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Defining the Influence of Fatigue Protocol on Kinematic Parameters of Ippon Seoi Nage

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Abstract: To achieve technical efficiency in a judo fight, it is necessary to know the technical details of each throw. The tempo of a judo fight is highly intense, and it is necessary for the competitor to be physically very well prepared. Considering the tempo, an important factor in the fight is the influence of fatigue, which can significantly affect the performance of a technique. The aim of this research is to determine the kinematic parameters and the influence of the fatigue protocol during the performance of ippon seoi nage (ISN) throw. The sample of participants consists of 30 young judokas (17.02 ± 0.91 year; 72.81 ± 6.52 kg; 178.60 ± 5.60 cm). The following variables were observed with Xsens Awinda kinematic system: the angle of the left shoulder (L_shou_A); the angle of the right shoulder (R_shou_A); the difference in the height of the pelvis in the tsukuri phase (Pel_tsu_H); the difference in the height of the pelvis in the kake phase (Pel_kake_H); hand velocity (Hand_V); head position (Head_pos). The participants performed three ISN throws before and after the fatigue protocol. A statistically significant difference (MANOVA) was found between the measurements ($F = 8.47$; $p = 0.00$). Additionally, observing the differences between individual variables (ANOVA), a significant difference was found in all measured variables, with a statistical significance of $p < 0.05$. This research presents key kinematic parameters that had not yet been observed in this manner. Furthermore, based on the established differences, it can be concluded that the participants significantly disrupt the performance of the ISN throw technique in situational, i.e., fight, conditions.

Keywords: hand throw; judo; kinematic analysis

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1. Introduction

Technical efficiency, in addition to conditioning, is an important factor for success in judo, a very complex sport of high intensity [1]. In order to overcome an opponent, a judoka must execute an offense technically correctly and quickly in order to score points and throw the opponent during a fight. Observing a fight structurally, by dividing it into a fight in a standing position and a fight in the parterre, most actions, offenses, and defenses take place in a standing position. Consequently, the highest points are achieved in a standing position by applying throwing techniques [2–5]. A large number of throwing techniques that a judoka can perform during a fight make this sport demanding and complex. However, research shows that certain throws are performed more often by judokas in fights. During a fight, after the kumikata, that is, grip fighting, the competitor tries to build a situation from which he will be able to launch an offense in order to overcome the opponent [6]. Since the tempo of the fight is highly intense, it is necessary for the competitor to be physically very well prepared. In situations where the fight between two judokas is tied, the result depends on who will be more affected by fatigue, while still being able to perform the throwing technique correctly [7,8]. Biomechanical analysis contributes to a better understanding of throwing techniques [9–14]. The aforementioned studies are focused on the analysis of throwing techniques by observing kinematic parameters, while a smaller number are focused on observing movement kinetics. This may be caused by the fact that it is currently very demanding to observe the elements of technique in situational conditions [12]. Furthermore, research focused on the study of kinematics (throwing techniques) has not yet proposed a biomechanical model, i.e., an ideal throwing model, or its modal values. There are multiple factors that contribute to this fact. One of the most important is that the assessment of the biomechanical characteristics of throwing techniques cannot be performed under real conditions. Instead, various systems have used, mainly cameras, markers, judo clothing (or lack of), and modified trainers under strictly controlled conditions [9–14]. Consequently, parameters that would contribute to a better understanding of judo throws cannot be detected or accurately measured. Given that judo consists of numerous elements, the need for a more exact definition of spatial and temporal parameters is becoming more and more important. The use of inertial sensors can make a significant contribution to observing a throwing technique [15]. The authors of [16] studied the uke's angular accelerations in the performance of the 'seoi nage' throw, while those of another study [17] determined the kinematic parameters of falls after the performance of the 'osoto gari' throw. In order for the tori to perform a successful throw, all phases must be completed precisely, quickly, and effectively. This creates the need to define the parameters or variables that most affect the effectiveness of a throw. Along with the correct performance of the throwing technique, an important factor in a fight is the influence of fatigue, which can significantly affect the performance of a technique. Research [18–20] confirms that fatigue significantly affects the performance of a technique of certain sports. Creatine kinase (CK) and lactate dehydrogenase (LDH) activities in plasma strongly reflect muscle injury, as proper biomarkers of muscle fibers disrupture. Furthermore, it was found that CK and LDH indicators increase significantly after a judo fight [21], and have a negative impact on motor abilities. Through segmental analysis of energy consumption, it was found that during the execution of the morote seoi nage throw, the lower extremities are activated the most, followed by the trunk and the upper extremities [22]. Fatigue due to the high intensity of the fight is an aggravating factor that can be alleviated by good conditioning preparation. The high demands of the fight require the judoka to apply a throwing technique when tired in order to either achieve a result or preserve the existing one, without receiving a penalty for inactivity, i.e., a shido. The definition of the parameters of individual elements of technique in judo, and the influence of different fatigue protocols that simulate situational conditions on these elements, need to be explained more clearly. It is also necessary to determine which factors change in the situational conditions of throwing. According to the authors of [23,24], ippon seoi nage (ISN) is one of the most frequently used throws in judo fights; therefore, it was selected as the focus of the here-presented research. This research aimed to determine the kinematic parameters and the influence of the fatigue protocol on the performance of ippon seoi nage throws.

2. Materials and Methods

2.1. Confirmation of the Ethics Committee

Prior to conducting the research, the participants were provided with detailed information about the measurement protocol, the benefits, and the risks of the research. Adult participants were asked to provide written consent for the testing procedure. For participants that were minors, their legal guardians provided consent for the measuring procedure and the use of personal data for scientific purposes. The research was approved by the Ethics Committee of the Faculty of Kinesiology, University of Zagreb, in accordance with the Declaration of Helsinki (Opinion No. 29/2021).

2.2. Participants

The sample of participants (Table 1) consisted of 30 youth judokas (17.02 ± 0.91 yr). With the use of G*power (v 3.1.9.2.) analysis, we calculated the total (N = 90) sample size (number of throws) required to conduct the study with error $p < 0.05$, statistical power of 0.8, effect size of 0.3, and with two measurements. The first inclusion criterion for the research was that participants must have at least a 3rd Kyu green belt degree and be actively competing. Regarding this criterion, participants had at least six years of active judo training and the following belt degrees: 3rd Kyu green belt (N = 5); 2nd Kyu blue belt (N = 9); 1st Kyu brown belt (N = 15), 1st dan black belt (N = 1). The second inclusion criterion for the study was health status (participants should not have had any musculoskeletal injuries in the past year). The participants were asked to avoid intensive activities two days prior to testing. Upon arrival, they were informed of the testing procedure, benefits, and risks during measurement. All judokas were right-handed and were throwing right ISN. Handedness was defined by the hand that is used for writing and is dominant in judo throws. Judokas were of different weight categories (60 kg-N = 1, 66 kg-N = 5, 73 kg-N = 12, 81 kg-N = 11, 90 kg-N = 1) and throws were performed with a uke from the same weight category. Based on previous experience of the participants and skilled performance of ISN, similar weight categories included in the research would not affect the presented results.

Table 1. Basic descriptive statistics of the participants (n = 30).

	N	Mean	Min	Max	St. Dev.
Weight (kg)	30	72.81	58.7	83.9	6.52
Height (cm)	30	178.6	169.6	190.6	5.6
Age (year)	30	17.02	15.11	18.6	0.91

2.3. Measurement Protocol

The measurement protocol begins with the definition of basic anthropometric characteristics and measurements necessary for the calibration of the kinematic system. The participant is then fitted with a kinematic suit, and the standardized warm-up protocol begins. The protocol consists of general preparatory exercises that include all parts of the body, ukemi waza (falls), and three methodical exercises: uchi komi, pushi gari, and nage komi (the studied throwing techniques). At the end of the warm-up, body and space calibration is carried out according to the previously defined protocol. The measurement and fatigue protocol were supervised by an expert laboratory researcher and the head of research. Testing was performed from 9–12 AM for 10 consecutive days (three participants per day) in the Judo hall at the Faculty of Kinesiology, University of Zagreb. Furthermore, the subject begins with the performance of ippon seoi nage (ISN) by throwing (Figure 1). Three consecutive throws are performed, with a pause between the throws lasting until the uke is raised and the starting position of the throw is taken. Upon completion of the initial set of throws, the tori performs the fatigue protocol. Immediately upon completion of the fatigue protocol, three consecutive ISN throws are again performed. The fatigue protocol consists of a 2 × 10-m shuttle run, at the end of which the participant performs two push-ups (Figure 1). This protocol is repeated for 10 cycles, and is used as measuring instrument to evaluate endurance in judo. After the 10th cycle, the examinee stands up and the test is ended. The total time required to perform the test is measured [25].

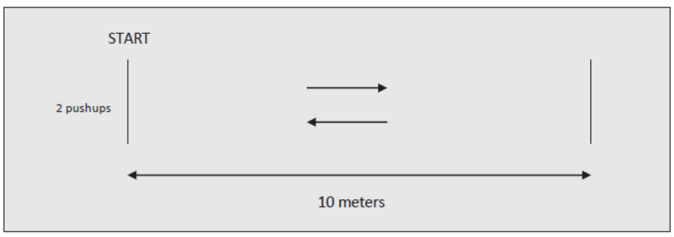

Figure 1. Specific endurance judo test [25].

The ISN throw was performed in place, without the uke's resistance (Figure 2). From the starting position (1), the tori moves forward with his foot. With both hands, he pulls the uke forward and up, breaking his balance (kuzushi, phase 1) (2). At the same time as he performs the kuzushi, the tori begins to perform the second phase of the tsukuri throw (3). Through the mae mawari sabaki movement, he turns his body 180 degrees and places it in the correct throwing position (tsukuri) (4). The final phase (5) of throwing (kake) follows, and it includes the uke's flight and the uke's control. The throw is finished (6) when the uke falls to the ground, while the tori must remain in a balanced position, and thus not fall forward (end of throw).

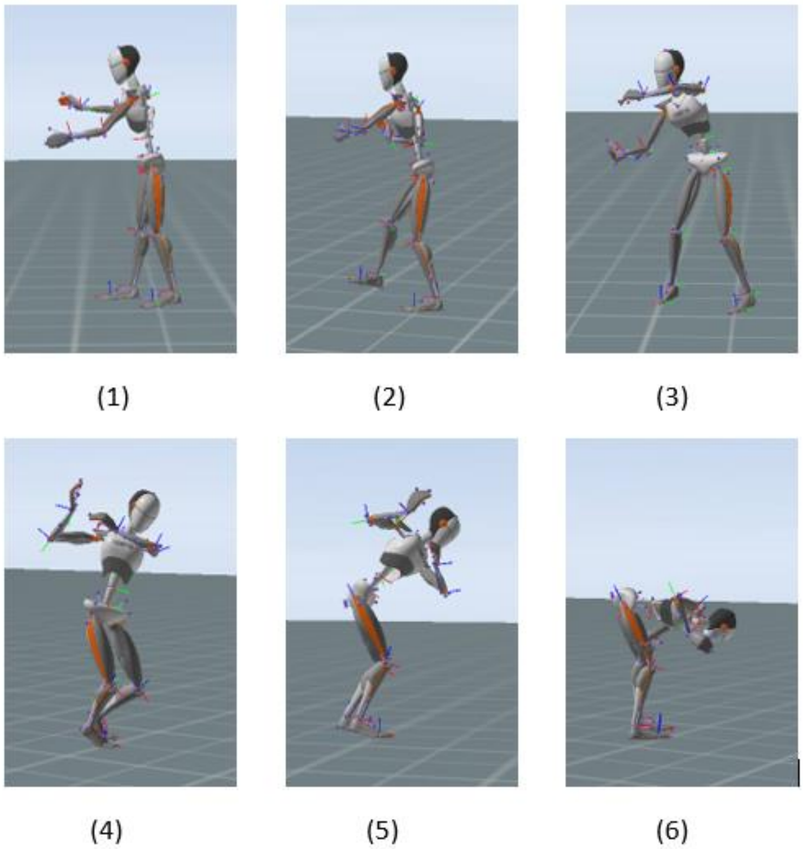

Figure 2. The performance of the ISN throw: (**1**) starting position; (**2**) kuzushi; (**3**) tsukuri; (**4**) tsukuri; (**5**) kake; (**6**) end of throw.

2.4. Materials

For the purposes of calibrating the system, i.e., the subjects and the measuring space, anthropometric characteristics were measured using a segmometer (Xsens MVN measuring tape), and a portable stadiometer (SECA 213). A TANITA scale (BC-545 n) was used to measure morphological characteristics (mass, fat tissue percentage, body mass index). Participants were instructed to stand barefoot on the scale with lower legs and thighs not touching. The skin and electrodes were precleared and dried before the measurement procedure [26]. The general measurement guidelines for bioelectrical impedance were followed [27]. A stopwatch (Witty Timer, Microgate, Bolzano, Italy) was used to measure the time required to perform the fatigue protocol, while a Polar H10 sensor connected to the Polar team application was used to measure the heart rate. The Xsens (Awinda, Enschede, Netherlands) kinematic system was used to observe the performance technique, i.e., the kinematic parameters of throwing (Xsens technologies BV, The Netherlands). Software package Xsens MVN ver. 2021.0. was used to process and analyze the measured parameters. Previous studies [28–30] confirm the reliability and validity (coefficient of multiple correlation > 0.96 for joint angle in flexion/extension) of the measurement system for observation and the possibility of its application in combat sports. Body and space calibration was carried out before the actual measurement procedure, according to a previously standardized protocol [31] provided by the manufacturer.

2.5. Variables

The kinematic parameters observed in the present research are the angle of the left shoulder (L_shou_A); the angle of the right shoulder (R_shou_A); the difference in the height of the pelvis in the tsukuri phase (Pel_tsu_H); the difference in the height of the pelvis in the kake phase (Pel_kake_H); hand velocity (Hand_V); head position (Head_pos). These variables were chosen as they present key factors in different phases of ISN throw.

Description of variables:

1. L_shou_A (°)—the phase of ejecting the uke from the balance position (abduction); the angle of the left shoulder represents the angle between the upper arm and the torso, which is achieved when pulling the uke's kimono sleeves in the kuzushi phase.
2. R_shou_A (°)—the phase of entering the throw and taking the optimal position for performing the throw (abduction): the angle of the right shoulder represents the angle between the upper arm and the tori's torso, which is present in the final phase of tsukuri, in which the right upper arm is placed under the uke's upper arm and ensures that the next phase of the throw is performed with complete control and high speed.
3. Pel_tsu_H (cm)—The difference in the height of the pelvis from the initial position to the final point of tsukuri, i.e., the moment when the pelvis is at its lowest point, and before the beginning of the upward lift, i.e., the beginning of the kake phase.
4. Pel_kake_H (cm)—the difference in the height of the pelvis from the lowest position in the tsukuri phase to the end of the throw (contact of the uke's body with the mat).
5. Hand_V (m/s)—maximum speed of the hand during the throwing phase.
6. Head_pos (cm)—the difference in the position of the head during the throwing phase (from the lowest position during the entry into the throw to the end of the throwing phase (kake))

2.6. Data Processing Methods

The Statistica v.14.0.0. (TIBCO software Inc.) software package was used for statistical data processing. The Shapiro–Wilk test was used to determine normality of distribution. Basic descriptive parameters (mean, minimum, maximum, and standard deviation) were calculated for all observed variables. Multivariate analysis (MANOVA) for repeated measures was used to determine difference between groups, and ANOVA for repeated measures was used to observe changes in variables. A total of 90 throws were observed before and after the fatigue protocol.

3. Results

The results of the basic descriptive indicators of ISN throwing before and after the fatigue protocol are presented in Table 2. During the implementation of the fatigue protocol, the average values of the heart rate (HR) were 188.17 ± 7.24 (Min = 177; Max = 202). The average results in the fatigue test were 86.16 s ± 5.26 s (Min = 78.70 s; Max = 100.91 s).

Table 3 shows the differences between the observed groups, that is, the kinematic parameters of the ISN throwing performance before and after the fatigue protocol. Significant differences were found between the observed groups ($F = 8.47$; $p = 0.00$). Considering the statistical significance of the differences, univariate analysis of variance was used to observe the differences between individual variables (Table 4). The statistical significance of the differences was determined in all the presented variables.

Table 2. Basic descriptive indicators of the observed kinematic parameters during the performance of the ISN throw.

	Protocol	N	Mean	Minimum	Maximum	St. Dev.
L_shou_A	Pre	90	29.92	3.36	57.23	14.02
	Post	90	19.76	−20.89	58.79	17.31
R_shou_A	Pre	90	44.89	14.68	88.21	16.81
	Post	90	37.65	13.04	76.24	15.10

Table 2. *Cont.*

	Protocol	N	Mean	Minimum	Maximum	St. Dev.
Pel_tsu_H	Pre	90	14.80	6.12	29.50	4.62
	Post	90	11.93	1.46	21.49	4.34
Pel_kake_H	Pre	90	12.60	−3.24	26.74	6.02
	Post	90	9.84	−2.58	22.72	5.21
Hand_V	Pre	90	3.37	1.91	5.47	0.88
	Post	90	2.45	0.55	5.82	1.30
Head_pos	Pre	90	65.02	25.79	84.44	10.94
	Post	90	68.87	39.10	104.07	13.25

Legend**:** **L_shou_A**—the angle of the left shoulder; **R_shou_A**—the angle of the right shoulder; **Pel_tsu_H**—difference in the height of the pelvis in the tsukuri phase; **Pel_kake_H**—difference in the height of the pelvis in the kake phase; **Hand_V**—hand velocity; **Head_pos**—head position.

Table 3. Results of MANOVA for repeated measures between the observed groups before and after the fatigue protocol.

	Test	Value	F	*p*	η^2
Group	Wilks	0.77	8.47	0.00 *	0.23

Legend: Value—Wilks' Lambda value; F—F value distribution; p—significance level; η^2—partial eta squared (measure of effect size). * Values are significant when $p < 0.05$.

Table 4. Results of ANOVA for repeated measurements for a single variable.

Dependent Variable	F	*p*
L_shou_A	18.73	0.00 *
R_shou_A	9.23	0.00 *
Pel_tsu_H	18.54	0.00 *
Pel_kake_H	10.76	0.00 *
Hand_V	30.85	0.00 *
Head_pos	4.52	0.03 *

Legend**:** **L_shou_A**—the angle of the left shoulder; **R_shou_A**—the angle of the right shoulder; **Pel_tsu_H**—difference in the height of the pelvis in the tsukuri phase; **Pel_kake_H**—difference in the height of the pelvis in the kake phase; **Hand_V**—hand velocity; **Head_pos**—head position. * Values are significant when $p < 0.05$.

4. Discussion

This research aimed to determine the influence of the fatigue protocol on the performance of ISN throws. The main findings of the presented research comprise the changes in kinematic parameters under fatigue conditions. As these conditions are similar to specific situations in judo combat, the stated results highlight the importance of understanding how fatigue conditions affect the performance of an ISN throw.

Ippon seoi nage is a throw that requires a significant level of connection, speed, timeliness, and technical excellence from the tori, in order to effectively apply it in situational conditions. Compared to other throws (osoto gari, harai goshi), in ISN performance, the influence of the tori's force on the uke is reduced, and more of the tori's own abilities, such as speed and explosive power, are applied in order to take the ideal position for throwing the uke [9]. Consequently, there are several studies on the kinematics of ippon seoi nage throwing. The goal of this research was to determine how fatigue protocol affects the observed performance parameters of ippon seoi nage throwing in all phases. By comparing HR values (188.17 b/min) with the results of a judo fight (174–185 b/min) [32], it can be concluded that the fatigue protocol made it possible to simulate conditions, i.e., fatigue manifested during a fight. The kinematic parameter data show that there is a statistically significant difference in all observed variables when performing the ISN throw before and after the fatigue protocol. Therefore, it can be concluded that the observed kinematic parameters are significantly affected in the simulation of situational conditions. Since, as with most previous studies [9,14,20–23], the throw was performed without the resistance of the uke, it can be assumed that with his resistance, it would be even more difficult to maintain the observed parameters at an optimal level. A judo fight in senior and junior competition lasts four minutes, during which both fighters are significantly exhausted. A fighter who, despite being exhausted, manages to perform throwing techniques at a technically higher level will certainly have a lower expenditure of energy and, at the same time, be at an advantage over his opponent. A drop in skill level leads to a whole series of difficulties in the kinematic chain responsible for throwing. The authors of [33] proved that fatigue due to a competitive judo fight affects the kimono grip strength in the right and left hand, as well as during simulated judo fights, i.e., during training. Since it is important not to lose control over the uke's kimono grip throughout all three phases of performing the ISN throwing technique, it is important to understand the connection between fatigue, a drop in the level of ability, and the disruption of kinematic parameters in the performance of throwing. Furthermore, poor execution of the throw under the situational conditions can lead to injury. According to previous research [34], in top-level judokas, the highest number of injuries occur in a standing position during the competition (78.0%), of which 22.3% are inflicted on the tori during throw performance. In the ISN throw, the majority of injuries relate to lower body extremities [35]. We state that highly trained judoka able to conduct the technically correct performance of the ISN have reduced risk of injury. Regarding muscle injury during competition, recent findings have shown that (MMA) fighters already present tissue injury and initiated inflammatory processes at the end of a competition [36,37]. Therefore, complex (metabolic) fatigue, such as complicated physiological status, during competition could also affect the mechanics required for the perfect application of the ISN throw in judo matches.

Kinematic parameters should not be viewed in isolation, but as an interconnected kinematic chain that leads to a successful throw. Disturbance or poorer performance in one part entails the need for compensatory actions in another part of the kinematic chain, and with it the overall reduced efficiency of the throw itself. The variable L_shou_A indicates the angle of the shoulder that occurs in the kuzushi phase, and is important because it disrupts the opponent's balance. A larger angle of the shoulder means a stronger action of the tori's left hand and, at the same time, raising the uke's COM to a higher level, which will enable the tori to be placed in a better position in the tsukuri phase. In this case, the values of the observed variables R_shou_a and Pel_tsu_H will be higher. This indicates the tori's lower position in the tsukuri phase and points precisely to the correct principle of performing the ISN throw. After the fatigue protocol, the angle of both shoulders in the observed variables decreases. In some participants, it decreased so much that they did not use their left hand at all in the initial phase of throwing when the uke's balance was disturbed. Since the uke does not resist, it can be assumed that in a fight without such an action, i.e., a quality kuzushi, the tori would not be able to perform a quality tsukuri. Consequently, such an attempt would end without the possibility of performing the final phase of the kake throw, or even with the performance of a counter throw by the opponent.

Observing the results of the L_shou_a variable before and after the fatigue protocol, it is evident that the differences between the minimum and maximum values are greater after the protocol, indicating that the differences between the subjects are increasing. It seems that some participants still managed to maintain the size of the angle of the shoulder at a slightly better level even in a state of exhaustion, which is exactly what training should achieve—technical excellence even in the zone of high physiological load in combat. Similar findings have been reported by Ishii et al. [14], who assert that there are differences between different groups of judokas in shoulder rotation, observing it as the angle between the axis of the uke's left and right shoulders and the axis of the tori's left and right shoulders in the kuzuhi and tsukuri phases.

Pel_tsu_H indicates how far the tori has descended under the uke at the end of the tsukuri phase. It was observed that the parameters change significantly after the fatigue protocol (F = 18.54; p = 0.00), but also that there is a large range in the participants from the minimum to the maximum result. Ishii et al. [14] observed that better trained judokas have a greater knee angle in the tsukuri phase than weaker judokas. The greater angle of the knee observed in that research is in direct positive correlation with the observed variable Pel_tsu_H, i.e., both indicate how much the tori has dropped below the COM uke in the tsukuri phase.

According to Melo et al. [38], when performing the ISN throw, the easiest way to perform it on a uke either taller than the tori or his height. A difference in the angle of left and right knee flexion was observed in the tori with a taller partner or one of the same height compared to a shorter uke. In this research, the participants were divided into pairs according to height and weight, and they performed the throw against each other. Certain results indicate a higher value of the pelvis in the kake phase compared to the tsukuri phase, which is a consequence of fatigue or compensation of the body segments (the throw is performed entirely by moving the body forward and swinging the arms). Similar results were obtained by Immamura et al. [9] where it was observed that the COM goes up or stays in the same position in the majority of participants, and in some it went down. According to Blais et al. [22], during a seoi naga throw in the tsukuri and kake phase, due to the heavy load, the legs and torso are most energetically involved, while the arms are dominant in throwing off balance and performing the throwing technique. These results are justified since the tori enters the crouching position and then lifts the uke out of the crouching position and throws him over himself using the strength of his trunk and arms. It was observed that before the fatigue protocol, the tori lowers his pelvis (Pel_tsu_H) and uses more the moment of lifting the uke with the hips off the floor (Pel_kake_H) and the hand speed (Hand_V). He also moves less into a forward bend (Head_pos), and thus is less rational, faster, and uses his body segments more efficiently, while remaining in a balanced position after the throw. The importance of the head position (Head_pos) during the throw defines how much the tori moves the upper part of the body into a forward bend, from the tsukuri phase to the kake phase, and whether he uses more body or hand influence when throwing the uke. ISN is a hand throw, and it is assumed that during the kake phase, the explosive power and speed of the arm and shoulder girdle muscles will be used more. This will be manifested in the parameters of the hand speed variable. It has been observed that some participants (Head_poss max.) use too much forward bend when throwing. This can lead to falling forward, which can give the uke an opportunity to turn the fight in his favor after the transition to the ground with a counterattack. Other authors [19,39,40] have studied the speed of the general center of gravity of the body and concluded that in the kuzushi and tsukuri phases, better judokas have a higher COM speed. However, they did not observe whether there is an influence of fatigue on their performance. Ishii et al. [23] also studied the joint speed in the kuzushi and tsukuri phases in from-the-spot throws between judokas of different quality. They found that there is a difference in the speed of the hip and ankle, but not in the speed of the shoulder and hand. In the present research, the speed of the hand was studied in each phase, and it was determined how fatigue affected this variable. It is interesting that there is a greater range in the studied velocity after the fatigue protocol with a greater minimum and maximum value. Some participants used their trunk to a greater extent by bending forward and less hand speed, while some used less forward bending and used their arms more for throwing. These differences confirm the assumption that better judokas manage to maintain the level of their technical efficiency at a higher level even in the fatigue phase.

As this research mainly focused on the influence of fatigue protocol, the limitations of the study relate to the lack of physiological parameters observed in testing procedure. Fatigue protocol could be implemented via a simulated judo fight with additional physiological parameters, such as blood lactate, to obtain even better insight into the associations between fatigue and technique performance in judo. Additionally, the fact that the tori performs throws without the uke's resistance is a limiting factor to achieving more exact conclusions about the kinematically ideal throwing performance. Additionally, observing these parameters between high-level and low-level judokas would provide more detailed insight into the differences in relation to the level of technical excellence.

5. Conclusions

The analysis of the technique of individual elements in judo is extremely important for a clearer understanding of spatial-temporal phenomena. Furthermore, fatigue is one of the factors that significantly affects throwing performance. The aim of this research was to determine the negative effects under the influence of the fatigue protocol. This research presents the key kinematic parameters that have not, until now, been measured in this manner. Additionally, by observing these variables, it can be concluded that the participants significantly violate the technique of performing ISN throws under situational or fighting conditions. Therefore, it is necessary to focus on the throwing performance in the training process under conditions of similar physiological load as in a competitive fight. Further research in the field of kinematic analysis and the influence of fatigue, and that also includes female judokas, is necessary to understand changes in technical performance. Certainly, future research should consider the study of throwing in motion, that is, simulated combat conditions that are dynamic with various changes in the direction of movement.

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