ensure stable execution conditions during all the assessments. The technique test began after 3 min of rest and included 3 repetitions of the *ippon-seoi-nage* with 1 min of rest between attempts. A complete description of the *ippon-seoi-nage* is provided elsewhere (Almeida et al., 2018). Kinematic variables transferred to the *uke* during the *ippon-seoi-nage* technique test were assessed by using a wearable sensor (Wimu, Realtrack System, Almería, Spain) placed on the back of the dummy. The sensor was fixed with a belt at waist height. This placement was considered as the centre of mass and ensured that the sensor was protected from direct impact from the judoka or the floor. The device analysed acceleration (G) and angular velocity (rad·s$^{-1}$) in the three axes ($x$ or longitudinal axis, $y$ or transversal axis and $z$ or anterior-posterior axis) at a 1000 Hz sampling rate (Figure 1). The beginning of the repetition was defined as the time when the dummy started to become unbalanced (*i.e.*, the angular velocity in the $y$ axis deviates from the baseline with a permanent change of at least 50 ms). Three peaks of the resultant acceleration (AccelT) were determined, the first related to the off-balance (Peak1_accelT), the second to the judoka's leg extension (Peak2_accelT) and the third to the dummy's impact on the ground (Peak3_accelT) (Figure 1A). In addition, three peaks of the resultant angular velocity (GyroT) were assessed, the first related to pulling the dummy off balance (Peak1_gyroT), the second to the dummy's flight over the *tori* (Peak2_gyroT) and the third to the end of the repetition (Peak3_gyroT). Lastly, the inflection point on the angular velocity of the $y$ axis normalized (GyroYnormalized) was assessed and associated to the dummy's horizontal position (Figure 1B). The studied variables were organized as (1) time variables (T): time to reach the first, second and third peak of the resultant acceleration (Tpeak1_accelT, Tpeak2_accelT and Tpeak3_accelT, respectively), and of the resultant angular velocity (Tpeak1_gyroT, Tpeak2_gyroT and Tpeak3_gyroT, respectively) and time to reach the dummy's horizontal position (Thor); (2) acceleration variables: values of resultant acceleration in the first (Max1_accelT), second (Max2_accelT) and third (Max3_accelT) peaks; and (3) angular variables: values of resultant angular velocity in the first (Max1_gyroT), second (Max2_gyroT) and third (Max3_gyroT) peaks. A video camera, Casio EX-F1 (Tokyo, Japan), was used to record the technical testing sessions at a 250 Hz sampling rate. Two experienced coaches rated the 3 *ippon-seoi-nage* repetitions based on the technical model approach of the Kodokan School (Daigo, 2005), displaying a high interrater reliability (ICC = 0.84; 90% CI: 0.67, 0.92). The two best repetitions were selected for motion and reliability analysis. Afterwards the repetition with the quickest time to reach the dummy's horizontal position was chosen as the best repetition for analysis. Finally, the best *ippon-seoi-nage* was classified by three experienced coaches according to the presence or not of a lower-limb flexion-extension action (ICC = 0.82; 90% CI: 0.68, 0.91).

***Statistical analyses***

Data are presented as mean and SD. Between-repetition reliability of the *ippon-seoi-nage* kinematic variables was assessed by the within-subjects coefficient of variation (CV) and intra-class correlation coefficient (ICC) with their respective 95% compatibility intervals (CIs). Additionally, the individual CV was also calculated for each variable. An acceptable variability was defined as a CV < 15% and an ICC > 0.70 (Haff et al., 2015).

For each outcome, an independent-samples T test was created to compare the effect of performing *ippon-seoi-nage* with lower-limb flexion-extension action *vs.* without it. This model was built for the technical variables and lower-limb mechanical variables. We calculated the between-group difference with 90% CIs using the bias-corrected and accelerated bootstrap with 2000 replicates, resampled on the subject level (Davison & Hinkley, 1997). To complement the inferential statistics, Hedges' g effect sizes (ES) were calculated by dividing the between-group difference by the pooled baseline standard deviations adjusted to the sample size of each group.

Correlation analysis between the *ippon-seoi-nage* kinematic variables and the lower-limb mechanical variables was assessed through a Pearson correlation coefficient (*r*). Predictions for the *ippon-seoi-nage* performance were estimated from the technique type, height and strength variables through multiple linear regression models using a manual stepwise approach. P-value and coefficient of determination ($R^2$) were used to assess the prediction models.

The reliability analysis was performed by means of a custom spreadsheet (Hopkins, 2000). SPSS software version 28.0 (IBM SPSS, Chicago, IL, USA) was used for all the other analyses.

## Results

### *Reliability*

Table 1 shows the reliability of the *ippon-seoi-nage* kinematic variables in the 2 studied groups, as well as considering all participants. All variables displayed a good individual reliability when all participants were considered that contrasted with a worse within-subjects reliability.

[Insert Table 1 near here]

***Comparisons***

Table 2 shows within-group descriptive statistics for the *ippon-seoi-nage* kinematic variables in both groups and the between-group differences and their respective CIs, p-values, and ES. The between-group effects for the *ippon-seoi-nage* times indicate lower times to perform the technique (i.e., a beneficial effect) in the group that performed the *ippon-seoi-nage* with the lower-limb flexion-extension action compared to the other group (ranging between -47 and -126 ms).

Likewise, the between-group effect for the angular velocity on the first peak (Max1_gyroT) also favoured the group that performed the *ippon-seoi-nage* with the lower-limb flexion-extension action (1.06 rad.$s^{-1}$; CI: 0.35, 1.77 rad.$s^{-1}$). No other notable differences were seen between groups, both in the kinematic variables of *ippon-seoi-nage* and in the lower-limb extension mechanical variables.

[Insert Table 2 near here]

***Correlations***

No significant positive correlations were found between the *ippon-seoi-nage* kinematic variables (Max2_accelT, Max2_gyroT and Thor) and the lower-limb mechanical variables (peak velocity, 1RM, jump height and variables from the force-velocity relationship) in both groups, as well as when all participants were considered.

***Multiple regression analysis***

Several multiple linear regression models were built to predict the time to horizontal position of the dummy (Thor), the acceleration (Max2_accelT) and the angular velocity (Max2_gyroT) on peak 2 (i.e., the technical performance) from all possible combinations between *ippon-seoi-nage* type, height, and the lower-limb mechanical variables. Results show that *ippon-seoi-nage* type contributed to explain 24% of the variance of the time to horizontal position of the dummy (Thor). The rest of the mechanical variables incorporated into the model hardly improve the prediction. 1RM and peak velocity have separately contributed to explain ~15% of the variance of the angular velocity on peak 2 (Max2_gyroT) (Table 3).

[Insert Table 3 near here]

**Discussion**

The primary aim of this study was to analyse the influence of the lower-limb extension mechanical variables (strength variables) on the *ippon-seoi-nage* kinematic variables (technical variables) in elite judokas. Additionally, we aimed to compare the effect of performing *ippon-seoi-nage* with lower-limb flexion-extension action *vs.* without it, on the technical and strength variables, as well as on their relationship. The strength parameters did not positively correlate with the technical ones, showing no transference between the variables studied. Furthermore, the judokas that performed the *ippon-seoi-nage* with lower-limb flexion-extension action presented lower times in the execution of the technique than the group that did not perform this action.

The relationship between strength variables and the *ippon-seoi-nage* performance has been scarcely investigated. Although the lower-limb extension action has been considered a fundamental parameter in the technical performance of *ippon-seoi-nage* (Laurent Blais & Trilles, 2004; Ishii & Ae, 2015; Ishii, Ae, Koshida, et al., 2018), no positive significant relationship was found between the strength variables and the acceleration or angular velocity transferred to the *uke.* This result is in accordance with a previous research (Almeida et al., 2018). There was no positive association even when only the participants that performed the *ippon-seoi-nage* with lower-limb flexion-extension action were considered. Moreover, 1RM and peak velocity were the only two strength variables that have contributed to explain the variance of the *ippon-seoi-nage* kinematic variables, but only for the angular velocity on peak 2 (Max2_gyroT), and only explained ~15% of the variance, regardless of the type of the *ippon-seoi-nage*. Judo techniques require high lower-limb muscle power (Bonitch-Domínguez et al., 2010) and a judoka should be capable of applying this power, especially during the lower-limb extension phase of the *ippon-seoi-nage* (represented in the movement sequence by the Peak2_accelT, Figure 1A). From a strictly technical point of view, the *ippon-seoi-nage* gold standard performance highlights the lower-limb extension action (Laurent Blais & Trilles, 2004; Ishii & Ae, 2015; Ishii, Ae, Koshida, et al., 2018). Consequently, from a mechanical point of view, strength variables should be positively linked to the acceleration and angular velocity in the peak 2 of this technique. However, this research failed to demonstrate this association. Although *ippon-seoi-nage* is a widespread technique, taught from early stages of training and consequently one of the techniques most used (Ishii, Ae, Suzuki, et al., 2018), the absence of association could indicate that, at least in the sample studied, the lower-limb implication during the *ippon-seoi-nage* was not sufficient according to the technical gold standard, even when considering only the judokas that performed the *ippon-seoi-nage* with lower-limb flexion-extension action. Several reasons for this can be outlined such as having initially learned an incorrect technique pattern, lacking lower-limb strength, or substituting part of the lower-limb action for actions of the arms, trunk, or the turn itself. Moreover, the presence of reliable individual adaptations of the technique to the participants' own characteristics can also affect the studied association.

Our findings provide evidence-based recommendations for teaching and training the *ippon-seoi-nage*. Ishi et al. (2018; 2018; 2014; 2016; 2013) found that a higher upper-limb angular velocity and a higher velocity in the sleeve pulling action (*hikite*), in the displacement of the centre of mass and in the hip action while throwing were determinant for the technical efficacy. However, these studies focused on the study of kinematic parameters of the *tori* and not on the capacity to transfer them to the *uke*, which is the main goal of a judo throw. In this sense, our study provide data about the angular velocity and acceleration that *tori* is able to transmit to unbalance *uke* and throw. This approach is becoming more extended in the last few years (Almeida et al., 2018; Almeida et al., 2021; Imamura et al., 2006; Ishii & Michiyoshi, 2014). Nevertheless, the present study is innovative because it differentiates between 2 types of *ippon-seoi-nage*. Although theoretically they are the same technique, the competition promoted the acquisition of 2 main different styles: *ippon-seoi-nage* with lower-limb flexion-extension action and without it. In this sense, our results suggest that to perform the first type of *ippon-seoi-nage* a high velocity of execution and a quick fit-in underneath the *uke*'s centre of mass to powerfully extend the lower-limbs should be prioritized, similarly to the description of *seoi-nage* made by Imamura et al. (2006). Contrary, the second type of *ippon-seoi-nage* is a much slower movement, where the judoka should prioritize the creation of a higher momentum prior to collision with *uke*'s centre of mass, to lift him, withdrawing his base of support, to subsequently turn and throw him. This type of technical performance resembles the *harai-goshi* description made by the same authors (Imamura et al., 2006).

Despite having divided the judokas in 2 groups according to their lower-limb action during the *ippon-seoi-nage*, there was still a low intra-group reliability. This seems to suggest that there may be more variations in the technical performance that interfere with the execution that we did not studied. Furthermore, the type of *ippon-seoi-nage* only predicts the time to horizontal position of the *uke* (Thor), explaining 24% of its variance. Contrary to what was expected, the inclusion of other variables related to the lower-limb power (jump height, peak velocity, 1RM, maximal theoretical power, velocity and force) hardly improve this predicting model (barely 1-2%). Moreover, as reported previously and also unexpectedly, the strength variables (1RM and peak velocity) only explained ~15% of the variance of the angular velocity on peak 2 (Max2_gyroT). The fact that the lower-limb power-related variables do not affect the predicting model (for Thor and Max2_accelT) or have a small contribution on the prediction (for Max2_gyroT) implies that there are other factors affecting them that we did not measure. Additionally, they did not worsen the prediction models, which means that they do not interfere with the technical performance in the terms it has been analysed.

Therefore, the transference from strength parameters to the performance of *ippon-seoi-nage* is not yet explained, even when considering different technical styles. Additionally, from a mechanical point of view the key difference between the 2 main *ippon-seoi-nage* styles concerns the times of execution. All these findings warrant the need to further study the kinematic parameters of the judo technique and its relationship with lower-limb muscle power to ultimately provide a better understanding of the factors that constitute a mechanically efficient throw.

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**Declaration of interest statement**

The authors have no conflicts of interest to disclose.

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**Figure captions**

Figure 1. Representation of the resultant acceleration (AccelT) (A), angular velocity in the three axes (GyroX, GyroY, and GyroZ) and resultant angular velocity (GyroT) (B) linked to the sequence of the *ippon-seoi-nage* performed by one judoka (C). Three landmarks of the AccelT (Peak1_accelT, Peak2_accelT, and Peak3_accelT) and of the GyroT (Peak1_gyroT, Peak2_gyroT, and Peak3_gyroT) are displayed. The beginning of the repetition (considering the baseline of the GyroY) and the dummy's horizontal position (represented by the inflection point on the GyroY normalized) are also displayed.