

Energy Metabolism in the Fundamental Throwing Techniques of Judo

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I Forword

Since A. V. Hill's studies on energy metabolism much work has been done in this field. For example, studies made by Liljestrand (1), Sato (2), and Yoshioka (3) in swimming; Liljestrand (1) in skating; Liljestrand (1), and Henderson (4) in boating; A. V. Hill (5), Furusawa and Sargeant (6), Klatschkow (7), and Ogasawara (8) in running; Yoshida (9), Ogasawara (10), and Ishii (11) in calisthenics; Sugimoto (12) in mountaineering; Iino (13) in skiing, etc. are well known. Recently, Yamaoka et al. have made extensive studies on the amount of energy required in soccer (14), baseball (15), and rugby (16).

Lately as judo has become internationally popular, interest in the scientific studies on judo from various angles has been aroused. To begin with a study on the energy metabolism during the performance of judo was selected. However, depending on the physique and skill of the individuals under investigation a wide fluctuation in the results is to be expected. In order to avoid this, performers with approximately the same physique and skill, and also with a considerable training experience were selected as experimental subjects. They were also made to perform the various representative techniques with a constant speed, while their energy consumption was being measured.

II Experimental Method

Measurement of energy consumption was done by the Douglas bag method. The air samples thus obtained were analyzed by the Roken type gas analysis apparatus, the oxygen consumption calculated by the prescribed method, and the amount of energy required and the R. M. R. computed therefrom.

Simultaneously with the taking of expired air, the subjects' movements were carefully observed, and the number of steps taken together with the number of techniques were recorded. Furthermore, the subjects, respiratory excursions, pulse rate, and blood pressure were also recorded before and after each performance.

Experimental subjects: The subjects were students at the Tokyo University of Education and all of about uniform physique, and excepting for Wamura (5th grade) they

Table 1 Body Measurements

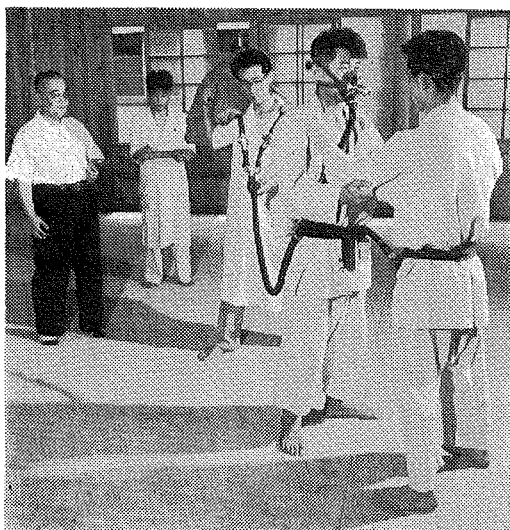
Name	Age	Height (cm)	Weight (kg)	Chest (cm)	Body area	Grade	Experience (yrs.)
Wamura	30	173	73	97	1.86	5	11
Yoshino	22	165	68	97	1.65	2	2
Ito	18	171	73	94	1.88	3	4
Katayama	18	167	64	90	1.73	2	4

Expired air at rest was taken after the subject had rested in a supine position for thirty minutes.

Expired air during the performances was taken by the following method: Instead of the experimental subject carrying the bag an assistant carried the bag which was connected to the mask of the subject by a long rubber tube.

After taking the subjects' expired air at rest he was made to move about freely for one minute until a steady state was reached, after which expired air while the subject was in action was taken for one minute and then continued for thirty minutes until recovery of normal physiological condition was attained.

In order to prevent leakage of air during the performances a special valve was attached to the mask.



The throwing techniques performed were divided into four groups, viz.: hand technique, hip technique, and Sutemi technique, and from among these Seoi-nage, Okuriashi-harai, Uchi-mata, Hane-goshi, Osoto-gari, Uchi-gari, and Uki-nage were selected. From the Newaza technique, Yokoshiho-katame and Kuzushishiho-katame were selected. The throwing technique was performed at the rate of five to six times per minute.

The expired air of the offensive and the defensive were analyzed separately as it is expected that the energy consumption between the two would be different.

III Results

As mentioned above the expired air of the subjects in action was taken for one minute during which interval the throwing technique was performed five to six times and the energy consumption of one performance calculated therefrom.

As a criterion of the quantity of motion the number of steps taken by the subject was also recorded (Table 2).

Table 3 shows the oxygen consumption of each technique with the time units in seconds. Ordinarily when indicating energy consumption it is common practice to use minutes as the time unit, but since in judo the changes in movement is extremely quick requiring

were of about the same skill and experience (Table 1).

Collection of expired air: Expired air was collected while at rest and also during performances. Basal metabolism was calculated from body weight and height.

Table 2. Respiratory air volume at rest and in action, steps taken during performance, and number of techniques.

Technique		Subject	Resp. p. min. at rest	Resp. p. min. in action	Number of steps	Number of techniques
Defensive movement	of	Ito III Katayama II	7.33 / 6.87	27.97 / 10.49	58 78	
	def	Katayama II Ito III	6.71 9.71	20.98 30.10	63 58	
Uchimata	of	" "	8.76 6.41	24.06 25.12	63 45	6 6
	nef	" "	7.03 6.49	22.00 25.11	47 50	— —
Osotogari	of	" "	7.13 6.59	24.95 27.29	63 63	5 5
	def	" "	8.12 9.52	21.30 33.17	47 58	— —
Ouchigari	of	" "	8.82 6.48	31.26 25.29	38 63	5 5
	def	" "	8.10 8.81	25.38 28.53	54 62	— —
Sutemi-waza	of	" "	7.77 7.29	35.47 28.45	62 42	5 5
	def	" "	5.93 8.12	23.31 19.23	61 50	— —
Seoi-nage	of	Wamura V "	8.74 6.08	23.96 24.21	51 41	5 5
	def	Yoshino II "	7.28 7.29	18.38 18.46	59 54	— —
Ashi-harai	of	Wamura V "	7.76 6.53	36.12 25.46	49 49	6 6
	def	Yoshino II "	6.37 7.81	24.86 31.12	64 67	— —
Hane-goshi	of	Ito III Katayama II	8.81 6.98	24.65 28.11	57 58	5 5
	def	Katayama II Ito III	9.48 7.88	32.92 28.62	61 50	— —
Attitude directly prior to Newaza	of def	Katayama II Ito III	5.94 7.15	13.17 12.69		
Yokoshiho-katame	of	Ito III Katayama II	8.97 9.58	12.24 16.32		
	def	Katayama II Ito III	10.39 6.64	14.90 23.00		
Kuzurekamishiho- katame	of	" "	9.01 6.41	16.70 17.74		
	def	" "	7.30 8.66	14.76 17.15		

Table 3. O₂ consumption & caloric consumption during performances

Techniques	Subjects	O ₂ consumption p. min.	O ₂ consumption p. sec. p. technique	Col/sec	Av. cal/sec
Deffensive movement	Ito III Katayama II	1.544 / 1.590	25.7 / 26.5	0.36 0.35	0.36
	Katayama II Ito III	1.223 1.435	20.4 23.9	0.29 0.31	0.33
Uchimata	" "	1.789 1.490	4.96 4.13	0.54 0.32	0.43
	" "	1.620 1.398	4.50 3.89	0.34 0.30	0.32
Osotogari	" "	1.610 1.752	5.36 5.84	0.33 0.80	0.57
	" "	1.054 1.558	3.52 5.20	0.15 0.32	0.24
Ouchigari	" "	1.461 1.823	4.88 6.08	0.34 0.99	0.67
	" "	1.420 1.390	4.74 4.64	0.31 0.32	0.32
Sutemiwaza	" "	1.591 1.625	5.3 5.42	0.35 0.51	0.43
	" "	1.424 1.319	4.74 4.40	0.35 0.31	0.33
Seoinage	Wamura V "	1.973 1.785	6.58 5.96	1.11 0.54	0.83
	Yoshino II "	1.732 1.436	5.78 4.78	0.62 0.37	0.5
Ashiharai	Wamura V "	1.632 1.633	4.53 4.53	0.35 0.35	0.35
	Yoshino II "	1.316 1.336	3.65 3.71	0.32 0.34	0.33
Hanegoshi	Ito III Katayama II	1.896 1.916	6.32 6.38	1.12 1.15	1.14
	Katayama II Ito III	1.136 1.626	3.78 5.42	0.32 0.86	0.59
Attitude directly prior to Newara	Katayama II Ito III	841 681	28.0 22.7	0.40 0.36	0.40
Yokoshihokatame	Ito III Katayama II	928 798	30.9 26.6	0.62 0.40	0.51
	Katayama II Ito III	1.043 1.196	34.8 39.2	1.68 1.93	1.81
Kuzurekamishiho- katame	" "	999 905	33.3 30.2	1.08 1.10	1.09
	" "	1.128 949	37.6 33.3	1.87 1.55	1.71

only 1-2 seconds for a single technique it is more convenient to use seconds instead.

As shown in Table 3 during a throwing technique the caloric requirement of the offensive is far greater than that of the defensive. This is quite understandable from the fact that the movements of the offensive is much more active and complicated than those of the defensive.

However, in the case of the Newaza technique the relation is reversed, and the energy consumption of the defensive is greater than that of the offensive.

It is quite natural that the energy consumption during the performance of a single technique should vary with the technique being used and the performer. For instance in the Hanegoshi which necessitates large movements the energy consumption was found to be notably large, and in the Sutemi technique which utilizes the momentum of the defensive, it was found to be rather small.

The defensive movements in judo occupy most of the time in a match or during training and require a large amount of energy, approximately 0.33-0.36 cal. per second.

The above values were obtained during the present experiment, but in an actual match it is expected to be higher. Iino's (17) experiments on the energy consumption during the defensive movements confirm this view.

The above relations may be seen in Table 4 in the form of energy metabolic rate.

The above metabolic rates when compared to those required by other sports like baseball (2.6), soccer (6.4), rugby (11.1), boating (1.6-2.3), radio exercise (5.0), and marathon (5.6) are not very high when the R. M. R. of the individual techniques only is considered, however when the R. M. R. of the defensive movements (13.5-18.0) is also taken into consideration, judo may be included among the strenuous sports, and it is suggested that 10-20 minutes is an appropriate time for a single match.

Respiration, pulse rate, and blood pressure at rest and after the performances are given in Table 5. These measurements were made in order to investigate the recovery process of oxygen consumption. It is to be noted that the experimental subjects were well trained judo experts, consequently their pulse rate and blood pressure at rest show lower values than the average healthy adult. The rise in their values directly after the performances depend on the various techniques being used, however the recovery time is very quick (10-15 mins.).

Table 4. R. M. R. of various throwing techniques

Techniques	Average of offensive	Average of defensive
Defensive attitude	18.2	13.5
Uchimata	2.9	2.6
Oсотogari	3.5	2.7
Ouchigari	4.0	2.8
Sutemiwaza	3.6	3.5
Seoinage	4.0	3.5
Ashiharai	2.9	2.4
Hanegoshi	4.3	3.4
Attitude directly prior to Newaza	18.5	17.7
Yokoshihokatame	18.4	30.2
Kuzurekamishiho-katame	21.0	29.9

IV Summary

1) The energy consumption during the performance of various techniques of judo was studied.

Table 5. Changes in pulse rate, respiration, & blood pressure

Techniques	Subject	Respiration		Pulse		Blood pressure	
		At rest	Directly after performance	At rest	Directly after performance	At rest	Directly after performance
Defensive movements	Ito III	16	32	52	104	112-74	152-86
	Katayama II	16	32	52	92	116-60	190-90
	Katayama II	17	32	54	112	110-72	158-90
	Ito III	16	36	53	96	118-70	145-72
Uchimata	"	16	38	61	92	100-52	140-60
	"	18	30	62	94	120-72	182-72
	"	17	31	60	124	108-60	132-66
	"	17	27	61	97	98-52	140-90
Osotogari	"	16	30	53	114	104-60	146-68
	"	15	24	53	112	96-50	132-70
	"	16	31	58	120	110-48	132-86
	"	18	29	60	118	102-58	124-68
Ouchigari	"	17	32	60	120	110-70	140-64
	"	17	26	61	114	108-42	165-66
	"	16	30	60	118	108-58	136-77
	"	17	26	61	116	112-52	128-60
Sutemiwaza	"	15	30	56	93	110-64	148-64
	"	14	27	51	76	106-70	136-58
	"	16	32	59	96	104-65	138-85
	"	16	26	53	76	110-72	130-70
Seoinage	Wamura V	16	25	56	106	113-52	178-93
	Konda I	15	27	56	82	112-65	147-64
	Yoshino II	17	22	56	65	109-48	168-68
	Miyazawa I	18	22	62	69	118-74	174-106
Ashiharai	Wamura V	16	30	60	92	117-68	171-67
	Konda I	17	24	52	66	126-72	142-73
	Yoshino II	18	21	58	75	116-61	146-69
	Miyazawa I	14	19	54	68	114-76	168-92
Hanegoshi	Wamura V	13	26	54	88	103-60	174-122
	Konda I	16	20	53	90	119-71	162-76
	Yoshino II	14	22	56	76	110-65	168-80
	Miyazawa I	17	19	52	88	100-56	140-78
Newaza	Katayama II	16	30	54	121	118-76	148-64
	Ito III	14	30	55	98	98-68	150-74
Yokoshihokatame	Ito III	18	36	60	104	116-75	168-70
	Katayama II	17	35	52	112	118-75	170-95
	Katayama II	14	31	60	108	108-60	154-70
	Ito III	17	37	63	120	110-65	162-80
Kuzurekamishihokatame	"	15	31	60	102	118-70	152-76
	"	14	36	64	118	112-64	172-68
	"	17	33	54	108	114-58	162-65
	"	16	35	64	125	118-64	168-68

2) Since the energy consumption is expected to vary greatly with the physique and skill of the individual, the subjects selected for this experiment were of approximately uniform physique and skill.

3) The defensive movements in judo require quite a large amount of energy, the R. M. R. of which was found to be 13.5-18.0. In the throwing technique the R. M. R. of the Hanegoshi was the largest with 4.3, and that of the Ashi-harai the smallest with only 2.9, the others showing intermediate values.

The R. M. R. of the Newaza was in general higher than that of the throwing technique (8-30).

4) In the throwing technique the R. M. R. of the offensive was found to be higher than that of the defensive, whereas in the Osae-Komi the R. M. R. of the defensive was higher than that of the offensive.

5) From the above results, judo may be classed under strenuous sports, and it is suggested that the appropriate time duration for a single match is from 10 to 20 minutes.

References

- 1) Liljestrand, G., u. Stenstron, N.: Skand. Physiol., 39 : 167, (1920).
- 2) Sato, I., Fujita, H., Takagi, H., Iino, F.: Jidai Seiri Ronbun-shu, 2 : 472. (1932).
- 3) Yoshioka, J.: Keio-igaku, 23 : 1143, (1943).
- 4) Henderson, H., & Haggard, H. W.: Am. J. Physiol., 72 : 264, (1925).
- 5) Hill, A. V., Furusawa, K., Long, C. N., Lupton, H.: Roy. Soc. Proce. B., 97 : 155, (1924).
- 6) Sargent, R. M.: Roy. Soc. Proce. B., 100 : 10, (1926).
- 7) Klatchkow, L. A. u. Wassiljewa, E. S.: Arbeit Physiol., 7 : 62, (1934).
- 8) Ogasawara, M.: Taiiku-kenkyu, 2 : 3, (1934).
- 9) Yoshida, A.: Fukuoka Un. Med. Journ., 13 : 38, (1920).
- 10) Ogasawara, M.: Taiiku-kenkyu. 8 : 34, (1937).
- 11) Ishii, Y., Kachiki, S.: Taiiku, (1948).
- 12) Sugimoto, R., Takagi, H.: Jidai Seiri Ronbun-shu, 2 : 466, (1932).
- 13) Iino, T., Hojo, K., Yuda, K.: Jap. Journ. Physiol. 1 : 87, (1936).
- 14) Yamaoka, S.: Taiikugaku-kenkyu, 1, (2) : 174, (1951).
- 15) Yamaoka, S., Inoue, G.: Tairyoku-kagaku, 1, (2) : 30 (1950).
- 16) Yamaoka, S.: Taiiku-gaku-kenkyu, 1, (3) : 220, (1952).
- 17) Iino, T., Chiku, G., Sasaki, S.: Jidai Seiri Ronbun-shu, 3 : 94, (1934).