"IDO MOVEMENT FOR CULTURE. Journal of Martial Arts Anthropology",
Vol. 11, no. 3 (2011), pp. 47–51

KINESIOLOGY

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Judo Performance Tests Using a Pulling Force Device Simulating a Seoi-Nage Throw

Submission: 07.11.2010; acceptance: 25.02.2011

Key words: biomechanics, force diagnostics, motion analysis, kuzushi

Abstract
A pulling force device (PFD) is used to carry out monthly performance tests on 12 judo squad athletes (8 male, 4 female, aged 19.4 ± 4.3 years) of the Olympic Center in Linz (Austria) to see the progress over a training period of six months. The variation of a friction brake simulates the resistance of the opponent in the throwing technique Seoi-Nage, which consists of three phases: balance breaking (kuzushi), fit-in (tsukuri) and throw (kake). Force and velocity over time are measured, and the parameters maximum force F_{max}, time to maximum force $t(F_{max})$, maximum force derivative dF_{max} and maximum velocity v_{max} are calculated with use of the software LabView. Displaying force and velocity curves together with the recorded videos of a synchronous 2x 2D motion analysis in Dartfish in a special graphic user interface (GUI) provides a helpful visualization and feedback for athletes and trainer and shows imperfections in technical skills in more detail. The relevant investigations comprise the position of center of mass (COM), knee and elbow angles, body axis, trunk rotation as well as chain pullout. Longitudinal studies, standardized by weight category, show improvements in all 4 parameters, especially $t(F_{max})$ has decreased by 64 %. The PFD has proven to be a valid method of determining specific abilities of judokas. The gained knowledge and experience will be used in optimizing individual motion structure and training. An improved, mobile PFD should also be used as a training device.

State of the art

Judo is a combat sport, which has made its way from Japan all over the world. Nowadays the "gentle way" is an Olympic discipline, but the traditional Japanese notion is still used [Kano 1937]. In competition, the attacker (tori) can achieve valuations by either immobilizing the opponent (uke) or throwing him on side or back, for what victory (ippon) is assigned [IJF 2004]. The performed technique is *seoi-nage*, one of the most successful throughout the last 30 years.

Performance testing in such a complex sport as judo requires a procedure as close to reality as possible. A judo throw lasts less than a second, so motion analysis helps even an experienced trainer in judging motion sequences. The task is to provide a tool for technical training, giving immediate and objective feedback concerning force abilities and motion performance. Due to the fast movements, explosive strength abilities are of special interest.

Existing training devices are either judo dolls supplied with force sensors [Farenholtz 2000] or modified force machines [Blais 2006], on which technical exercises such as *tandoku-renshu* can be performed. Most investigations so far have been done by [Nowoisky 1990] who used different types of PFDs since the 1970s. The judoka carried out the throwing motion holding a torso with judogi, while separate sensors for left and right arm measured force and velocity. In addition, there was a grid behind and beneath the athlete for coarse motion analysis (fig. 1a).

Further motion analyses were carried out from either competition videos with the disadvantage that the not skin-tight judogi does not allow for automatic tracking [Imamura 2007] or in laboratory studies with a human Uke, where markers can be used [Blais 2004; Blais *et al.* 2005] (fig. 1b). The problem here is that the resistance given by *uke* cannot be measured, so only motion analysis can be done.

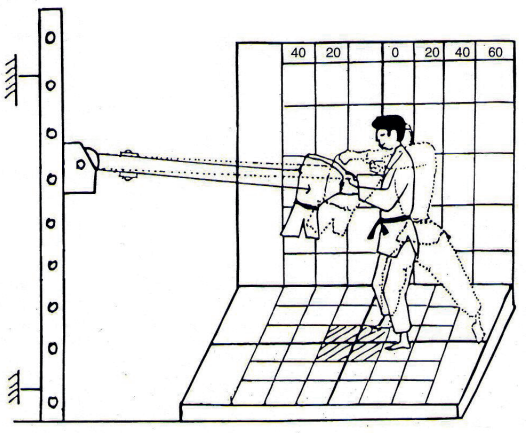

Figure 1a: Pulling force device as in [Nowoisky 1993]

Figure 1b: Placing markers on Tori as in [Blais 2005]

Materials and methods

In this study, a new type of PFD is used, where the variation of a friction brake simulates the resistance of Uke in the throwing technique Seoi-Nage [Müllner 2008] according to the biomechanical model described in [Nowoisky 1990] and adjusted for different weight categories. Force and velocity are measured over time with use of the software LabView. The calculated four parameters correspond to the desired force abilities in judo: maximum force F_{max} and time to maximum force $t(F_{max})$ – maximum force respectively maximum force index; maximum force derivative dF_{max} – explosive force; and maximum velocity v_{max} – speediness.

A synchronous 2x 2D motion analysis in Dartfish, using one camera view from one side and one from above, helps analyzing the quality of movement. The relevant investigations comprise the trajectory and velocity of COM, knee and elbow angles, body axis, trunk rotation as well as chain pullout. A GUI for viewing curves and videos together for an immediate and useful feedback for both athlete and trainer is created (fig. 2). All results are compared to findings in [Nowoisky 1990] which is supposed to be an optimum way of carrying out *seoi-nage*.

The subjects are 8 male and 4 female judokas from the Olympic Center in Linz (Austria), in different weight categories, aged 19.4 ± 4.3 years. Each athlete performs three valid tries at each of the six test series. Cross-sectional studies are done in SPSS, with F_{max} and dF_{max} standardized by weight category and $t(F_{max})$ and v_{max} in absolute values, making them comparable for all athletes. Significance is assumed for $p < 0,05$. Longitudinal studies display training progress over six months, regarding the abilities focused on during several training periods. The following improvements are expected:

— preparation phase – maximum force: $F_{max} \uparrow$
— build-up phase – explosive force: $t(F_{max}) \downarrow$, $dF_{max} \uparrow$
— competition phase – speediness and technical performance: $v_{max} \uparrow$

In order to get a complex overview of the judokas' performance, results are correlated to isometric maximum force diagnostics of Mm. biceps brachii [Buchegger 2009], competition results on national and international level, and if a variation of *seoi-nage* is in their special technique repertoire, which is the case for 8 subjects.

Results

The linear regression of the longitudinal analysis of series I to VI show statistically significant improvements in dF_{max} (+53 %, $R^2 = 0.50$) (fig. 3a) and $t(F_{max})$ (-64 %, $R^2 = 0.62$) (fig. 3b), whereby the decrease of $t(F_{max})$ means a better performance in terms of reaching an earlier force maximum during Kuzushi phase. Standard deviation for this parameter is rather high during the first four test series (I to IV). The increases of F_{max} (+16 %, $R^2 = 0.19$) (fig. 3c) and v_{max} (+15 %, $R^2 = 0.22$) (fig. 3d) are slight and non-significant.

The 12 athletes are divided into junior and senior, having different season highs and therefore different training phases:
— junior: competition phase between series I and II, build-up phase between series II and IV
— senior: preparation phase between series II and IV
— all: competition phase between series V and VI.

From the correlation with the training periods, significant increases in most of the parameters representing the force abilities they focused on during each period can be concluded. Table 1 gives the correlation values of the so-called

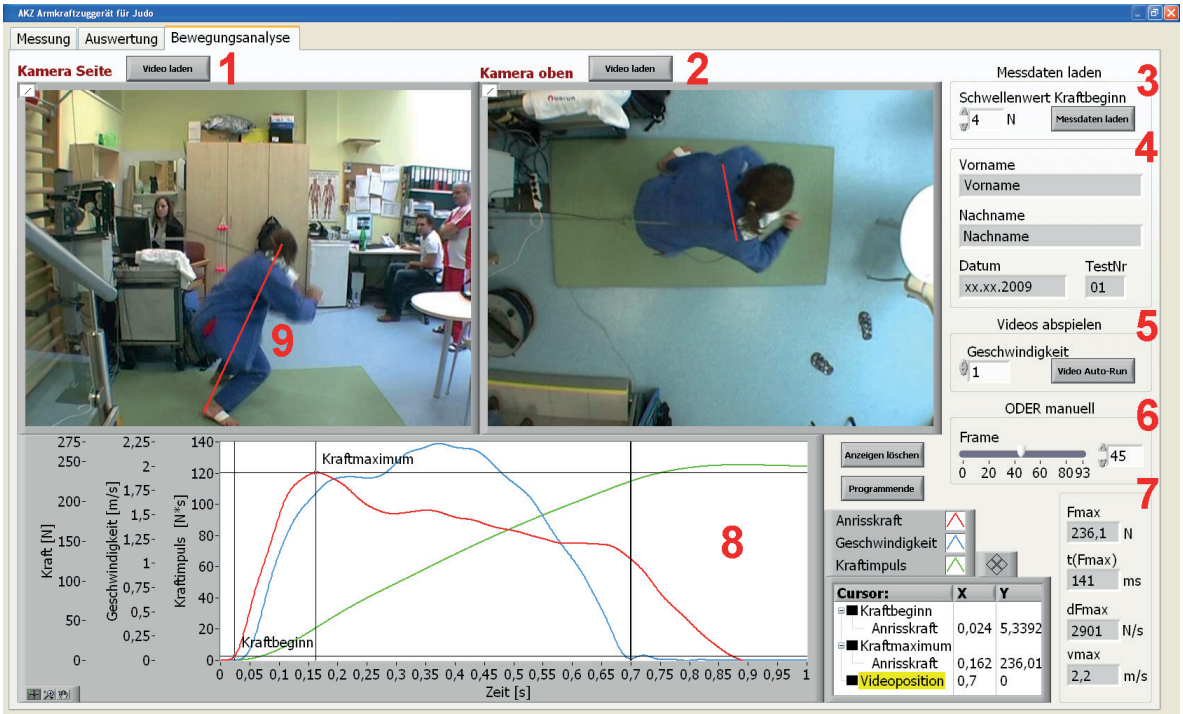

Figure 2: GUI used for motion analysis together with force (red), velocity (blue) and force impulse (green) curves. The black cursor in the graph (8) shows the current video frame position (6), the displays to the right (7) calculate the parameter values F_{max}, $t(F_{max})$, dF_{max} and v_{max} from loaded sensor data.

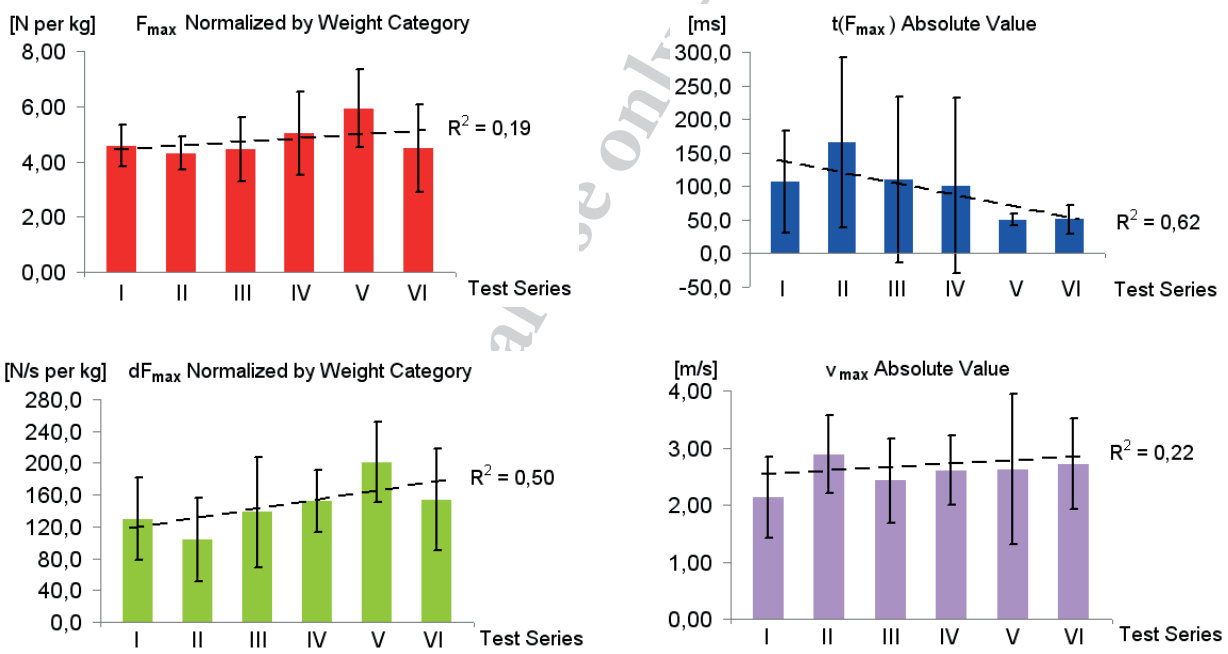

Figure 3a to d: Longitudinal analysis of parameter values of series I to VI, with linear regression coefficient R^2

Table 1. Correlation of parameter values with training periods, p-values of t-test in SPSS

Parameter	Series I / II Junior	Series II / IV Junior	Series II / IV Senior	Series V / VI All
F_{max}	0,034	0,009	0,247	0,112
$t(F_{max})$	0,263	0,306	0,776	0,047
dF_{max}	0,535	0,032	0,033	0,075
v_{max}	0,125	0,892	0,033	0,019

T-Test in SPSS, where positive developments are marked in green and negative effects in red. The correlation to isometric maximum strength test results, competition achievements and Seoi-Nage as a special technique show no significance at all.

The 2x 2D motion analysis is done as seen in fig. 2. Both recorded videos are loaded into the GUI and can be viewed either frame by frame (6) or played automatically in 1 / 0.5 / 0.25 times the original speed (5). Lines can be drawn by the trainer to display the desired motion characteristics (9). On the left video picture – the camera view from the side – in fig. 2, the line shows the body axis (from the middle of the feet to the middle of the head), in the right video picture – the camera view from above – the shoulder axis in the end of Kake is depicted.

Discussion

The slight and non-significant increase of F_{max} and v_{max} and rather low absolute values for these two parameters throughout all tests and subjects depict a deficit compared to results in [Nowoisky 1990]. The high standard deviations for $t(F_{max})$ in the first four series resulted from poor technical performance in the beginning, but they improved significantly. In series V and VI, they reached an average of $t(F_{max})$ = 50 ms, which is much lower than the proposed 100 ms in [Nowoisky 1990]. Together with the good development of dF_{max} and technical performance, it probably shows a much higher importance of explosive force compared to the maximum force level. The modern competition judo is characterized rather by speediness than by rude force exertion [Gold 2004].

As this specific PFD test shows only one component of the complex abilities needed in judo fights, correlations are done with the training periods, so this performance test can prove the effectiveness of special training measures and exercises. For example, during preparation period the athletes focused on maximum force training and the normalized values of F_{max} increased.

This is a laboratory testing procedure, where the athlete pulls out a rope fixed to a chain, so haptic differences between the rope and the judogi have to be accepted. Also the first step towards Uke in order to overcome the distance does not take place, because the chain of the PFD cannot be pushed back in.

Conclusion

The use of the PFD as a testing device has proven to be a useful and valid method of determining maximum force, explosive force and speediness abilities of judokas, represented by the parameters F_{max}, dF_{max}, $t(F_{max})$ and v_{max}. Testing a whole squad can be done quite easily and efficiently. Displaying force and velocity curves together with the recorded videos in a special GUI provides a helpful visualization and feedback for athletes and trainer. Differences and imperfections in technical skills can be found out much better and more impartially than even an experienced trainer's opinion can with the naked eye. The gained knowledge and experience will subsequently be used in the construction of an optimized, mobile pulling device, which can also be used for training sessions.

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Testy wydajnościowe w judo przy użyciu urządzenia do pomiaru siły ciągnięcia symulujące rzut seoi-nage

Słowa kluczowe: biomechanika, diagnostyka siły, analiza ruchu, kuzushi

Abstrakt

Urządzenie do pomiaru i diagnostyki siły ciągnięcia jest używane do przeprowadzania comiesięcznych testów wydajności w grupie 12 zawodników judo (8 mężczyzn, 4 kobiety, w wieku 19,4 ± 4.3 lat) w Centrum Olimpijskim w Linzu (Austria) w celu obserwacji postępów w ciągu 6 miesięcy treningów.

Zmiana hamulca ciernego symuluje opór przeciwnika w technice rzutu seoi-nage, która składa się trzech faz: wytrącenia przeciwnika z równowagi (kuzushi), „wejścia" do rzutu (tsukuri) i rzutu (kake). Siła i prędkość są mierzone na przestrzeni czasu, a parametry maksymalnej siły F_{max} czasu w stosunku do maksymalnej siły $t(F_{max})$, maksymalna siła pochodnych dF_{max} oraz maksymalna prędkość v_{max} są wyliczane przy użyciu programu komputerowego LabView. Wyświetlanie krzywych siły i prędkości razem z nagranymi video synchronicznej analizy ruchu 2x 2D w Dartfish w specjalnym graficznym interfejsie użytkownika (GUI) zapewnia pomocną wizualizację oraz informację zwrotną od sportowców i trenera oraz pokazuje niedoskonałości w umiejętnościach technicznych w większych szczegółach. Przetestowanie całej grupy zawodników może być wykonane szybko i efektywnie. Odpowiednie badania przedstawiają pozycję centra masy (COM), kolana, kąty łokcia, oś ciała, rotację tułowia, a także siłę ciągnięcia liny przymocowanej do łańcucha. Badania podłużne znormalizowane według kategorii wagowej, wykazują poprawę we wszystkich 4 parametrach, w szczególności wartość $t(F_{max})$ wzrosła o 64%.

Urządzenie PFD okazało się być odpowiednią metodą ustalającą określone umiejętności zawodników judo, w szczególności określanie maksymalnej siły, siły wyrzutu i szybkości. Uzyskana wiedza i doświadczenie zostaną użyte w optymalizacji indywidualnej struktury ruchu i treningu. Ulepszone, mobilne urządzenie PFD powinno być używane jako sprzęt treningowy.