

Influence of judoka height when using the *seoi nage* technique

Influência da estatura do judoca na aplicação da técnica seoi nage

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Abstract – Judo techniques use the assumption of maximum efficiency with minimum energy expenditure, which means to try to use the strength of the opponent against himself, causing an imbalance that, associated with a technique, helps execute a throw. This study is aimed to evaluate the mechanical efficiency of the *seoi nage* technique applied to judokas (uke) of different heights in relation to the thrower (tori). The knee and trunk angular variation of tori was compared with the total throw time, the time to perform each phase of the technique, and the behavior and vertical variation of the trajectory of tori's center of mass (Δ CM). Ten throws using the *seoi nage* technique on three uke of shorter, equivalent, and taller statures compared to tori were cinematically analyzed. The images were recorded at 180 Hz using the Peak Motus System. The data was analyzed by descriptive statistics, ANOVA, and Tukey's post-hoc ($p < 0.05$). The tori's mechanical efficiency was greater when throwing a uke of a stature taller or of his same height, while the total throw time was shorter for a taller uke. The Δ CM of the tori was greater to throw a uke of a shorter stature. The conclusion is that the *seoi nage* technique is most effective when applied against opponents of heights equal to or taller than the tori.

Key words: Body height; Judo; Kinematics.

Resumo – As técnicas do judô usam o pressuposto da máxima eficiência com o mínimo dispêndio de energia, ou seja, buscam usar a força do oponente contra ele mesmo, causando um desequilíbrio que, associado a uma técnica de arremesso, facilita a aplicação da mesma. Este estudo objetivou avaliar a eficiência mecânica da técnica *seoi nage* aplicada em oponentes (uke) de diferentes estaturas em relação ao executante (tori). Foram comparados a variação angular do joelho e do tronco do tori, o tempo total de projeção, o tempo de cada fase de aplicação da técnica e o comportamento e a variação vertical da trajetória do centro de massa (Δ CM) do tori. Foi realizada a análise cinemática de 10 projeções da técnica *seoi nage* com uke de estaturas menor, equivalente e maior que a do tori. As imagens foram adquiridas a 180 Hz, utilizando-se o Sistema Peak Motus. Para o tratamento dos dados, utilizaram-se estatística descritiva e ANOVA com post-hoc de Tukey ($p < 0,05$). Houve maior eficiência mecânica do tori ao projetar o uke de estatura maior e equivalente a sua; o tempo total de projeção foi menor para o uke mais alto; o Δ CM do tori foi maior para projetar uke de menor estatura. Conclui-se que a técnica *seoi nage* é mais eficiente quando aplicada contra oponentes com estaturas equivalentes ou maiores que a do tori.

Palavras-chave: Cinemática; Estatura corporal; Judô.

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INTRODUCTION

Judo is a Japanese martial art whose word can be translated as “gentle way”. Several techniques from different sources are used, and the throwing ones are the primary means for obtaining victory or continuing the work on the mat. These techniques were developed to be applied using the Seiryoku-Zenyo principle, which means better efficiency with less energy expenditure¹. However, several factors influence the choice of the technique and they can be better applied depending on the anthropometric characteristics of the opponent and used more effectively with the application of forces.

However, little research is done on the biomechanical efficiency of judo's throwing techniques, especially with regard to the implications of the body's proportions. Although literature indicates that the anthropometric characteristics of the individual may help or hinder the execution of certain moves², even so few judokas choose their technique of preference (tokui waza) depending on their own physical structure or because it is appropriate considering the physical structure of their opponent³, but because of their admiration or ease of execution in training⁴.

It is worth pointing out that throwing techniques can be executed using the hand (te waza), the foot (ashi waza), the hip (koshi waza), or sacrifice techniques (sutemi waza), meaning that it is necessary to fall in order to throw the opponent. Each of these groups of techniques, depending on the group, require different skills and involve more than a certain body segment¹. Thus, the biomechanical efficiency of a technique is directly related to the biotype of the judoka and considering the use of levers, momentum, and torque². Therefore, for techniques using the hip as support, the judoka making the throw (tori) who has a proportionately larger trunk than the lower limbs, would be able to produce more torque, using less effort and causing more rotation speed of the opponent (uke)⁵.

The few studies that have investigated the mechanical efficiency of judo techniques were those done by Melo et al.⁵ and Melo et al.⁶ In the first, the authors investigated the throwing characteristics of a hip technique greatly used in judo competitions, the harai goshi, and found a higher mechanical efficiency in angular displacement and a shorter throw time of the tori when throwing a uke taller than him. In the second, the same parameters were investigated for a leg technique, the soto gari, and a better efficiency of application for this technique was obtained when throwing a uke shorter than the tori.

Therefore, since the efficiency of a technique is also dependent on the biotype of the opponent judokas (tori and uke), this study was done with the general objective of evaluating the mechanical efficiency of the seoi nage technique applied to judokas of different heights. The specific objective was as follows: characterize and compare the angular variation ($\Delta\theta$) of the knee, hip, and trunk of the tori during the phases of fitting (tsukuri) and falling (kake); characterize and compare the time to perform each one of the different stages of the technique (balance break or kuzushi, fitting, and falling);

as well as characterize and compare the vertical trajectory displacement of the center of mass (ΔCM) of tori when throwing an uke of different heights.

METHODS

For this descriptive study, four male judokas (one tori and three uke) were investigated who were selected intentionally with at least 10 years of practice, black belts, one tori 25 years old with 14 years of practice, 78 kg. and 1.71 m tall, and three uke: one shorter (1.66 m) than the tori, 30 years old with 16 years of practice, 62 kg.; another of an equivalent height (1.74 m) of the tori, 22 years old with 12 years of practice, 78.6 kg; and another taller (1.84 m) than the tori, 23 years old with 13 years of practice, 81.7 kg. All reported not having any injuries in the last six months prior to the study.

The following procedures were adopted once the project was approved by the Research Ethics Committee of the University of the State of Santa Catarina, process 021/06, and the term of free and informed consent was signed by the subjects: a) calibration of the Peak Motus system using the standard calibrator manufactured by Peak Performance Inc., which consists of a structure with eight rods and 25 control points; b) demarcation of the articular axes with reflecting sticker markers between 0.3 and 0.5 cm stuck directly on the skin of the subjects in the following places: right and left temporomandibular joint, 4.9 cm from the distal top corner of the right and left acromion, 1.1 cm from the proximal side slit of the proximal joint on the right and left elbow, 1.1 cm from the distal point of the right and left radial styloid process, 0.3 cm from the distal tip of the right and left trochanter, 2.6 cm from the proximal slit of the joint on the right and left knee, and 1.3 cm from the distal point of the medial malleolus, heel, and head of the third metatarsal; c) after warm-up, the images were captured at 180 Hz of 10 valid repetitions of the seoi nage technique using four video cameras integrated into the Peak Motus System, which also was used to process the data; d) cutting, synchronization, and digitalization of the images according to the three-dimensional reconstruction method DLT (Direct Linear Transformation); e) filtering the data using a Butterworth filter of a third-order; f) determination of the events characteristic of the technique for classification of the balance break (kusushi), fitting (tsukuri), and falling (kake); g) calculation of the values of angular displacement, velocities, and linear accelerations on the axes x, y, z, and exportation of the values of the variables to the Origin 6.0 program for interpolating and normalizing the data by the time in % of the technique and in its respective phases of kusushi, tsukuri, and kake; h) selection of the angular variables of study: maximum extension/flexion angle of the trunk (a); maximum flexion/extension angle of the right knee (attack) (MFARK/MEARK), maximum flexion/extension angle of the left knee (support) (MFALK/MEALK), and the absolute maximum flexion/extension angle of the trunk (MFAT/MEAT) with respect to the vertical line; i) determining the variation of the vertical displacement of the center of mass (ΔCM) for three heights.

Descriptive statistics and one-way ANOVA was used for the characterization of the data in order to compare the variation of the $\Delta\theta$, of the time spent for performing each of the phases, the total time between ΔCM followed by the Tukey's post-hoc test ($p \leq 0.05$).

RESULTS

Preliminarily, the $\Delta\theta$ of the knee, hip, and trunk of tori when throwing uke of different heights in comparison to him was compared in the phases of fitting and falling. The results of these comparisons are presented in table 1.

Table 1. Comparison of the intersegment angular variations ($\Delta\theta$) of tori during the fitting and falling of the seoi nage technique on uke of different heights

Variable	Phase	Height	$\overline{\Delta\theta} \pm dp$ (degrees)	F	p
MFARK	Fitting	Taller	91.41 \pm 1.18	4783.002	0.000
		Equivalent	87.88 \pm 0.71		
		Shorter	55.76 \pm 0.72		
MFALK	Fitting	Taller	88.06 \pm 0.83	1070.251	0.000
		Equivalent	89.22 \pm 0.98		
		Shorter	72.33 \pm 0.93		
MEAT	Fitting	Taller	4.23 \pm 0.57	12.003	0.000
		Equivalent	3.35 \pm 0.59		
		Shorter	4.50 \pm 0.49		
MEARK	Falling	Taller	141.87 \pm 1.03	355.246	0.000
		Equivalent	154.90 \pm 1.37		
		Shorter	155.05 \pm 1.38		
MEALK	Falling	Taller	151.49 \pm 0.90	995.747	0.000
		Equivalent	142.25 \pm 0.89		
		Shorter	160.60 \pm 1.97		
MFAT	Falling	Taller	80.43 \pm 1.05	2081.213	0.000
		Equivalent	79.60 \pm 0.70		
		Shorter	58.32 \pm 0.82		

MFARK/MEARK = maximum flexion/extension angle of the right knee (attack); MFALK/MEALK = maximum flexion/extension angle of the left knee (support); MFAT/MEAT = maximum flexion/extension angle of the trunk.

Table 1 shows that for all stages of execution, at least one of the heights of the angular values was different from the other body segments of tori. The following differences were identified after the post hoc Tukey analysis was carried out:

- for the fitting, the MFARK of tori was greater (55.76°) when throwing the shorter uke and smaller (91.41°) when throwing the uke taller than tori;
- for falling, the MFARK was smaller when throwing the taller uke (141.87°) in relation to the equivalent heights (154.90°) and shorter (155.05°) than tori;
- for the fitting, the MFALK of tori was greater (72.33°) when throwing the shorter uke than himself and smaller (89.22°) when throwing the taller uke;

- for the falling, the MFALK was greater (142.76°) when throwing the uke of an equivalent height and smaller (160.60°) when throwing the uke taller than tori;
- for the fitting, the MEAT of tori was smaller when throwing the uke of an equivalent height (3.35°) in relation to the taller (4.23°) and shorter tori (4.50°).
- for the falling phase, the MEAT of tori was smaller when throwing the shorter uke (58.32°) in relation to the equivalent heights (79.60°) and taller (80.43°) than tori;

After this, in order to meet the second specific objective, the execution times of each phase of the technique were compared as well as the total execution time against uke of three different heights (Table 2).

Table 2. Comparison of the times of each phase and the total time of the technique in three heights

Phase	Height	$\bar{t} \pm dp$ (s)	F	p
Balance break	Taller	0.33 ± 0.0054	4757.605	0.000
	Equivalent	0.31 ± 0.068		
	Shorter	0.54 ± 0.0054		
Fitting	Taller	0.51 ± 0.0125	79.642	0.000
	Equivalent	0.53 ± 0.0072		
	Shorter	0.44 ± 0.0067		
Falling	Taller	0.70 ± 0.046	518.359	0.000
	Equivalent	0.88 ± 0.0083		
	Shorter	1.12 ± 0.020		
Total time	Taller	1.70 ± 0.0082	34261.574	0.000
	Equivalent	2.26 ± 0.0063		
	Shorter	2.92 ± 0.0102		

When analyzing the comparisons (Table 2), the results showed that in both the execution time of each phase as well as in the total execution time there were significant differences during the throwing of uke of different heights in relation to tori. Some of the highlights were as follows once the post-analysis was completed:

- for the balance break, the time was shorter for throwing the uke of an equivalent height (0.31 s), but increasing for the taller uke (0.33 s) and for the shorter uke (0.54 s);
- for the fitting, the time was shorter for throwing the taller uke (0.51 s), but increasing for the uke of an equivalent height (0.53 s) and for the shorter uke (0.56 s);
- for the falling, the time was shorter for throwing the taller uke (0.70 s), but increasing for the uke of an equivalent height (0.88 s) and for the shorter uke (1.12 s);
- the total execution time was shorter for throwing the taller uke (1.54 s), followed by the uke of equivalent height (2.26 s) and then the shorter uke (2.33 s);

Finally, to reach the third specific objective, the behavior of the CM

(height and Δ CM) of tori was analyzed when throwing uke of different heights in relation to himself during the execution of the technique (figure 1).

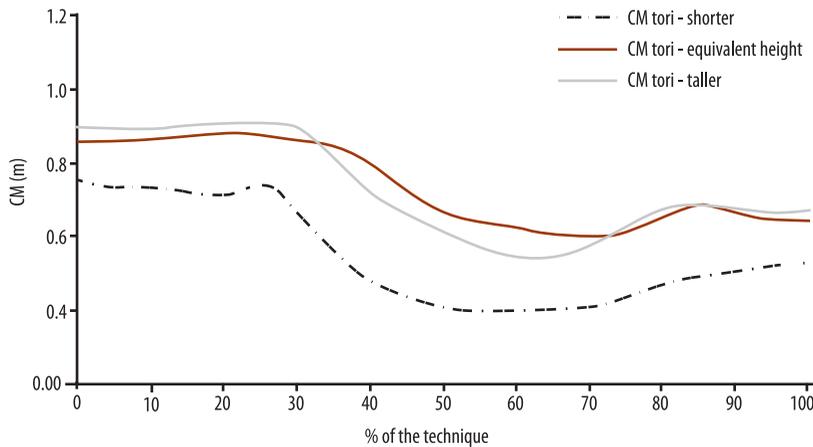


Figure 1. Behavior of tori's CM during the throwing of uke of different heights in the seoi nage technique.

The figure shows that the height of the tori's CM was similar when throwing an uke of equivalent statures and taller than himself, and lower when throwing a shorter uke. The Δ CM of tori was lower when throwing a taller uke than himself (0.25 ± 0.09 m), but there were no differences when throwing an uke of equivalent height (0.37 ± 0.015 m) and shorter (0.34 ± 0.017 m) than himself.

DISCUSSION

According to table 1, during the fitting stage, the tori had to have a greater knee flexion on both the right and left knee (MFARK and MFALK) when throwing a shorter uke, and a smaller flexion of the knees when throwing an uke of a similar height as his own. These results agree with Detanico et al⁷, Tegner¹ and Figueroa⁸ when they say that the techniques that use hip support require greater flexion of the knees than the others when keeping the trunk in a vertical position. Also in the seoi nage technique, the tori should put his waist line lower than the waist line of the uke and with this placing his CM lower than the uke's CM⁸. This means that in most throwing techniques, wider angular moments occur applied by the lower limbs and by the trunk than by the upper limbs⁹.

Melo et al.⁵ found similar results for the tori's maximum flexion angle of the knee during the fitting stage of throwing in the hip technique harai goshi and the flexion was greater (107.56°) to throw the shorter uke and smaller (131.84°) to throw the uke of an equivalent height as the tori. However, the same was not observed in the soto gari technique as this is a leg technique⁶.

The MEAT found in the fitting stage was smaller for throwing the uke of an equivalent height as tori. Judo's didactic literature postulates that, for the best quality when executing the seoi nage technique, the trunk should be

parallel with the trunk of the uke^{10,11}. Thus, the angle values of the trunk extension of tori should vary according to the opponent's stature, and this variation being smaller for an uke of similar height to tori, as observed in this study.

During the falling phase, the highest values of knee extension (MEARK and MEALK) of tori occurred when throwing a shorter uke. This result indicates a greater effort and greater articular amplitude of motion performed by tori considering that this position corresponds to lifting uke from the mat. According to Robert¹¹, a greater mechanical efficiency of the technique corresponds to a relatively smaller energy expenditure. This better use of the mechanical component of the gesture leads to an advantage in the individual's osteoarticular preservation because it prevents an excessive burden on these functional components⁴.

It was also observed in the falling stage that tori had a greater trunk flexion to throw uke higher. These results are similar to those obtained by Melo et al.⁵ when they found a greater flexion of the trunk to throw an uke taller than tori in the harai goshi technique. For this technique, seoi nage, the classic literature¹⁰ emphasizes the need for flexion movement of the trunk associated with the movement of knee extension in order to lift and throw the opponent who rolls over tori's shoulder. The greater flexion of the trunk in the final phase of throwing has the help of gravitational force, which reduces the effects of fatigue and overload in this region.

In summary, for the angular variables, the results of this study indicate greater mechanical advantage for tori when throwing ukes who are taller or of similar stature than themselves. Up until now, no other studies have been found about the throwing characteristics of the seoi nage technique in relation to the biotype of the opponents to compare with the results found in this study. Judo's didactic literature^{8,11,15} mentions only the movements considered fundamental for the throwing, such as the flexion of the knees during the fitting phase and trunk flexion forward during the falling phase. Other studies analyze the tori's CM during the throw in different throwing techniques¹² or during training and competition¹³ without mentioning or comparing the kinematic data of the technique performed on judokas of different heights.

In the variable of total execution time (Table 2) of the seoi nage technique, it was found that the tori took longer to throw an uke shorter than him. In the phases of balance break and falling, the throwing time was longer for the shorter uke and only in the fitting stage was the throwing time greater for the uke of an equivalent height and taller, most likely due to the greater body mass of these uke. These results were also confirmed by Melo et al.⁵ for the technique harai goshi, confirming what is presented in judo's descriptive literature that there is a greater ease in applying the seoi nage technique on opponents taller than the thrower¹¹.

Some authors emphasize the importance of carrying out the hip techniques with speed, but do not consider the different heights of the opponent^{7,14}. No studies were found relating the speed of application with the throwing efficiency of the technique in judokas of different statures, or even at different throwing stages and in different judo techniques, which

represents the need for research and information on these variables and their relation to the performance of judokas.

As for comparing the CM values, it was found that tori needed to get lower to be able to throw a shorter uke than him. However, the largest Δ CM occurred during the throws of uke of a height equivalent and taller than himself. Analogous results were obtained by Melo et al.⁵ in the harai goshi technique, confirming that the descriptive literature of judo mentions about the need for tori to position his trunk at a level that is lower than uke's to be able to perform the seoi nage and harai goshi techniques efficiently^{1,10,15}.

Among the few studies that consider the anthropometric characteristics, Lech et al.¹⁶ determined the relationship that exists between height and technique of preference used by judokas as observed in competitions over 518 fights conducted by 315 judokas, and obtained a moderate correlation between height and technique of preference: the hand techniques were dominant in shorter judokas (50.6%) and those of equivalent height (47.2%), while the taller judokas preferred leg techniques (32.0%). Similar results were found by other authors^{17,18}, which serve as foundations and justify the results found in this study. This means that the efficiency of the hip and hand throwing techniques, which have support at the hip, in this case the seoi nage, is greater when applied to a uke that is taller than the tori.

However, there is a lack of studies in the literature that investigate in more detail the behavior of tori's Δ CM in the different types of throwing techniques in judo, perhaps due to the complexity of kinematically analyzing this technique, which involves rotational movements of the trunk, leaning over before and after the rotation, vertical and anteroposterior dislocations, which are all performed simultaneously on three axes of spatial direction¹⁹.

CONCLUSIONS

Based on the results found in this study, it can be concluded that, of the six variables of angular amplitude related to the efficiency of applying the seoi nage technique, the best performance occurred when the tori threw the uke that was of an equivalent height (MFALK, MEAT, MEARK) or taller than himself (MFARK, MEALK). Only for MFAT was the application of the move most advantageous against a shorter uke.

The time to execute the throw of the seoi nage technique demonstrated a lower efficiency of tori to throw an uke shorter than him.

The largest Δ CM occurred when throwing a shorter uke, which shows that the seoi nage technique is biomechanically more efficient and indicated when applied against opponents that are taller or equal to the attacker's height.

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