

6-3. MUSCLE STRENGTH, MOTION VELOCITY, MUSCLE POWER, AND ENERGY EXERTION IN NAGEWAZA OF WOMEN JUDOISTS

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Today, the Judo Championship is played off under the classified body weight system to relieve the handicap of body weight. The idea behind the establishment of the body weight classification system, is that the difference of body weight equals the difference of the muscle strength as observed in other sports, such as wrestling, boxing, and weight lifting, and it creates a decisive influence over crucial the result of the game. Therefore, besides Judo, wrestling, boxing, and weight lifting have adopted the body weight system.

In weight lifting, for instance, there is a remarkable difference of absolute muscle quantity and absolute muscle strength among the players of 60 kg and 75 kg classes. Basically, the same thing can be said about Judo. However, in Judo which uses a trick *waza* by responding to the opponent's movements, and by making use of the opponent's power, it seems that the active muscle strength in the act of *waza* and its timely utilization are more important than the mere possession of muscle strength.

There is a saying "Gentle turns away sturdy" in Judo which explains how much the muscle power play an active part in the act of *waza* and how important it is to execute *waza* in good timing.

The purpose of this survey is to analyze women Judoists and to find out in what pattern the muscle strength in the Judo *waza*, *kuzushi*, *tsukuri*, and *kake*, is to be manifested as a real power,—how it is converted into the speed of *waza*, and how it is used as an attacking power. Also a quantitative calculation and study was made on the energy revealed in the act of *nagewaza*.

I. Method

(1) *Measurement Method*

The measurement of muscle strength, velocity, muscle power, and muscle energy manifestation in *nagewaza* has been developed by Ueya.²⁾ As shown in Fig. 1, the measurement was taken by pulling the wire of the inertia wheel. As shown clearly in Block Diagram of Fig. 1, in this study the muscle power was automatically recorded at the moment when the power was manifested by the execution of Judo *waza* and the momental values of the motion speed, and the strength, velocity and power curves were also recorded continuously.

(2) *Practice of Waza*

In performing *waza*, the subject held with both hands a wire, one end of which was wound into an inertia wheel, and performed *waza* of *kakari-rensu* (*uchikomi*) with full strength from the *shizentai* position. The wire was adjusted so that it would go off the inertia wheel when *waza* came to an end. The *waza* employed in this survey were 4 kinds: (1) *maesumi-no-kuzushi*, (2) *ippon-seoinage*, (3) *taiotoshi*, (4) *goshiharai*.

(3) *Equivalent Mass of Inertia Wheel*

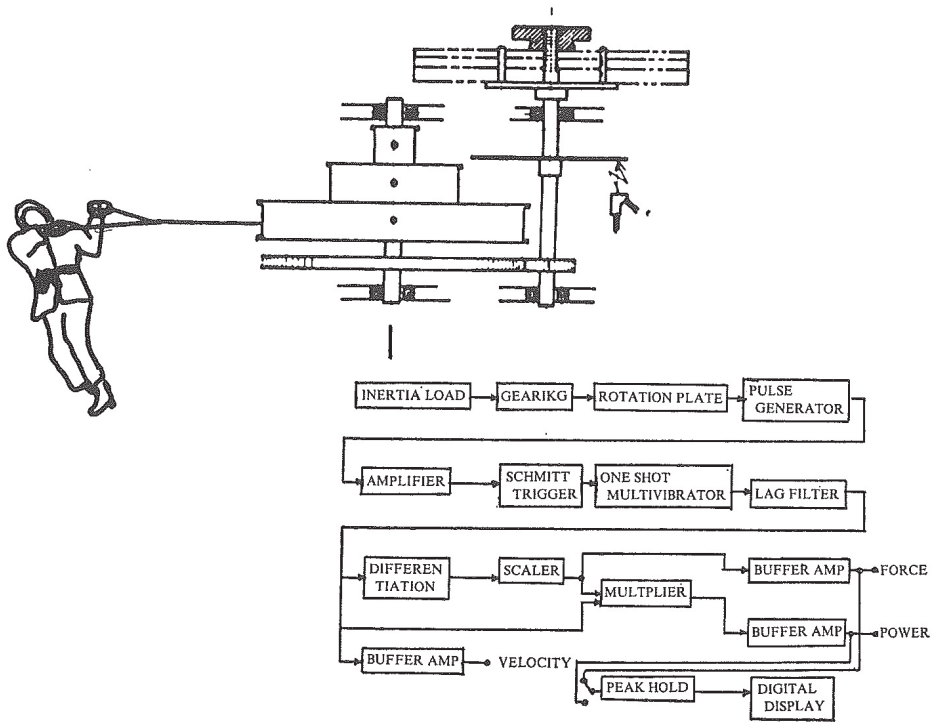


Fig1. Experimental design and block diagram of measuring strength, velocity and power of throwing motion in Judo.

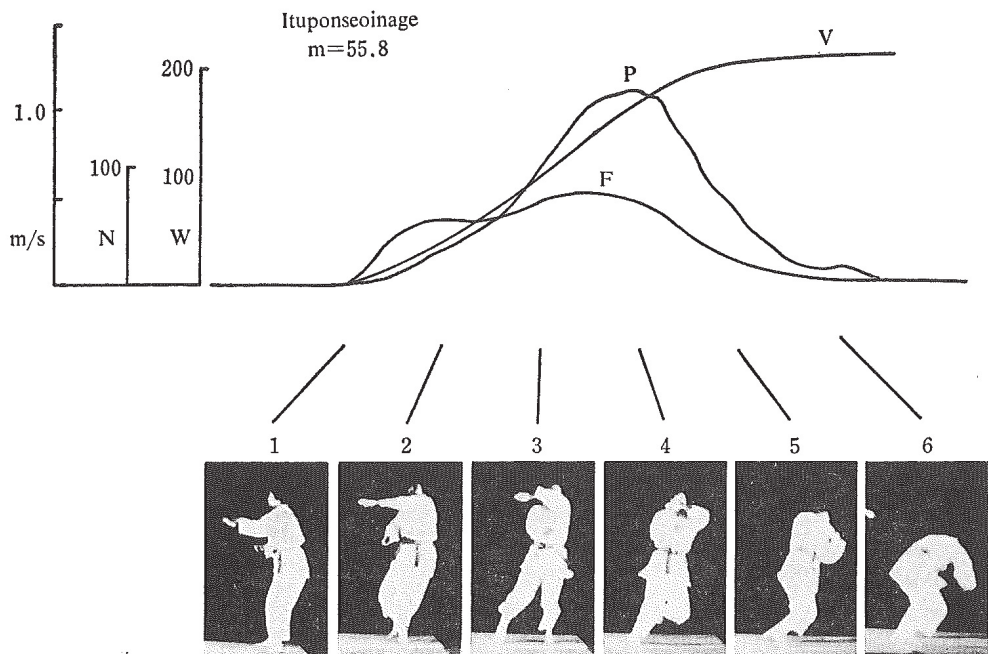


Fig2. Force (F), velocity (v) and power (p) during doing Ituponseoinage : One Arm Throw. Subject was H (Three-Dan : Black belt holder) Maximum strength was 75,8 newton, maximum power was 175,5 watt and final velocity was 1,25 m/s.

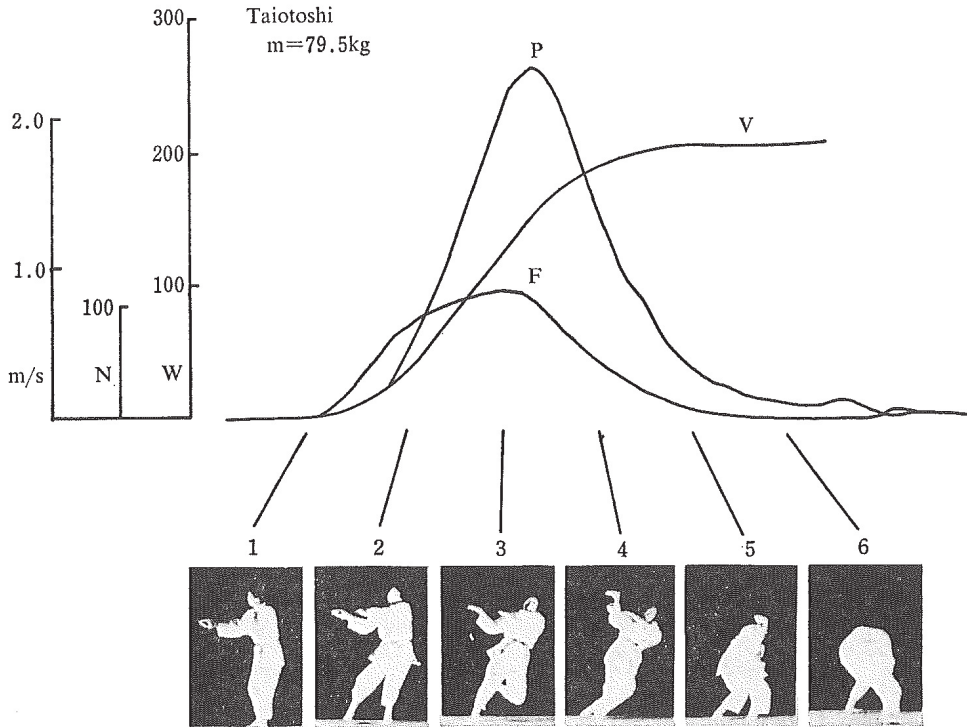


Fig3. Force (F), velocity (v) and Power (p) during performing Taiotoshi : Body Drop Subject was H. Maximum strength was 112,0 newton, maximum power was 260,0 watt and final velocity was 1,80 m/s.

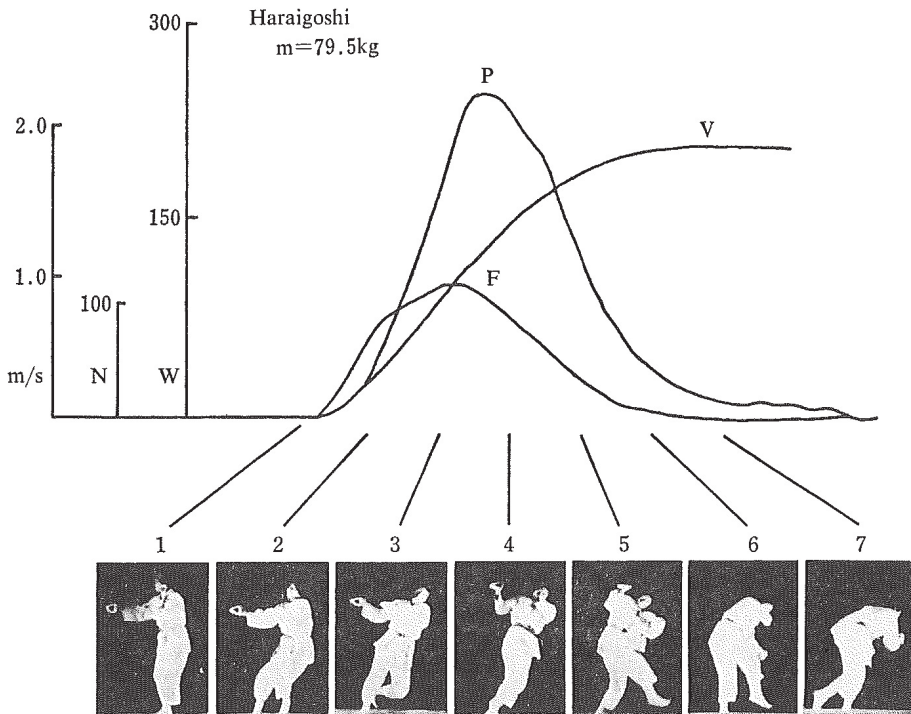


Fig4. Force (F), velocity (v) and power (p) during performing Haraigoshi : Sweep Throw Subject was H. Maximum strength was 117,0 newton, maximum power was 245,5 watt and final velocity was 1,78 m/s.

Measuring the opponent's body weight (inertia), the inertia wheel was used in this survey. The load was divided into five grades: 8.0 kg, 26.9 kg, 30.9 kg, 55.8 kg, and 79.5 kg.

(4) *16 mm High-speed Photographing*

The motion of all Judo *waza* were photographed 64 frames/second by a 16 mm camera set aside. The strobe flash was used in order to synchronize with the 3 curves of "strength, velocity, and power".

(5) *The subjects were two women 3-dan Judoists (K and H).*

II. Results

(1) *Muscle Strength, Velocity, and Muscle Power*

Muscle strength, motion velocity, and muscle power manifested in performing *waza* and their movements synchronized with the progress of time are shown in Figs. 2, 3, and 4. All *waza* were performed by H player. The case of 55.8 kg equivalent mass in *ippon seoinage* is shown in Fig. 2. The case of 79.5 kg equivalent mass in *taiotoshi* is shown in Fig. 3. The case of 79.5 kg equivalent mass in *haraigoshi* is shown in Fig. 4. In the Figures, the letters "F" (muscle strength), "V" (motion velocity), and "P" (muscle power) indicate the curves of manifestation. The patterns of the 3 curves and the maximum values were different every time, and furthermore it was confirmed that the moments of each motion when maximum muscle strength and power was displayed.

The values of maximum muscle strength, motion velocity, and maximum muscle power were 75.8 newton, 1.25 m/s., 175.5 watt in *ippon seoinage*, 112 newton, 1.80 m/s., 260.0 watt in *taiotoshi*,

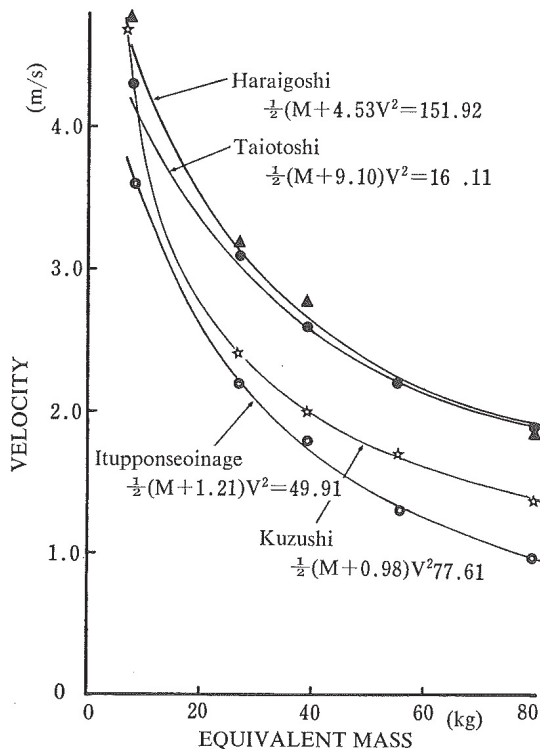


Fig5. The relation between equivalent mass and performing maximum velocity of throwing motions, and their energy equations, Subject was K.
(Three-Dan : Black belt holder)

and 117 newton, 1.78 m./s., 245.5 watt in *haraigoshi*. It was confirmed in each *waza* that muscle strength increased in accordance with equivalent mass of the inertia wheel increased, and the motion velocity and the value of muscle power decreased.

Comparing with maximum muscle strength, muscle power and motion forms, the curves were comparatively sharp in *taiotoshi* and *haraigoshi*, whereas in *ippon seoinage* the curve was rather slow with double peaks. The maximum values of the muscle strength, the muscle power and the motion velocity were observed at the moments when both arms were in the act of pulling the wire as far as the upper body was concerned and when the lumbar was twisted and both feet landed on the tatami-mat. The same tendency was seen in K player and in each load (equivalent mass).

(2) Energy Rational Formula of *Waza*

The energy rational formula was calculated concerning the energy produced by each *waza* (4 kinds of *waza* were practiced in this survey), the energy transmitted to the opponent, and the energy consumed in the action of *waza*. The computation theory was devised by measuring the maximum m./s. velocity (v) of each 5 kinds of equivalent mass (M). The formula $1/2 (M + A) v^2 < Ed$ was set up and the constant A and Ed were computed by the method of least square. Ed is a motion-generated energy and A is a coefficient of the expended energy.

The result of computation of the player H is shown in Fig. 5. The mass of generated energy was 162.11 J (joule) in *taiotoshi*, 151.92 J in *haraigoshi*, 77.61 J in *kuzushi*, and 49.91 J in *ippon seoinage*. The energy generated and consumed in the performance of *taiotoshi* was approximately 2.09 times as much as *kuzushi* and 3.25 times as much as *ippon seoinage*. Also it was confirmed that the energy generated in *kuzushi* by pulling both arms of the opponent was larger than *ippon seoinage*.

The values of factor A of expended energy were 9.10 kg in *taiotoshi*, 4.53 kg in *haraigoshi*, 1.21 kg in *ippon seoinage*, and 0.98 kg in *kuzushi*. The values of factor A have something to do with the quantity and its velocity of the body employed to execute *waza*. It was suggested that wide areas of the body was employed for the execution of *taiotoshi*, while in *ippon seoinage* and *kuzushi* the particular areas of the body contributed to these *waza*. From the relation between generated energy Ed and expended energy factor A , it was found that the generated energy in *haraigoshi* was slightly less than in *taiotoshi* (93.7%), but the motion velocity in *haraigoshi* was higher than in *taiotoshi*, since the value of A was about 50%.

In the case of very light load such as 8.0 kg of equivalent mass, the velocity of *kuzushi* of *ippon seoinage* was 4.60 m./s., which was as fast as that of *taiotoshi* and *haraigoshi*. However, as the value of load increases, the velocity decreased and generating energy also decreased because of the lack of muscle strength.

III. Discussion

In this survey the measurements of muscle strength, motion velocity, and muscle power were made by using an inertia wheel. In *randori* and the Championship of Judo, the opponent always takes the defense posture when *waza* is performed and tries to prevent the execution of *waza* for defense. Thus the power which is stronger than "inertia plus defense" power of the opponent is necessary in order to successfully perform *waza* throw the opponent. In this survey, however, the production of power in performing of *waza* was computed from inertia load—the measurement was made by the different values of equivalent mass of an inertia wheel. Therefore, the defense power usually seen in an actual Judo Championship is ignored here, and the measurement was done under the condition that throwing was made simply with no resistance from the opponent when *waza* was performed.

Though in the measurement of small equivalent mass a series of *waza* motions went smoothly, there was a case of around 79.5 kg when the subject herself was pulled toward the inertia wheel when she made an attempt at pulling the wire. The performances were done over and over again and arranged pulling the wire should be closer to the actual *waza* motions.

We¹⁾ had done the same experiment and measured equivalent mass (in the range from 8.0 kg to 127.3 kg) of 9 male college Judoists as subjects. As a result, it was found that the muscle strength, velocity and muscle power of the women Judoists in this survey were very low compared to those of the male Judoists. In *taiotoshi*, for instance, the maximum muscle power of male college Judoists was 79.5 kg equivalent mass and 480 watts on the average, the muscle strength was 330 newton, and the velocity was 3.0 m./s. In the comparison with the male Judoists the maximum power of H player in *taiotoshi*, corresponded to 61.2% of the maximum power of the male Judoists. The maximum power of women Judoists showed about the same degree of percentage not only in *taiotoshi* but also in other *waza*. The reason comes from the fact that the maximum muscle strength of women Judoists was smaller than that of male Judoists. The isometric maximum muscle strength of the subjects was not measured in the laboratory. However, it can be conjectured that the values of arm flexion muscle strength, back muscle strength, leg muscle strength, and body twisting strength of women Judoists were much smaller than those of the male Judoists and this might be one of the contributive factors.

In order to analyze the energy output in *nagewaza* by women Judoists, Ueya, one of the collaborators of this research, made a study on the comparison of forearm flexion motion by one arm⁴⁾ and rowing-boat motion.⁹⁾ The average value of this experiment of college Judo club members was 72.0 J, other 14 different collegiate sports club members' average was 60.0 J, and the inter-college crews' average was 952.9 J. The factor A of expended energy in a forearm flexion motion was 4.5 kg–6.5 kg, and in a rowing motion it was 75.75 kg, which was much higher than the measurements of this survey. This indicates that 5 to 6 times as much energy used in *haraigoshi* and *taiotoshi* by women Judoists was produced in a rowing motion, which requires full back- and-forth movements of the upper body as well as the flexion of both arms and legs.

On the other hand, the factor A value of expended energy was much smaller in *nagewaza* than in rowing. The energy consumed in the motion of *kuzushi* and *ippon-seoinage* alone was almost none in comparison to that consumed in a rowing motion. This denotes that the entire body must be fully collaborated in the performance of *taiotoshi*, since the value (9.10 kg) was the largest of the 4 kinds of *waza*. Conversely in *kuzushi* ($A=0.98$ kg), it can be conjectured that only light arms were employed. In the case of using not only arms but also the swing of the upper body in a *kuzushi* motion, the generated energy increases and thus the value of A also increases.

The quantity of generating energy is determined by the ratio between generated energy mass and factor A. Therefore, it is considered that in *nagewaza* the energy, which is comparatively smaller than a rowing motion, is efficiently changed into energy output and it is used to pull and throw the opponent down.

The investigation of 4 kinds of *waza* more in detail from the energy side revealed that the velocity of *waza* as in the case of K player shown in Fig. 5, was high, even though the production of energy was slightly smaller in *haraigoshi* than in *taiotoshi* and that *haraigoshi* was considered to be a fast *waza*. It seems in *haraigoshi* and *taiotoshi* that a great amount of energy was generated at the stage of *kuzushi* more than the process of judging from *tsukuri* and *kake*.

Further investigation of the point mentioned above revealed that in the case of 55.8 kg equivalent mass, the generated energy of *kuzushi* was computed 76.23 J by the energy equations, and that of *haraigoshi* was 140.49 J and 139.37 J in *taiotoshi*. The figures 54.7% in *haraigoshi* and 54.3% in *taiotoshi* were the energy generated by *kuzushi*, and the differences might be the energy generated by the power of sweeping of the loin and pulling of the upper body of the opponent.

The above-mentioned is only the fruits of our investigation of the subjects who started the experiments from *shizentai* or the static state. Therefore, it is very important to investigate how muscle strength, muscle power, and motion velocity were revealed in the movements of the player together with the opponent. A further study is to be as a future assignment, though it is an experiment with great difficulties.

IV. Conclusion

The following conclusions have been obtained from this survey:

- (1) The size and pattern of generating muscle strength and muscle power produced in the process of *nagewaza* depends on the kinds of *waza*.
- (2) The energy output accompanied by *nagewaza* was computed and studied by the use of energy equation, $1/2 (M+A) v^2 = Ed$.
- (3) Ed is energy generated in the motion, $1/2 Mv^2$ is the generated energy conveyed to the opponent, and A is the factor of expended energy accompanied by the motion.
- (4) The energy generated in the performance of *waza* in the order of quantity was: *taiotoshi*, *haraigoshi*, *kuzushi*, and *ippon-seoinage* and the quantity of expended energy of in the act of *waza* was also in the same order.
- (5) The muscle strength, velocity, muscle power, and energy output of women Judoists were largely low in the values compared with the values of male Judoists and the values of the crew members in the rowing motions.

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