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Structural Analysis of Action and Time in Sports: Judo

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Abstract

Judo is an intermittent sport. As such, it is important to characterize the actions involved in combat so that training may be structured in such a way as to simulate competitive demands. However, to do so, an objective notational analysis system is necessary. The aim of the present study was to design a computer program that would aid in the analysis of time structure of specific actions during judo combat and test its inter-evaluator and intra-evaluator reliability. Ten male judokas, divided by class and category, were evaluated during three combats each. The matches were filmed and the evaluators used the computer program Saats™ (Structural Analysis of Action and Time in Sports) to analyze the following actions: break, grip, technique, fall and groundwork. The sequences were characterized by the sum of actions between each break. A total of 276 action sequences were evaluated, with a mean of 11 action sequences per combat, with four on the ground. Two evaluations were carried out by three evaluators for each judo match (inter-evaluator agreement), with only one being an expert in the software used. There was a lack of similarities in the results of only two of the variables ($p < 0.05$). Evaluations by the same evaluator (intra-evaluator agreement) demonstrated a high reliability on all six variables. It was concluded that the use of this computer software for notational analysis in judo greatly assists in the detailing of actions performed by the athletes. The use of this software by professionals unfamiliar with it likely requires a short learning period. Knowledge of judo actions will very likely allow practitioners of the sport to be trained more specifically.

KEYWORDS: judo, notational analysis, software, time structure, combat, Saats™

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Introduction

Many sports involve activity patterns that are intermittent in nature. Sports such as soccer, basketball, handball and many combat sports are characterized by brief periods of maximal or near maximal effort interposed by periods of moderate to low-intensity activity in a fluctuating random fashion (Glaister, 2005). Judo has been characterized as a high-intensity intermittent combat sport (Franchini et al., 2009), consisting of many different techniques and actions during a match (Franchini et al., 2008). Previous studies described the effort to pause ratio in high-level judo competitions (Castarlenas and Planas, 1997; Sikorski et al., 1987; Malderen et al., 2006). In these studies a typical 2:1 or 3:1 effort to pause ratio were found. Specifically, they identified 20 to 30 seconds of effort interposed by approximately 10 seconds of pause. Although these studies presented important information concerning the time profile of a judo match, they did not offer details concerning the distribution of actions performed by the athletes during the effort period. Additionally, these studies did not present the reliability or the objectivity of the time measurements conducted. This approach, presenting the activity profile during the effort period, has been reported in studies analyzing other combat sports, like karate (Beneke et al., 2004; Iide et al., 2008), taekwondo (Matsushigue et al., 2009) and wrestling (Cipriano, 1993).

The quantitative analysis of team and player activity is now an important aspect of the coaching process in many sports (Barris and Button, 2008). A detailed description of the activity profile during intermittent sports has both technical-tactical and physiological applications. Concerning technical-tactical aspects, a training program could be improved by simulating the main occurrences during judo matches. From a physiological point of view, this information could help to establish a better understanding of the energy system contribution during a competition, which could be used to design more specific training programs to enhance performance during competitions (Aziz et al., 2002).

The ability of portable data recording and analysis systems in processing large amounts of information for motion tracking has improved in the last decade. This is greatly due to accuracy and precision improvements in equipment such as global positioning systems (GPS), high-speed video and accelerometers. These instruments are increasingly been used in the measurement and evaluation of sports and physical activity profiling (Barris and Button, 2008). However, as previously discussed, few studies were conducted with combat sports and only a small proportion of them reported the reliability and the objectivity of the notational analysis process. Inter-observer consistency is considered essential in establishing the reliability of motion analysis systems where the total time, frequency and mean duration of movements can exhibit large variations (Barris

and Button, 2008) as in combat sports, where actions can be as short as a few seconds (a judo throwing technique can be as short as 1.14s; Blais et al., 2007), while other actions can be as long as 25s (an *ippon* score is given when an athlete immobilizes his opponent during this time). Additionally, many actions are performed repeatedly during the match and no study has so far investigated the specific activities carried out during a judo match and the time structure of each combat. A simple, accessible method for evaluating the time structure of judo combat would enable greater understanding of the actions that occur during matches. A specific computer program would certainly help achieve these objectives in a simple, practical way and at low cost. Thus, the aim of the present study was to test the inter-evaluator and intra-evaluator reliability of a computer program specifically designed to assist in the analysis of judo matches.

Material and methods

Sample: Ten male judokas between 18 and 32 years of age (23 ± 4) participated in the study and were characterized by weight category. Each judoka participated in three combats. All athletes signed a terms of informed consent form and the study received approval from the ethics committee of the Federal University of Sao Paulo (Brazil).

Inclusion criteria: Affiliates of the Sao Paulo State Federation of Judo; being healthy; uninterrupted training for at least five years; black belt ranking in judo.

Exclusion criterion: Non-acceptance of signing the term of consent.

Combat analysis: The matches were carried out with adaptations from an official competition. The athletes were divided into groups according to their body mass (commonly denominated weight category). All participants took part in three matches. Each athlete took a 20-minute interval between matches.

The matches were filmed using a high resolution digital camera system. Activities were analyzed by qualified evaluators all having a minimal belt rank of *Shodan* (black belt) using Saats™ (Structural Analysis of Action and Time in Sports), a computer program specifically designed for this purpose. For a more detailed analysis of the actions of the athlete during the prescribed period of activity, a temporal structure of specific actions was identified. Evaluators considered the following actions during the matches:

1) *Break* – a period of interruption, when the referee calls *Matte* to discontinue any activity of the judoka;

2) *Preparation* – a period of movement, observation and non-contact preparation;

3) *Grip* – a period of the match in which the judoka disputes for the best grip (*Kumi-kata*), when there is contact with one or both hands;

4) *Technique* – a period in which the judoka executes a technique or throw during standing combat (*Tachi-waza*);

5) *Fall* – the moment of the fall (*Kake*) when the analyzed athlete falls to the ground being possible that both judokas fall as a result of the application of *technique*.

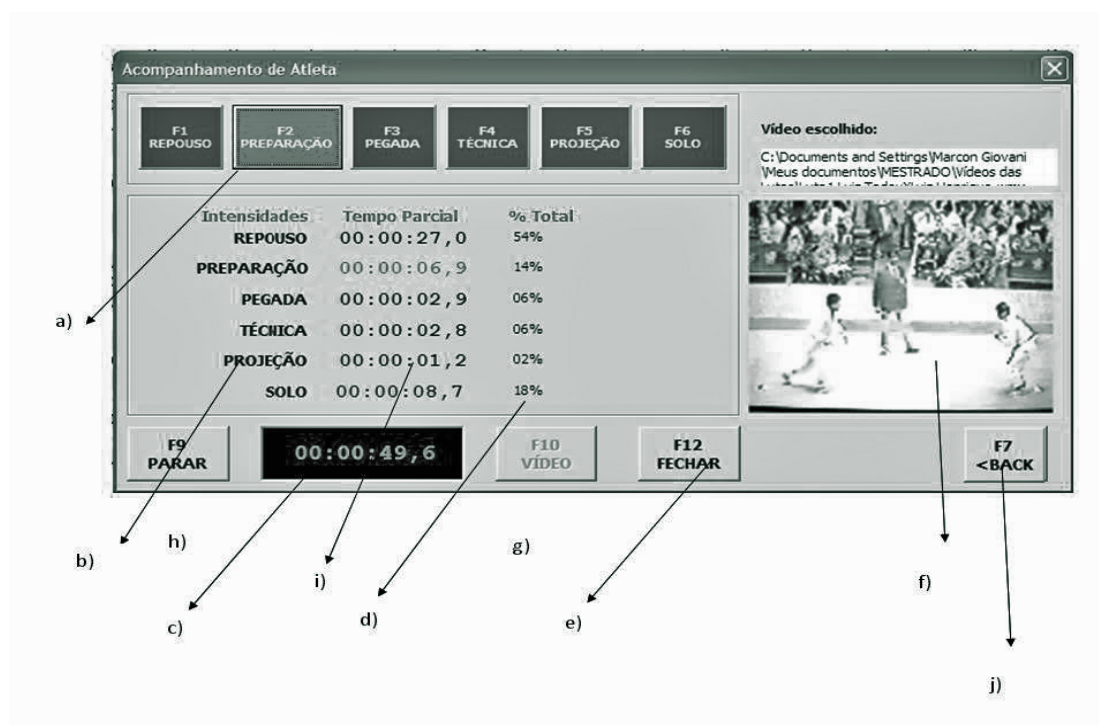
6) *Groundwork* – any combat that takes place on the ground (*Ne-waza*), when strangle or arm-lock techniques are applied with the aim of immobilizing or finalizing an opponent.

Matches were filmed and later viewed and analyzed by the evaluators at normal speed with each specific action input directly into the computer using the Saats™ analysis software. Saats™ calculates the precise duration of activities through the use of an internal clock. For each judoka under observation, a table was constructed with two inputs – the first corresponding to the classification of the action (*break, preparation, grip, technique, fall* and *groundwork*) and the second corresponding to the duration of the action in seconds.

With this data, the number of actions and their durations were calculated. This data meant that every second of the match was accounted for. Once the video to be assessed is chosen, the program recognizes the total time of the video clip and displays its length in minutes and seconds and as a percentage (total time = 100%). After which actions are registered using predetermined keys on the keyboard and their time durations are displayed in minutes and seconds, as its percentage of the total time and the exact moment in the match when the action occurred. To assist evaluator accuracy a “back” key was introduced which allowed the evaluator to correct input mistakes.

The command actions of the program are displayed in Figure 1.

Figure 1: Representation of command actions for use of the program



- a) Button for command action for internal clock
- b) Specific combat activity
- c) Total combat time
- d) % of time of specific activity in real time
- e) Button for exiting the program
- f) Video in real time
- g) Button for video search
- h) Button for pausing the program
- i) Partial time of each stimulus
- j) Command for correcting previous command

Intra-evaluator agreement procedure: The evaluator familiar with using the program was selected for the analysis of intra-evaluator agreement. The evaluator analyzed each opponent of the three matches on different days, with an interval of several days between evaluations in order to minimize memory bias regarding the athletes' actions during combat.

Statistical analysis: To determine intra-evaluator and inter-evaluator reliability, a method proposed by Weir (2005) was followed. Analysis of variance (ANOVA) for repeated measurements was used to determine significant differences between inter-evaluator and intra-evaluator agreements regarding the time components of the matches. The intraclass correlation coefficient (ICC) was calculated from the squares obtained from ANOVA for repeated measurements. Mean of the residual squares was transformed into a natural logarithm for the calculation of the typical measurement error (TME) in the form coefficient of variance (CV) relative to the dependent variables (time components of the combat) (Hopkins, 2000). The uncertainty related to the estimate of the ICC, TME and CV was represented by the calculation of 95% confidence intervals. From these items, it was determined whether the evaluators were capable of generating similar results, thereby indicating whether the proposed protocol could be considered objective. Intra-evaluator reproducibility was used to further determine the reliability of the protocol. Statistical significance was set at $p < 0.05$.

Results

A sequence is defined as a period of activity; from the moment the referee calls *Hajime* so that combat may start, until he interrupts combat with the order *Matte*. The sequences performed were characterized by the combination of actions between each *break*. There were 276 sequences of actions when all was considered, with an average of 11 sequences per match of which 4 were *groundwork*. There were no significant differences between matches (Tables 1 and 2).

Table 1: Analysis of sequence (time between *Hajime* and *Matte*) and *break* time regarding the main occurrences in judo matches (measured in seconds)

	Match 1 (s)	Match 2 (s)	Match 3 (s)
Preparation	4 ± 1	4 ± 2	4 ± 1
Grip	16 ± 5	18 ± 3	17 ± 3
Technique	1.4 ± 0.3	1 ± 0.4	1.7 ± 0.5
Groundwork*	$17 \pm 12 (6 \pm 4)$	$9 \pm (4 \pm 2)$	$13 \pm 6 (5 \pm 2)$
Break	7 ± 1	6 ± 2	7 ± 1

* Values represent mean time and standard deviation for action on the ground, considering that not all match sequences have ground action. Values between parentheses are mean and standard deviation values in approximately 11 sequences, four of which are on the ground.

Table 2: Analysis of the percentage of each match sequence and *break* time of main occurrences in judo matches

	Match 1 (%)	Match 2 (%)	Match 3 (%)
Preparation	12 ± 4	13 ± 7	13 ± 3
Grip	49 ± 15	56 ± 9	49 ± 10
Technique	4 ± 1	3 ± 1	5 ± 2
Groundwork*	18 ± 13 (7 ± 5)	11 ± 5 (4 ± 2)	14 ± 7 (5 ± 1)
Break	19 ± 3	16 ± 6	19 ± 3

* Values represent mean time and standard deviation for action on the ground, considering that not all match sequences have ground action. Values between parentheses are mean and standard deviation values in approximately 11 sequences, four of which are on the ground.

Inter-evaluator agreement: Statistically significant differences were found between evaluators regarding the variables *preparation* and *technique* ($p < 0.05$), whereas no significant differences occurred with regards to the other four variables (Table 3). The analysis of typical error – expressed in the form of the coefficient of variance – revealed that the percentage of variability for *preparation*, *technique* and *fall* was greater than that of the other variables (Table 4). These variables also had lower ICC values.

Table 3: Description of mean total time profile defined by each evaluator individually

Variable	Evaluator 1	Evaluator 2	Evaluator 3
Break (s)	59.0 (19.1)	55.50 (16.3)	53.00 (14.8)
Preparation (s)*	58.0 (15.8) **	70.67 (15.3)	83.33 (10.8) **
Grip (s)	160.2 (20.4)	146.33 (40.5)	145.83 (24.4)
Technique (s)*	5.0 (1.9) **	10.33 (4.7) **	8.50 (5.2)
Fall (s)	5.0 (2.8)	9.83 (5.5)	6.67 (7.2)
Groundwork (s)	63.7 (37.0)	65.50 (47.6)	51.67 (37.2)

Data are expressed as means (standard deviation) * indicates statistically significant difference ($p \leq 0.05$). For *preparation*, ** indicates statistically significant difference between evaluators 1 and 3; for *technique*, ** indicates statistically significant difference between evaluators 1 and 2.

Table 4: Inter-evaluator reliability indicators for each component of the time profile of judo matches

Variable	ICC	TME (s)	TME (%)
Break	0.90 [0.67; 0.98]	4.69 [3.02; 7.26]	7.19 [4.58; 11.36]
Preparation	0.00 [0.00; 0.37]	14.14 [9.89; 20.23]	24.29 [16.42; 36.48]
Grip	0.75 [0.35; 0.96]	13.99 [9.03; 21.69]	9.95 [6.31; 15.83]
Technique	0.28 [0.00; 0.79]	3.30 [2.13; 5.12]	38.00 [23.09; 64.74]
Fall	0.13 [0.00; 0.73]	5.06 [3.27; 7.86]	75.62 [43.01; 142.64]
Groundwork	0.61 [0.11; 0.93]	4.10	6.80

Data are expressed as means [95% confidence interval]

Intra-evaluator agreement: There were no statistically significant differences between the intra-evaluator analysis (Tables 5 and 6). However, the items *preparation* and *fall* had ICC values of 0.7 [0.3 to 0.9] and *technique* had an ICC value of 0.2 [0.0 to 0.7]. These three items achieved the lowest reproducibility values from the relative standpoint. An analysis of the TME values expressed in the form of CV revealed the items *fall* and *technique* had a variation of more than 20% (Table 6).

Table 5: Description of mean total time profile defined by a single evaluator for three matches

Variable	Match 1	Match 2	Match 3
Break (s)	51.3 (13.09)	50. 7 (11.63)	53.0 (13.70)
Preparation (s)	81. 7 (10.23)	86. 0 (6.03)	83.0 (6.32)
Grip (s)	142.8 (36.96)	143. 7 (29.78)	141.3 (33.83)
Technique (s)	4.2 (1.17)	5.2 (2.86)	3. 7 (1.51)
Fall (s)	4. 7 (2.16)	4. 7 (1.75)	3. 7 (1.51)
Groundwork (s)	54. 7 (21.62)	48. 7 (21.68)	53.3 (21.63)

Data are expressed as means (standard deviation)

Table 6: Intra-evaluator reliability indicators for each component of the time profile of judo matches

Variable	ICC	TME (s)	TME (%)
Break	0.97 [0.88; 0.99]	2.19 [1.41; 3.40]	4.60 [2.94; 7.22]
Preparation	0.74 [0.33; 0.95]	3.74 [2.41; 5.80]	4.95 [3.16; 7.78]
Grip	0.97 [0.89; 0.99]	6.17 [3.98; 9.57]	4.78 [3.06; 7.51]
Technique	0.19 [0.00; 0.77]	1.78 [1.14; 2.76]	46.3 [27.7; 80.4]
Fall	0.75 [0.34; 0.96]	0.81 [0.52; 1.26]	21.0 [13.1; 34.3]
Groundwork	0.94 [0.78; 0.99]	4.69 [3.02; 7.27]	9.6 [6.1; 15.2]

Data are expressed as means [95% confidence interval]

Discussion

Over the last few years, several authors have published their experiences with automated tracking systems, although reports on manual tracking systems have been published for over 30 years (Sanderson and Way, 1977).

Whilst trying to analyze a tracking system for the sequences of squash intervention and technique, a manual tracking system called “Game Analysis” was developed, an idea based on other manual notational systems of analysis of motion and games and the analysis of techniques for basketball and football (Sanderson and Way, 1977). This study, using illustrative symbols and word abbreviations to define techniques, interventions and errors relating to the court plan, could in a quick and reasonably precise way, solve the problem of data extraction, being considered the first manual tracking system published on the subject (Barris and Button, 2008).

Manual notation systems of analysis have been highly applied in different sports as they are relatively cheap and practical. With the reliability and cost reduction of computer equipment today, researchers are concentrating on the application of new technologies in sports so that the extraction of more reliable and efficient data can be promoted (Pers and Kovacic, 2000a; Pers and Kovacic, 2000b; Pers et al., 2002). According to Barris and Button, thanks to advancements in technology, automated systems capable of collecting, analyzing and quantifying information of technical demand will aid in the development of training programs. Also, in a more subjective manner, we will be able to collect data that can possibly identify physiological, psychological and biomechanical features of athletes in real time.

Our study describes a computer program that allows an evaluator to analyze an athlete’s actions during judo combat sequences in detail. Requiring minimal equipment to collect and analyze data (a video camera per combat area

and only one computer) this methodology has a relatively low cost. In order to minimize operator participation and a dependence on trained evaluators, a task that can be time consuming, expensive and monotonous, Saats™ automatically generates a worksheet offering numerous analysis and archival possibilities. With an athlete's detailed performance profile easily at hand, coaches should be able to improve training systems and easily review performances during competitions.

What this study proposes is the use of a computer program in the evaluation of action sequences during judo combat. Judo, as an indoor sport, facilitates optimal recording conditions as it provides good sound quality and spatial dimension (Intille and Bobick, 1994; Ekin and Tekalp, 2003; Iwase and Saito, 2004; Pers and Kovacic, 2000b).

It is important to evaluate the time structure of judo combat. According to Garcia and Luque (2007), a match has an average of 8 to 9 periods of pause or intervals. Sterkowicz and Maslej (1998) report that the mean total of these intervals is 61.5 ± 59.4 seconds. Previous values published range from 71 ± 65 (Malderen et al., 2006) to 91 seconds (Castarlenas and Planas, 1997).

Regarding time spent in the upright position, Sterkowicz and Maslej report 131.6 ± 88.0 seconds, whereas Castarlenas and Planas report an average time of 120 seconds. Analyzing only male athletes, Malderen et al. report a value of 129 seconds for *Tachi-waza* (standing combat). Regarding time on the ground, Sterkowicz and Maslej found a mean duration of 42.9 ± 42.3 seconds, whereas Castarlenas and Planas report a time of 52 seconds. Analyzing only male judokas, Malderen et al. detail 23 seconds of *Ne-waza* (groundwork).

The time structure of judo combat in the present study differs from that described in the literature cited above. The present analysis takes into consideration that in judo combat a period of activity, from *Hajime* to *Matte*, is divided into 6 actions, which no previous study has done. Our study reports an average of 11 action sequences per match, with 4 being on the ground. This number of sequences is the same reported by Castarlenas and Planas and slightly higher than that described in a recent study, which reports 9 to 10 sequences (Garcia and Luque, 2007).

As demonstrated in (Tables 3 and 4), when the time profile was defined by different evaluators, there were statistically different results for the actions *preparation* and *technique*. On the other hand, there were similarities in the results on the other four variables reveals that, although two evaluators were only introduced to the program moments before analyzing the combats, they had little difficulty in using it.

We believe that statistically different results occurred because of evaluator's lack of familiarity with the program as well as athlete motion unpredictability. As athletes seek victory, they move quickly and suddenly change the direction of their moves. Also, it could happen that the interpretation of the

information is correct, but the mistake occurred because of the observer's inexperience in commanding the program (Pers and Kovacic, 2000a; Pers and Kovacic, 2000b; Pers et al., 2002; Needham and Boyle, 2001; Pers et al., 2001).

When match analysis was done by a single evaluator trained in the use of the program, there were no statistically significant differences between evaluations (Tables 5 and 6). The inter-evaluator and intra-evaluator agreement demonstrated that the use of the program requires familiarization. We did not determine how many sessions would be necessary to achieve consistently reliable results, but we believe that the learning process would likely be of short duration as the two evaluators with no prior experience with the program were able to achieve similar results to the trained evaluator, regarding the majority of actions.

An analysis of the data obtained by a single evaluator trained in using the program allows an overview of the main occurrences in a match during phases of activity. *Preparation*, occurring at the beginning of combat, involved movements to establish first contact with an opponent. This is a low-intensity action and lasted an average of three to five seconds (Tables 1 and 2). The dispute for *grip* comprised the largest portion of the match, with periods lasting 11 to 21 seconds. This normally requires a high degree of energy expenditure, with considerable solicitation of the lower limbs. During combat, athletes perform this type of action repeatedly, at a ratio of approximately 2 periods of *grip* to each period of *preparation*. *Groundwork* lasted slightly less time than that of the *grip* actions. *Technique* application may be characterized as a power move, and it occurred approximately every 30 seconds, considering the time spent wrestling on the ground, *break*, *preparation* and *grip*. *Technique* applications are executed in a very short time span, which results in a physiological demand that is quite different from the other actions. Regarding the lower limbs, actions during combat alternate from very mild solicitation to extremely high solicitation, depending on whether the athlete is moving upright, executing a move or in the combat phase on the ground.

In conclusion, the use of this computer program in the evaluation of a judo match saves time and provides and processes accurate and reliable results in a practical way. Its use likely requires a brief training period of familiarization but it is hoped that a well-trained evaluator would eventually be able to use the program during a live event. Processed and archived information regarding the action sequences of judokas should assist in the development of specific training programs for athletes and improve competition performance.

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