KINEMATIC AND TEMPORAL CHARACTERISTICS OF SELECTED JUDO HIP THROWS

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The sport of judo, developed in 1882 in Japan by Jigoro Kano, is a refined version of the ancient martial art of jujitsu. Typically when one envisions martial arts, the mental image includes kicks, punches, and other striking techniques. The sport of judo involves none of these, but does permit the use of throwing techniques, mat work similar to wrestling, strangle holds and joint locks at the elbow. Despite its original role as a martial art, judo as practiced today is essentially the highest form of wrestling practiced anywhere in the world (Reay & Hobbs, 1979).

It is interesting to note the virtual non-existence of scientific studies focusing on a sport which is over 100 years old and is practiced world-wide. The few studies that do exist are primarily kinematic analyses derived from cinematographic data that were carried out under the auspices of the Association for Scientific Studies on Kodokan Judo based in Tokyo, Japan (Ikai & Matsumoto, 1958; Matsumoto, Yanagita & Sato, 1963). To date, only one study (Tezuka, Funk, Purcell & Adrian, 1983) has measured the ground reaction forces (GRF) of tachiwaza, or standing judo techniques.

The purposes of the study were 1) to measure the ground reaction forces of two judo hip throws, 2) to describe the activity through the use of selected parameters determined from the ground reaction force-time curves, and 3) to identify any kinetic and/or temporal patterns that were present.

A judoka is taught that each throw consists of three key kinematic elements: Kuzushi, the unbalancing of the opponent; Tsukuri, the mechanical aspects of the technique; and Kake, the point of maximum power of the throw. As a secondary purpose of the study, GRFs were employed to define the point of maximum power in the two judo throws examined.

METHOD

Instrumentation

A force platform (Kistler Model 9281A) mounted on a steel frame embedded in a large concrete base in the basement floor of Gerlinger Annex at the University of Oregon was used to measure GRFs. The raw voltage signals from the platform were input to eight KIAG charge amplifiers (Type 5001), and were additionally processed by two summing amplifiers (RTC Instruments) designed specifically for the system. The summing amplifiers were interfaced via a TransEra A/D converter to a Tektronix 4051 Graphics Calculator. The sampling rate was 200 Hz and the digital signals were stored on magnetic tape for later processing.

Additionally, film data were collected to assist in the interpretation and analysis of the force curves and to determine the end point of the activity, as the subjects remained on the force platform following the completion of the judo throws. A Visual Instrumentation high speed Super 8 mm camera (Model SP-1) with a 7.5 - 65 mm zoom lens was placed perpendicular to the sagittal plane of motion and was used to film selected trials for all conditions. The trials were filmed at 150 frames per sec with a shutter factor of six, resulting in an exposure time of .0011 sec. A Mamiya-Sekor 35 mm camera with a 100 mm lens was placed perpendicular to the frontal plane of motion to record the position of the supporting foot on the force platform.

Judo Techniques

The two judo hip throws selected for analysis have been recognized as being used extensively in world-class competition (United States Judo Federation, 1975). Harai-goshi (sweeping hip throw) (HG) and uchi-mata (inner thigh throw) (UM) are similar in that both require the thrower to support his body weight on one leg while the other leg "sweeps" the opponent off the ground and to the mat. The major difference between the two throws is the point of contact of the sweeping leg on the uke's (the defender) body. In performance of harai-goshi, the tori's (the attacker) sweeping leg makes contact with the antero-lateral aspect of the hip and thigh of the uke (Figure 1). Only the two-step approach style of harai-goshi was used in the study.

An uchi-mata throw requires that the sweeping leg follow a path between the legs of the uke, striking high inside the defender's upper thigh and/or groin (Figure 2). All subjects used the kouchi-mata version of the uchi-mata, in which the sweeping leg of the attacker is kept as straight as possible, with contact being made by the lateral aspect of the tori's thigh (Reay & Hobbs, 1979).

Subjects

Five highly-skilled adult males from the University of Oregon Judo Club volunteered to serve as subjects for the study. Data were collected on four subjects performing the throws while the fifth served as uke for all throws to standardize this major factor and minimize its effect upon both between and within subject variability.

Figure 1. Harai-goshi (sweeping hip throw).

TABLE I

SUBJECT INFORMATION

Sub-ject	Height (cm)	Weight (kg)	Age	Years Experience	Judo Rank
1	170	77.56	24	5	Ikkyu
2	168	71.55	28	4	Sankyu
3	180	79.74	31	18	Nidan
4	183	85.28	29	7	Sankyu
Uke	174	72.35	29	3	Sankyu

Figure 2. Uchi-mata (inner thigh throw).

The subjects all held the minimum rank of Sankyu (brown belt) with an average of 7.4 years of judo experience (range = 3 to 18 years). The subjects who performed the throws averaged 175.3 cm in height and had an average weight of 78.5 kg in comparison to the uke's height and weight of 174 cm and 72.4 kg. Additional subject information is provided in Table I.

Testing Protocol

Subjects performed the experiment in bare feet, dressed in judogis (judo uniforms) with the substitution of running shorts in place of the loose-fitting judo trousers to enable the joints of the lower extremity to be located more accurately on film. Practice trials were permitted to make the transition from performance of judo throws on soft wrestling mats to performing them on a wooden floor and the metal surface of the force platform.

In the initial position, the uke and the tori stood facing each other with their feet off the force platform, grasping each other's judogi in a right-handed grip. The tori initiated the throw by stepping onto the force platform with his right foot and pivoting on this foot approximately 180 degrees counterclockwise (ccw). This was followed by a step with his left foot onto the platform and a transfer of his and the uke's weight to that leg. The throw was completed by sweeping the uke off the ground with the tori's right leg, over his right hip and to the mats that surrounded the testing site (Figure 3).

After satisfactory completion of ten trials of the first judo condition, i.e. harai-goshi or uchi-mata, a five-minute rest period was imposed. Activity was then resumed with tori's performance of ten acceptable trials of the second test condition, following the protocol previously described. At the conclusion of the data collection, each subject's height and weight was measured for use in data analysis.

RESULTS AND DISCUSSION

Twenty-five parameter values describing critical aspects of the ground reaction force-time data were identified and evaluated for each trial and average results computed for all subject conditions. Following data reduction, each of the 25 descriptors was statistically evaluated using a repeated measures ANOVA ($p < .05$) design.

In the study the uke never actually made contact with the force platform and therefore, the 'system weight' determined by combining the body weight of the tori and uke previously used by Tezuka, et al. (1983) was considered to be inappropriate. Thus, the body weight of each individual tori comprised the 'system'. To enable more realistic between subject comparisons to be made, all force data were normalized to Newtons per kilogram body mass.

The beginning and end points of the judo throws were not immediately obvious from the GRF data. In the starting position of both throws neither the tori nor the uke were in contact with the force platform. Analysis of the film data revealed that an average of .324 sec was required from the time

of initial movement to contact with the force platform. Consequently the total time as measured by the force platform significantly underestimated the duration of the activity.

Unlike force platform studies that involve walking or running, the judo subjects remain on the force platform following the completion of activity. To determine the end point of the activity, the first value encountered following the maximum vertical GRF equal to or less than the tori's body weight was used to designate the completion of the throw. Verification of the selected kinetic end point was provided by examination of the cinematographic data.

On the basis of the consistent tri-modal pattern observed for the vertical GRF component, the force-time curves were divided into three phases: 1) the loading phase, which included initial contact with the right foot, the pivot on the right foot, and the step with the left foot onto the force platform. These events were marked by two sub-maximal vertical force peaks on the Z-axis force curves; 2) the sweeping phase, which involved the anterior-to-posterior motion of the right leg of the tori lifting the uke off the ground. The end of the sweeping phase was defined by the kake, or point of maximum power of the throw; and 3) the follow-through phase, which began following the occurrence of the kake and included the uke's fall to the mat (Figure 4).

In the context of the study, maximum 'power' was identified as maximum force (Newtons/kg) instead of calculating the rate of work in watts. The vertical GRFs comprised the greatest magnitude of forces in the study and therefore, the kake was defined as both the time and value of the maximum vertical GRF.

Vertical Component

The vertical GRF component comprised 78.1% of the resultant force measured in all throws. Of the five vertical force parameters examined, only the total time of performance demonstrated significant differences between HG and UM. Utilizing GRF data alone, HG required an average of .780 sec to complete compared to .640 sec for UM (Table II).

Average vertical force values were the same for the two judo throws analyzed, as subjects experienced average vertical forces 1.39 times body weight (BW). Maximum vertical GRFs were likewise similar for HG and UM with both throws resulting in forces 2.46 times BW. The algebraic impulse values were 10.58 N•sec/kg for HG compared to 8.80 N•sec/kg for UM.

With regard to the tri-modal nature of the vertical GRF curves, the maximum vertical force was observed at the third peak in all trials. As previously mentioned, this point was identified as the kake. Although the total time taken to perform HG was significantly greater than UM, the relative occurrence of the kake was similar for both throws, 63.7% to 67.9%, respectively.

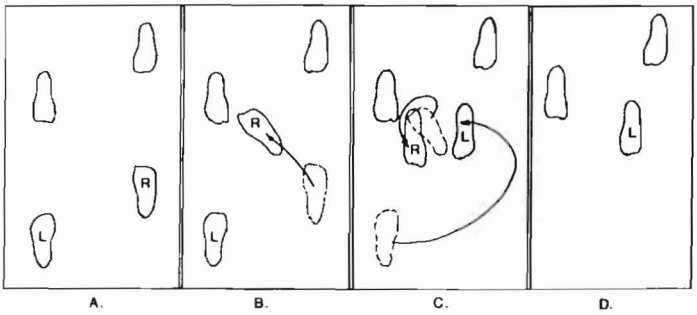


Figure 3. Footwork for judo hip throws. A) Initial position, B) Diagonal step by tori in anterior direction C) Pivot 180 degrees counterclockwise and follow-up step with the left foot, D) Tori supports his and the uke's weight on his left leg while sweeping with the right leg.

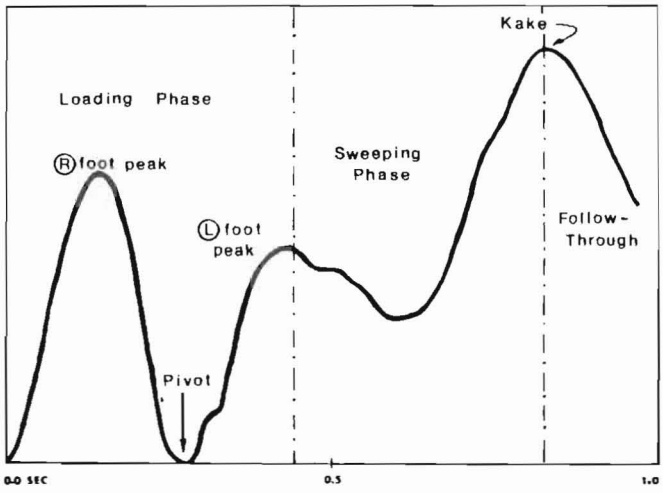
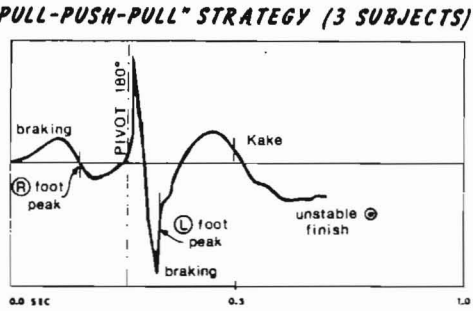


Figure 4. Representative vertical ground reaction force-time curve with critical events identified.

Table II

Means, Standard Deviations (below) and Significant Effects for Descriptors of the Vertical Component of the Ground Reaction Forces.

Descriptor:	Harai-Goshi	Uchi-Mata	Source
Maximum Vertical Force: (N/Kg)	24.08 (2.34)	24.06 (2.88)	
Time to Maximum Vertical Force: (seconds)	.566 (.026)	.457 (.026)	CXS $<.01$ S $<.05$
Average Vertical Force: (N/Kg)	13.62 (0.78)	13.65 (1.06)	
Algebraic Impulse: (N·sec/Kg)	10.58 (1.39)	8.80 (1.25)	S $<.05$
Total Time of Activity: (seconds)	.780 (0.21)	.640 (0.11)	C $<.05$ S $<.05$



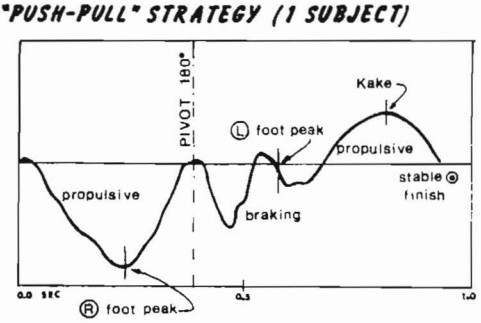


Figure 5. Representative anterior-posterior ground reaction force-time curves with critical events identified.

Anterior-Posterior Component

This component accounted for 11.6% of the mean resultant force measured for both throws. The average anterior (propulsive) GRF comprised 5.2% while the mean posterior (braking) GRF constituted 6.4% of the resultant force.

Three of the ten descriptors of the anterior-posterior force-time curves demonstrated significant differences ($p<.05$) between HG and UM. The parameters that described the time of maximum braking force, mean algebraic force and propulsive impulse were found to be significant. Maximum braking force values averaged .36 BW, while the mean maximum propulsive GRF was .26 BW (Table III).

Identification of kinetic patterns presented a difficult challenge, as the direction of movement over the force platform changed during the throws. Specifically, the direction of motion changed with tori's pivot 180 degrees ccw during the first step with the right foot. A diagram of the footwork, nearly identical for HG and UM, was provided in Figure 3.

The initial activity in all judo throws requires the techniques of kuzushi, the unbalancing of the opponent (uke) prior to throwing him. Two distinct anterior-posterior ground reaction force-time curve patterns were identified and are presented in Figure 5. Three subjects used a "pull-push-pull" strategy while one subject used a "push-pull" strategy to initiate the throws.

Medial-Lateral Component

The medial-lateral component comprised 10.3% of the resultant force (medial = 1.9%, lateral = 8.4%). Significant differences were present between HG and UM on four of ten variables. The parameters describing 1) the time to maximum medial force, 2) maximum lateral force, 3) mean algebraic force and 4) average lateral force were all significantly greater in favor of uchi-mata (Table IV). The remaining variables were statistically non-significant but contained values that were all greater in favor of HG.

During the performance of both HG and UM, the tori was subjected to significantly greater maximum (3.18 N/kg) and average (1.47 N/kg) lateral GRFs than maximum (1.05 N/kg) and average (0.34 N/kg) medial GRFs. Average lateral impulse values (.768 N sec/kg) were approximately 13 times greater than the medial impulse values (.059 N sec/kg).

CONCLUSIONS

The following conclusions were drawn based upon the results of the study:

1. The total time required for uchi-mata was significantly less than the time required to perform harai-goshi. In contest situations, the faster a throw can be executed, the less time the opponent has to mount a counterattack. Thus uchi-mata has been shown to have an advantage over harai-goshi in this respect.

Table III

Means, Standard Deviations (below) and Significant Effects of Descriptors of the Anterior-Posterior Component of the Ground Reaction Forces.

Descriptor:	Harai-Goshi	Uchi-Mata	Source
Maximum Propulsive Force(+): (N/Kg)	2.78 (1.01)	2.24 (0.76)	CXS (.01
Time to Maximum Propulsive Force (seconds)	.580 (.355)	.564 (.292)	
Maximum Braking Force(-): (N/Kg)	3.38 (.98)	3.43 (.94)	CXS (.05
Time to Maximum Braking Force: (seconds)	.333 (.172)	.569 (.299)	C (.05
Mean Algebraic Force: (N/Kg)	- 0.01 (0.79)	-0.41 (0.74)	C (.05 S (.001
Algebraic Impulse: (N·sec/Kg)	-.043 (.301)	-1.55 (.227)	S (.01
Average Propulsive Force: (N/Kg)	1.04 (0.40)	0.74 (0.45)	CXS (.01
Average Braking Force: (N/Kg)	1.05 (0.31)	1.18 (0.43)	S (.01
Propulsive Impulse: (N·sec/Kg)	.420 (.116)	.260 (.095)	C (.05 S (.01
Braking Impulse: (N·sec/Kg)	.451 (.197)	.418 (.164)	S (.01

Table IV

Means, Standard Deviations and Significant Effects for Descriptors of the Medial-Lateral Component of the Ground Reaction Forces.

Descriptor:	Harai-Goshi	Uchi-Mata	Source
Maximum Medial Force(+): (N/Kg)	1.55 (0.73)	1.48 (0.64)	
Time to Maximum Medial Force: (seconds)	.518 (.333)	.700 (.258)	C (.01 S (.01
Maximum Lateral Force(-): (N/Kg)	2.84 (0.74)	3.52 (0.72)	C (.05
Time to Maximum Lateral Force: (seconds)	.678 (.200)	.557 (.079)	CXS (.01
Mean Algebraic Force: (N/Kg)	-0.91 (0.34)	-1.35 (0.35)	C (.01 S (.05
Algebraic Impulse: (N·sec/Kg)	-.662 (.243)	-.782 (.170)	S (.05
Average Medial Force: (N/Kg)	0.36 (0.16)	0.31 (0.13)	CXS (.01
Average Lateral Force: (N/Kg)	1.28 (0.38)	1.66 (0.38)	C (.01 S (.05
Medial Impulse: (N·sec/Kg)	.069 (.043)	.049 (.017)	
Lateral Impulse: (N·sec/Kg)	.724 (.223)	.811 (.134)	S (.05

2. At least two different strategies for unbalancing the uke are possible for successful completion of harai-goshi and uchi-mata. Subjects used either a "push-pull" or a "pull-push-pull" strategy to initiate the throws. The necessity of some form of kuzushi (unbalancing) is thereby substantiated by the results of the study.

3. The most experienced judoka, with the rank of Nidan and 18 years experience, was the least consistent performer in the study. One possible explanation for these results is that a higher skilled performer makes subtle adjustments in technique dependent upon the environment presented to him, whereas the lesser skilled judoka executes the same technique regardless of the circumstances present, e. g. the amount of resistance offered by the uke, a mid-flight counterattack initiated by the uke.

Summary

Between subjects differences were considerably greater than within subjects differences as might be expected, suggesting that the subjects developed different styles of the judo throws based upon their individual capabilities and morphological characteristics. Significant differences between harai-goshi and uchi-mata were observed for nine of 25 parameters describing the two throws, however, the overall kinetic and temporal patterns were more statistically and behaviorally similar than dissimilar.

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