

## 10. REGULATION OF RESPIRATION DURING NAGE-WAZA IN JUDO (1)

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Ordinarily, respiration is regulated automatically in order to maintain homeostasis in the body. All muscles taking part in respiratory movements are striated muscles, and consequently, do not possess automatism like the heart muscles or the muscles lining the gastro-intestinal walls. The respiratory muscles are under the involuntary control of the respiratory center situated in the medulla oblongata, and contract and relax alternately. In involuntary respiratory movement there is a regular rhythm of inspiration and expiration, and the rate and depth of respiration indicate the excitability of the respiratory center. However, since respiratory muscles are voluntary muscles, the respiratory rhythm may be freely controlled by the will, thus complicating the meanings of respiratory rate and respiratory phase. Furthermore, sometimes, during an athletic performance it is not possible to control respiration voluntarily. For example, an unaccustomed athlete on the starting line feels nervous and excited and finds that his respiration has become uncontrollably accelerated. This is caused by stimulation of the respiratory center by the excitation of the cerebrum.

The increased breathing noted during athletic performances is due to the increase of  $\text{CO}_2$  tension in the body. There are two ways by which  $\text{CO}_2$  in the blood stimulates the respiratory center of the medulla: one is by direct action on the respiratory center of the medulla, and the other indirectly via the aortic arch and the carotid body. Not only  $\text{CO}_2$  but any compound which increases the acidity of the blood stimulates the respiratory center of the medulla. For example, when lactic acid accumulates in the blood breathing is accelerated, because the acidity of the blood is increased, thereby stimulating the respiratory center of the medulla. The action of the muscle may also become a stimulating factor in increasing breathing. Flexion and extension movements of the knee after ligaturing the thigh and obstructing venous return from the periphery causes acceleration of breathing (Asmussen, E., 1939). In this case, it is quite obvious that the increased breathing is not due to stimulation of the respiratory center by the accumulation of  $\text{CO}_2$  in the blood, and it is thought that stimulation of the sensory nerve within the muscle acts on the respiratory center. However, the flexion and extension movements of the knee are caused by one's volition, and consequently, the influence of the cerebrum cannot be altogether neglected. Thereupon, an experiment was conducted in which the flexion and extension movements of the knee was caused by electrical stimulation, and it was found that even under these conditions breathing was also increased. Consequently, it may be thought that the respiratory center was excited by the sensory nerves in the muscles. Also, breathing may be increased by a rise in body temperature. Elevated blood temperature stimulates the respiratory center. Thus, respiration is influenced by the central nervous system, peripheral nervous system and also by various compounds which accumulate in the blood. Consequently, a good sportsman should train himself so that his breathing will be unaffected by these factors, and also well adapted to the sport.

Breathing has long been studied in Zen and Yoga as a means of promoting one's health and also for mental training. In athletics, breathing has been investigated from the standpoint of gaseous exchange. However, only a few reports are available regarding the relation between the various actions in each kind of sports and the respiratory phase. For instance, it has been found that at the crouching start in a running event, the pattern of breathing is somewhat inhibited and shallow at "on your marks"; in the next "ready", breathing shifts from the expiratory to the inspiratory phase; breathing then stops temporarily in this inspiratory phase and the athlete waits for the "go" signal. Also, a study of respiration in Judo has been made by Ikai (University of Tokyo). By using the "thorax recording method" and the "mask method", respiratory movements were recorded of the Tori and the Uke immediately before performing the technique during Seoi-nage, Tai-otoshi, or O-sotogari. Although differing slightly in the kind of technique performed, it was found that the respiration of the Tori, as he neared the moment of executing the technique, became accelerated and shallow, and respiration gradually shifted to the inspiratory phase. Immediately before executing the technique he held his breath after inspiring approximately 80% of the usual respiratory amount, and while shifting into the expiratory condition, and still holding his breath executed the technique. On the other hand, in the Uke, no definite pattern was noted, since the technique was performed while the Uke was in varying phases of respiration. However, the following common feature was noted in the Uke: a) when the technique was performed in the last stage of expiration, his breathing was inhibited in this phase, b) when the technique was performed at varying phases of inspiration, breathing was inhibited in that condition and while tending toward expiration, his respiration stopped temporarily. Interruption of breathing was pronounced when the Uke was offering strained resistance. However, when his attitude was passive, his breathing did not stop, but was only inhibited and tended toward expiration. In conclusion, Ikai states that respiration is inhibited in the expiratory state both in the Tori and in the Uke at the moment of execution of the throwing technique. Also, an analysis of the relation between respiratory phase and timing of the throwing technique in the Tori was made at the Sports Research Institute, Tokyo University of Education, by recording changes in respiration by means of a small thermister. The technique used was the O-goshi. Actually, the experiment was conducted under the following conditions.

**A. Signal to perform technique given randomly.**

- (1) Experimental subject made to perform technique by signal of "ready" and "start" given without notice.
- (2) Experimental subject made to perform technique by "start" after being notified to stay in a "ready" condition for some time, i.e., in a prolonged state of tension.

**B. Signal to perform technique given to experimental subject after preliminary notice.**

- (1) Signal of "start" given at the end of expiratory phase.
- (2) Signal of "start" given to experimental subject at the end of inspiratory phase.

**C. Experimental subject made to perform technique freely.**

In A (1) considerable tension of the sympathetic nervous system was observed after the signal "ready" was given accompanied by increased and shallow breathing as the subject passed into the tension stage, i.e., the stage of preparedness for the next move. Consequently, a marked inhibition in respiratory phase became evident. The technique was performed when the signal "start" was given, however in this case the experimental subject was not notified as to when the signal would be given. In spite of this, the technique was performed mostly in the inspiratory phase.

In A (2), i.e., the signal of "start" given unexpectedly after a prolonged period of tension, the respiratory phase in which the technique was executed varied in each case. When the technique had to be performed at the end of the expiratory phase, a short inspiratory phase followed by a short expiratory phase was observed directly prior to executing the technique. When the technique had to be performed at the middle stage of the inspiratory phase, a short expiratory phase followed by an interruption of breathing was observed just prior to performing the technique. The technique

was rarely performed at the start of the inspiratory phase.

In B (1), i.e., signal of "start" given at the end of the expiratory stage, a short inspiratory phase followed by a short expiratory phase preceded the interruption of breathing at the moment of performing the technique.

In B (2), i.e., signal of "start" given at the end of inspiratory stage, an immediate shift to the expiratory phase was noted directly preceding interruption of breathing and execution of the technique, thus showing a very smooth progress.

In C this relation was observed more distinctly.

From the foregoing, it may be concluded that the most suitable moment to execute the technique is at the end or the middle stage of the inspiratory phase or at the beginning of the expiratory phase. When the technique is performed at or near the peak of the expiratory phase, bodily movement is restricted and as a result the reaction time is delayed. Especially, at the end of the expiratory phase a shift to the inspiratory phase is required before the technique can be executed.

The present paper deals with a study of the changes in the respiratory pattern from the Kake (execution of the technique) to the Nage (throw) during performance of various throwing techniques. A respiration thermister was used and recordings made while the Judoists were performing the techniques. Simultaneously with these recordings, serial photographs were taken and the relationship between the various movements and the respiratory phase was analyzed. Also, a study was made to determine whether there was any difference in the mode of respiration between well trained athletes and non-trained individuals.

## METHOD OF INVESTIGATION

### 1) Materials.

As experimental subjects six members of the Judo Club of the Tokyo University of Education were selected, viz., Kadonaga III-dan, Kawasaki III-dan, Nakamura IV-dan, Kitai IV-dan, Shigeoka III-dan, and Sato III-dan. One member of the Kendo (Japanese fencing) Club of the same university was chosen as the control. Although a IV-dan holder in Kendo he was quite inexperienced in Judo.

### 2) Date and Locality.

The experiment was conducted in the laboratory of the Research Institute of Physical Education, University of Tokyo, from 10:00 a.m. to 3:00 p.m. on 1st (Friday) November, 1963. Four Judo Tatami (mats) were brought into the laboratory so that the experimental subjects could perform the required Judo techniques.

### 3) Recording Method.

The usual method of obtaining a respiratory curve has been by recording the expansion and contraction movements of the thorax. For this purpose, two methods have been used: a) air conduction method, and b) electric method. Before describing the thermister method used in the present study, a simple explanation of the two traditional methods will be given.

a) Air conduction method.—A thoracograph (an apparatus which transforms the contraction and expansion movements of the thorax into changes in air pressure within a rubber bag) is wrapped around the thorax and changes in air pressure are transmitted through a thick rubber tube to a Marey's tambour which records these changes in pressure on a kymograph. In another method a gas mask is used and air is led therefrom via a respiratory bottle into a large tambour which records changes in respiration volume on a kymograph (mask method).

b) Electric method.—The apparatus used consists of a flexible rubber tube filled with a saturated solution of zinc sulfate (Fig. 1). Zinc electrodes are inserted at both ends to form a circuit through which an electric current of low intensity is passed. Changes in pressure within the tube change the

conductivity of the zinc sulfate solution, which may be recorded on a direct current meter. When this rubber tube containing zinc sulfate solution is wrapped around the thorax the contraction and expansion movements accompanying breathing change the conductivity of the zinc sulfate solution in the tube causing changes in current flow which may be recorded by a galvanometer.

The mask method has the advantage of recording respiration volume and the standard of respiration, however, it is not adapted to prolonged measurements. Also, it has the disadvantage of restricting bodily movements to a certain extent. In the thoracic movement recording method, the tension of the thoracic muscles accompanying various actions interfere with recording of the respiratory curve, and consequently, is not suitable for recording respiratory pattern while the subject is moving. In order to obviate these difficulties the thermister which records only changes in temperature of respiratory air, was used in the present study.

c) Thermister Method.—The thermister consists of a semi-conductor made of a mixture of the oxides of nickel, cobalt, manganese and iron sintered at 1300°–1500°C. It is usually used as a resistance thermometer. In the usual bead type thermister the elements are enclosed in a glass tube, and consequently, although very slight, there is a time difference. In order to obviate this time difference, the glass tube was removed exposing the elements and in this state it was inserted into the nostril and fixed therein with an adhesive tape. The conductivity of the elements in the thermister is influenced by changes in temperature due to ventilation caused by respiratory movements. The fluctuation in temperature is recorded by an oscillograph. Fig. 2 illustrates the electrical circuit of a thermister. The techniques used in the study were Te-waza (Uki-otoshi, Seoi-nage, Kata-guruma), Koshi-waza (Uki-goshi, Harai-goshi, Tsurikomi-goshi), and Ashi-waza (Okuriashi-harai, Sasae-tsurikomiashi, Uchimata) totalling 8 feats, and 2 feats of the favorite technique of each experimental subject (see Table below).

Name of Judoist	Kind of Nage (throwing techn.)	Favorite techn.
Shigeoka	Te-, Koshi-, Ashi-waza	Seoi-nage, Kouchigari
Kitai	Te-, Koshi-, Ashi-waza	Seoi-nage, Tai-otoshi
Sato	Sasae-tsurikomiashi	Oсотogari Sasaetsurikomiashi
Kawasaki	Okuri-ashiharai	Okuri-ashiharai Renraku-waza
Nakamura	Te-, Koshi-, Ashi-waza	O-сотogari, Uchimata
Kadonaga	Harai-goshi	O-сотogari, Harai-goshi
Non-trainee	Uki-goshi, O-сотogari, Ippon-seoi, and Uchimata	

No particular restrictions were imposed on the experimental subjects as to when or how to perform the technique. Serial photographs were taken simultaneously with performance of the technique by a Nikon motor driven camera at the rate of 6 frames per second. In order to correlate these action photographs with the recordings, clappers with electrical contacts were used, and these clappers were closed at the moment of inception of action and opened at the moment of Nage (throw) so that the actions in the serial photographs coincided with the respiratory phase of the recordings (see accompanying Figs.).

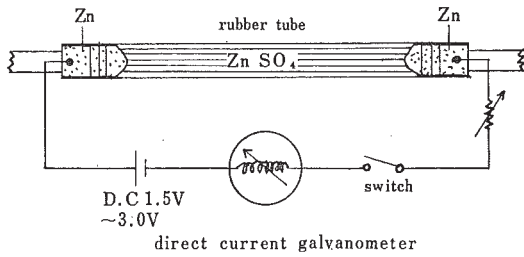


Fig. 1 Structure of the respiration band

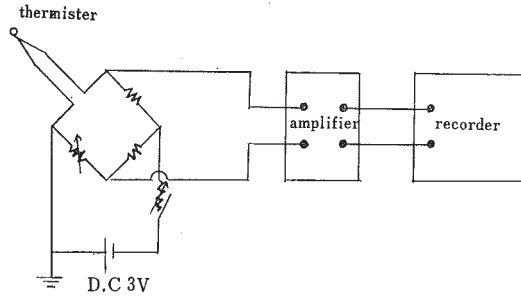


Fig. 2 Wiring of the thermister

**RESULTS AND DISCUSSION**

The amplitude and cycle of respiration at rest differ in each individual, however, there is a similarity in the pattern of respiration. We shall first consider the respiratory curve and the corresponding action photographs of the Tori while performing various forms of Nage.

**(1) Uki-otoshi (Kata)**

Compared to other techniques the movements are simple and the change in respiratory curve was not very remarkable. As shown in Fig. 3, the Tori's respiration shifts to the inspiratory stage with inception of action, and reaches the peak of the inspiratory stage during the Kuzushi (unbalancing the opponent) (Photographs 1 and 2). During the Kake (Photograph 3) he expires slightly, and coinciding with the action of drawing down the opponent he expires fully. Respiration is disturbed considerably after performance of the technique.

**(2) Seoi-nage (Kata) Fig. 4.**

The Tori executes the throw while holding his breath and taking hold of the Uke's attacking arm and unbalancing him toward the front corner (Photograph 2). He holds his breath from the moment of Kake (Photograph 3) to the termination of the throwing action. The timing of this Kake corresponds to the middle stage of the inspiration and, if we assume that the amplitude of respiration

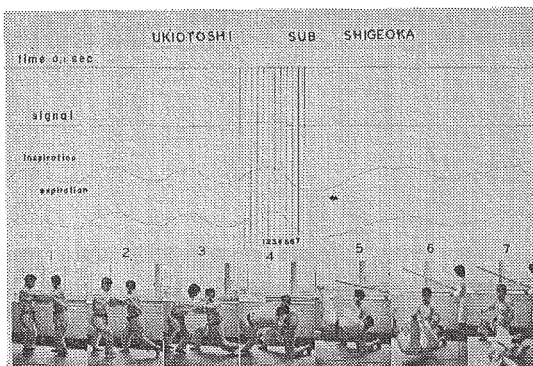


Fig. 3 UKIOTOSHI

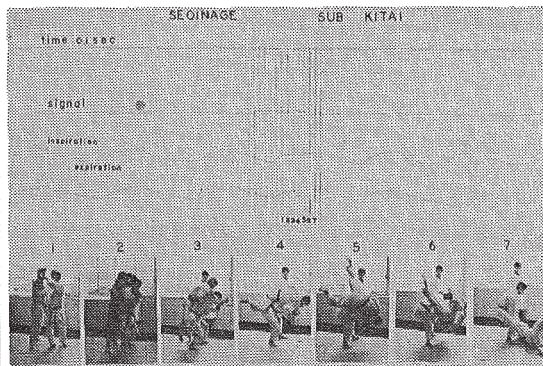


Fig. 4 IPPON-SEOI-NAGE

From top to bottom: time 0.1 sec, signal • initiation of action, • moment of "Nage", respiration curves are those of the "Tori" (crests indicate inspiration, troughs indicate expiration). Longitudinal lines synchronized with speed (0.17 sec) of serial photographs.

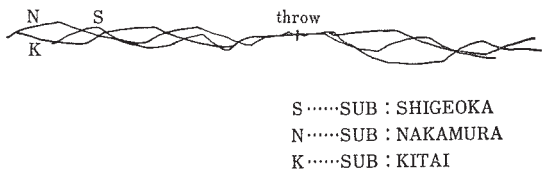


Fig. 5 IPPON-SEOI-NAGE (The forms of throwing)  
(crest: inspiration, trough: expiration)

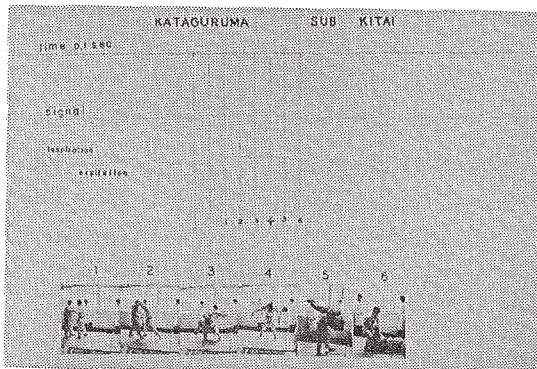


Fig. 6 KATA-GURUMA

and the amount of inspired air are in parallel relation to each other, then it is in agreement with Ikai's view that the technique is executed while holding breath after inspring 80% of the usual inspiratory volume.

It is evident from Fig. 5 that although the respiratory phase before performance of the technique differs in different individuals, it becomes almost identical at the moment of execution of the technique, i.e., the technique is executed while the breath is held in the middle stage of the inspiratory phase, and after termination of the throw breathing shifts fully into the expiratory phase.

(3) Kata-guruma (Kata) Fig. 6.

In the Kata-guruma as in the Ippon-seoi, the technique is executed while holding the breath in the middle stage of the inspiratory phase and remains in this condition until the throw is fully terminated. As shown in Fig. 7, although the technique is performed by a different Judoist the respiratory pattern at the moment of executing the technique remains identical. The duration of breath holding is prolonged during execution of Ippon -seoi and Kata-guruma in which the time of Kake is long.

(4) Uki-goshi (Kata)

Fig. 8 shows that the Tori unbalances the Uke and executes the technique while his respiration is held in an inspiratory state (Photographs 1-6). This is because the Uke in this case was already in an unbalanced state and the Tori did not require much effort to execute the throw, and consequently, did not hold his breath. Other experimental subjects held their breaths in the middle stage of the inspiratory phase when executing the throw. Fig. 9 shows the same Judoist performing the technique three times. The respiratory phase before the execution of the technique differed in each of the three performances, however, the respiratory pattern was identical from the Kake to the termina-

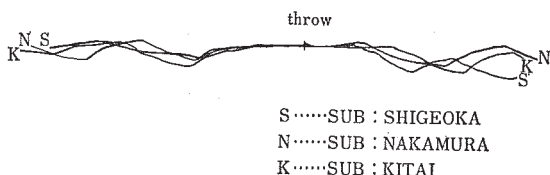


Fig. 7 KATA-GURUMA (The forms of throwing)

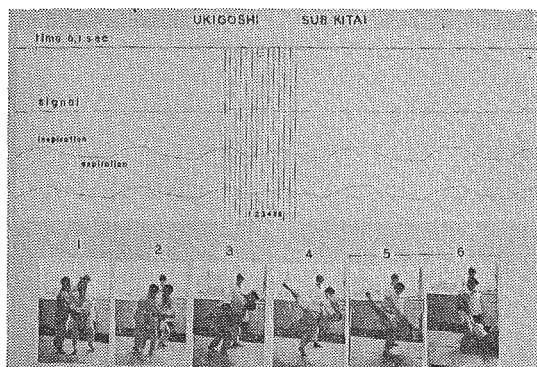


Fig. 8 UKI-GOSHI

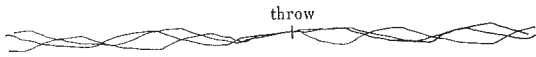


Fig. 9 UKIGOSHI (The forms of throwing)  
SUB: NAKAMURA

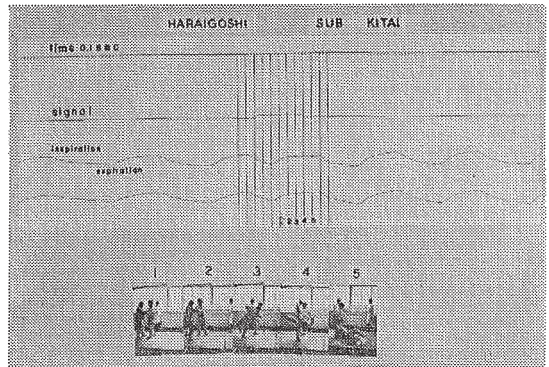


Fig. 10 HARAI-GOSHI

tion of the throw in all of the three performances. From this it is evident that the respiratory pattern during the Kake consistently shows the same pattern, and breathing is temporarily arrested, regardless of the respiratory pattern prior to execution of the throw.

(5) Harai-goshi (Kata)

Fig. 10 shows an example in which the throw is executed by the Tori while holding his breath in the middle stage of the inspiratory phase.

(6) Tsurikomi-goshi (Kata)

In Fig. 11 the Tori goes into the inspiratory phase as soon as he commences action, and unbalances his opponent while inspiring and holds his breath from the moment he executes the throw until he terminates the throwing actions. This Judoist holds his breath at the end of the inspiratory phase.

(7) Okuriashi-harai (Kata).

The special feature of this Kake as shown in Fig. 12 is that the respiratory movement is inhibited after entering the expiratory phase (Photograph 3). In some other examples, also, the technique was executed while respiration was in the expiratory phase. By making the same Judoist perform the same technique twice, it was found that he regulates his breathing just one respiratory cycle before executing the technique. Most probably, well trained Judoists are skillful in regulating their respiration. Fig. 14 illustrates the respiratory pattern of another Judoist performing the Okuriashi-harai, and it will be seen that in this case a considerable individual difference exists in the respiratory pattern during the Kake. From these findings it is thought that the shorter the time duration of the Kake the less stereotyped becomes the respiratory pattern while executing the Kake.

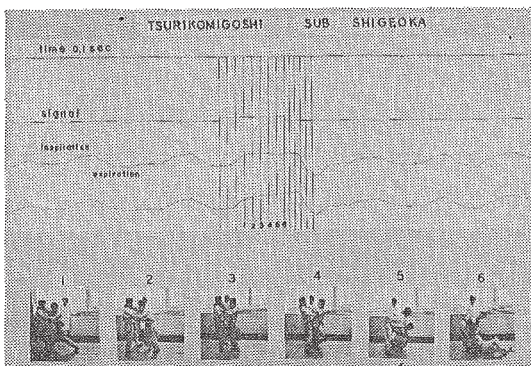


Fig. 11 TSURIKOMI-GOSHI

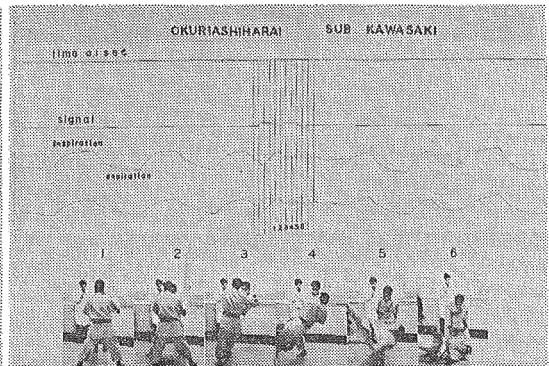


Fig. 12 OKURIASHI-HARAI

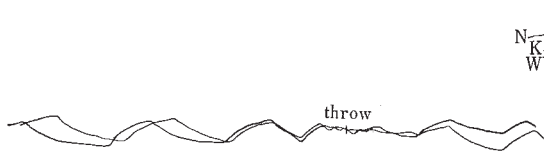


Fig. 13 OKURIASHI-HARAI (The forms of throwing) SUB: KAWASAKI

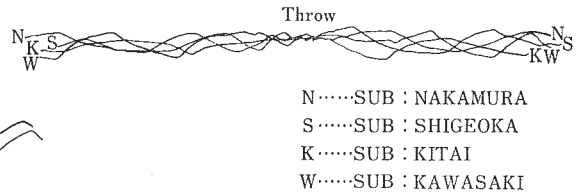


Fig. 14 OKURIASHI-HARAI (The forms of throwing)

(8) Sasae-tsurikomiashi (Kata).

As shown in Fig. 15 the Tori unbalances the Uke while in the inspiratory stage, and holds his breath in the terminal stage of the inspiratory stage, and executes the technique. Fig. 16 illustrates the respiratory curve of another Judoist performing the same feat (Sasae-tsurikomiashi), and it will be seen that the respiratory pattern from the Kuzushi to the termination of the throw takes on an identical form as the one shown in Fig. 15.

(9) Uchi-mata (Kata).

As shown in Fig. 17 the Tori is already holding his breath when he is pulling around the Uke and at the moment of the pull he expires slightly. At the moment of the Kake he again holds his breath, and at the time he executes the throw his respiration tends somewhat toward inspiration, and then completes the throw when he reaches the terminal stage of the inspiratory phase.

We have so far discussed on the respiratory curve of the Tori when he executes various throwing techniques. However, the performances were in the form of the Kata, and consequently the actions were to a certain extent standardized. As a result, the respiratory patterns of different Judoists performing the same technique tended to become identical. This tendency was very pronounced in techniques with a short time duration of the Kake.

We shall now consider the respiratory patterns of Judoists while performing their favorite techniques. In these performances different respiratory patterns were observed when different Judoists performed the same technique.

(1) Ko-uchigari (favorite technique).

As shown in Fig. 18 the Tori is holding his breath in the middle stage of the inspiratory phase,

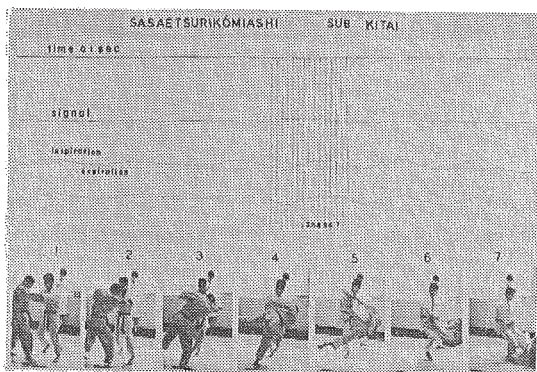


Fig. 15 SASAE-TSURIKOMIASHI

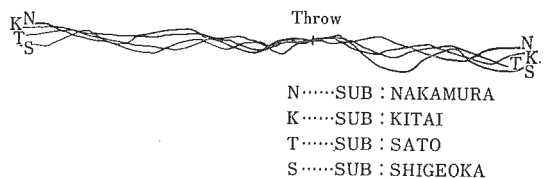


Fig. 16 SASAE-TSURIKOMIASHI (The forms of throwing)



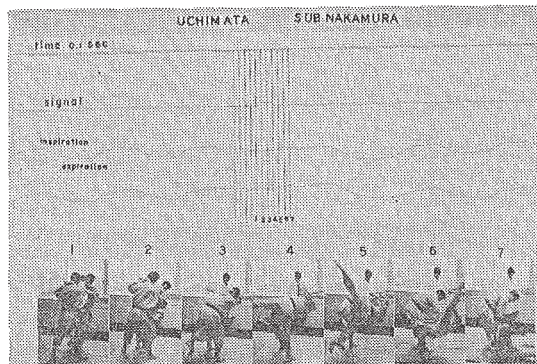


Fig. 17 UCHIMATA

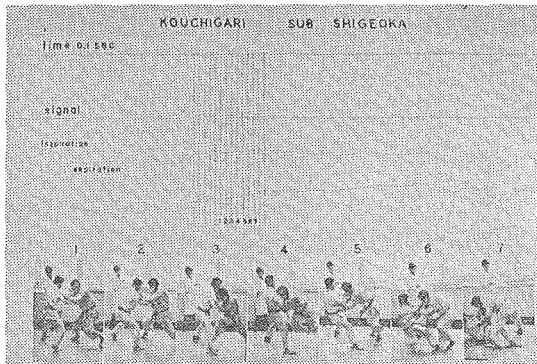


Fig. 18 KOUCHI-GARI

already at the time of starting action, and when he finds the chance to execute the technique shows restlessness. In this case the Tori fails to sweep his opponent's foot, and pushes the Uke toward the rear corner and keeps on holding his breath until he completely terminates the technique (see accompanying Photograph). On the other hand, in the case illustrated in Fig. 19, the Tori effectively sweeps his opponent's foot and his respiration during the Kuzushi, Kake and Nage shows a typical pattern, and expires fully upon completion of the technique.

**(2) Seoi-nage (favorite technique).**

The same Judoist who performed the Ko-uchigari performed the Seoi-nage illustrated in Fig. 20. The Tori holds his breath, already, before executing the technique and shows restlessness upon finding the opportunity for the Kake. The Kake (Photograph 1) is executed toward the terminal stage of the inspiratory phase and he shifts into the expiratory phase at the moment of execution of the throw (Photographs 3, 4, 5). This is thought to be due to the fact that the Tori's body is in anteflexion, thereby pressing his thorax. This tendency was not observed in the Seoi-nage performed in the Kata form, and consequently, the respiratory patterns in the two cases were not identical.

**(3) Osoto-gari (favorite technique).**

Fig. 22 illustrates performance of Osoto-gari. The Tori unbalances the Uke and plunges forward while his respiration is in the inspiratory phase, and executes the Kake by temporarily shifting into the expiratory phase after interrupting his inspiration in the middle stage of the inspiratory phase (Photographs 4, 5). The special feature in this case is that the Tori again shifts into the expiratory phase at the moment of Nage.

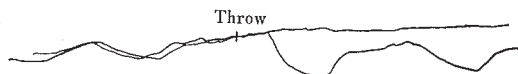


Fig. 19 KOUCHI-GARI (Favorite technique)  
SUB: SHIGEOKA

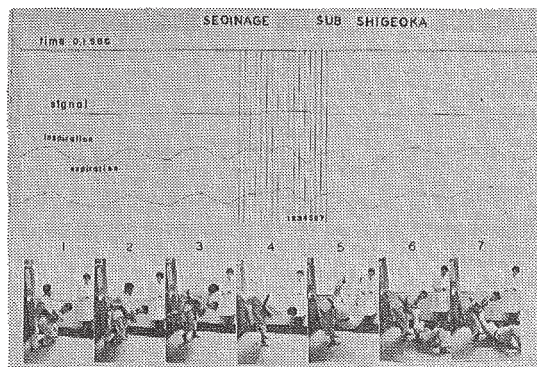


Fig. 20 SEOINAGE

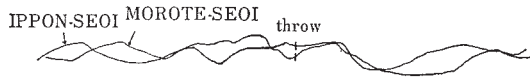


Fig. 21 IPPON-SEOI-NAGE  
MOROTE-SEOI-NAGE  
SUB: SHIGEOKA

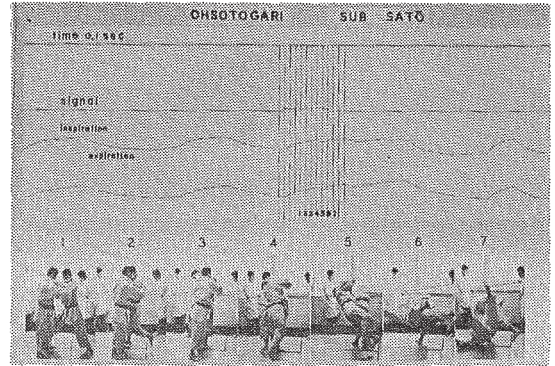


Fig. 22 OHSOTO-GARI

(4) Sasae-tsurikomiashi (favorite technique) (Fig. 23).

As the same Judoist who performed the O-sotogari was used in this case, a tendency to shift into the expiratory phase during the Kake may be seen. And, as in the Kata form of the throwing technique he holds his breath in the middle stage of the inspiratory phase when he executes the Kake.

(5) Uchi-mata (favorite technique).

As indicated in Figs. 24 and 25, in this performance unlike in the Kata form of the throwing technique, there is no necessity of pulling the Uke around, and consequently, the breath is not interrupted immediately before the Kake. During the Nage, breathing which had been interrupted by the Kake shifts into inspiration just as in the Kata form, and reaches the peak of the inspiratory phase.

(6) Harai-goshi (favorite technique).

In the Harai-goshi, also, as shown in Fig. 26 the respiratory patterns of the Kata form performance and the favorite technique performance are similar to each other from the Kake stage to the Nage stage.

(7) Renraku-waza (Ouchi-gari Uchimata)

As shown in Fig. 27, in the Renraku-waza, also, the Kake of the first Waza is performed while holding the breath in the middle stage of the inspiratory phase. The connection to the second Waza is made by once going into the expiratory phase and after reaching the middle stage of this phase shifts to the inspiratory phase and the technique is executed in this condition. The Renraku-Waza is less effective than the single Waza, and the reason for this inferiority is due to the fact that the Tori in the Renraku-waza before executing the second Waza shifts to the inspiratory phase without going completely to the last stage of the expiratory phase.

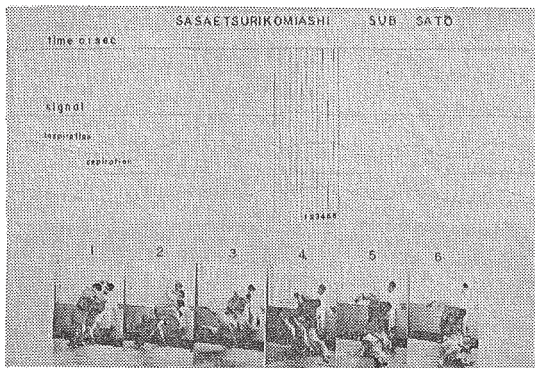


Fig. 23 SASAE-TSURIKOMIASHI

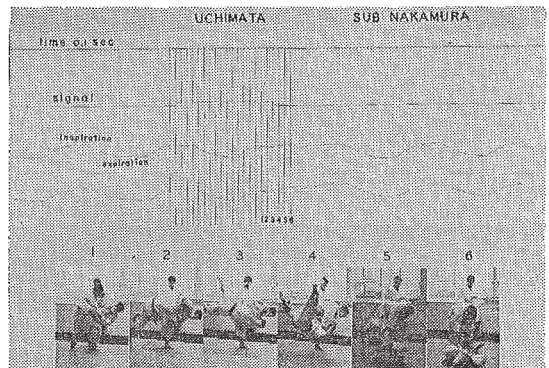


Fig. 24 UCHIMATA

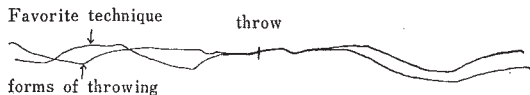


Fig. 25 UCHIMATA  
SUB: NAKAMURA

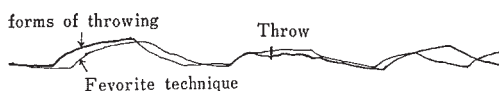


Fig. 26 HARAI-GOSHI  
SUB: KADONAGA

**(8) Performance by a non-trainee.**

In the non-trainee, also, the Tori unbalances the Uke in the inspiratory stage, and after inspiring 80% of the usual inspiratory amount holds his breath and executes the technique. Consequently, no significant difference in the respiratory pattern was seen between trainees and non-trainees. However, in the same Waza, when the respiratory phase preceding the Kake is different, sometimes a shift to the inspiratory phase is seen halfway in the expiratory phase (Fig. 28). This is thought to minimize the effect (speed and force) of the Waza as already described under Renraku-waza. In contrast to this the well trained Judoist regulates his respiration just before the Kake and executes the technique after going through the terminal stage of the expiratory phase. Although only one non-trainee was used in the present study, and consequently, no definite conclusion may be drawn, this regulation of breathing just before the Kake may be considered to be an important difference between trainees and non-trainees.

**CONCLUSION**

A study of the respiratory phase of the Tori during performance of various techniques was made. The techniques were performed in the Kata form and also freely by selecting the experimental subject's favorite technique. Results of the study may be summarized as follows:

- 1) In the Kata form of the Nage, the Kuzushi (unbalancing of the opponent) is performed while his respiration is in the inspiratory phase, i.e., he inspires while he unbalances his opponent.
- 2) The timing of the interruption of breathing during the Kake differs somewhat in different Judo-

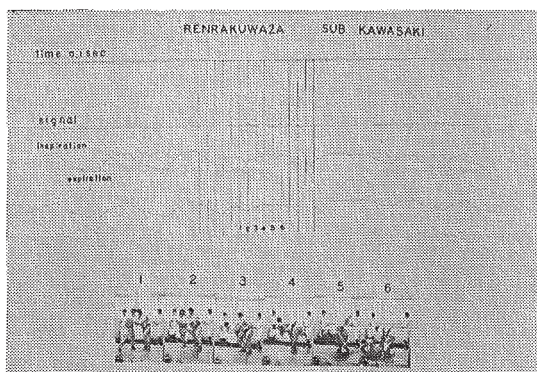


Fig. 27 27 RENRAKU-WAZA



Fig. 28 UKI-GOSHI  
SUB: KAGAYA (Non-trainee)

ists, and there are three types, viz., interruption of breathing in a) the middle stage of the inspiratory phase, b) the terminal stage of the inspiratory phase, and c) the inception of the expiratory phase. However, generally, most Judoists hold their breath in the middle stage of the inspiratory phase. Assuming that the amplitude of the inspiratory phase is in parallel relation to the amount of inspired air, most Judoists hold their breath after inspiring 80% of the usual inspiratory amount and then executes the throw.

3) In the Kata form of the throwing technique, breathing is interrupted from the *Kake* to the completion of the *Nage*, and after the action of the *Nage* is completed the *Tori* expires fully. The longer the time duration of the *Kake* the longer the interruption of breathing.

4) When the same technique is performed several times, regardless of the discrepancy in the respiratory phase preceding performance of the technique, almost identical respiratory patterns are observed from the *Kuzushi* to the *Nage*.

5) In the Kata form of the throwing technique, almost identical patterns of respiration are observed from the *Kuzushi* to the *Nage* when the same *Waza* is performed by different Judoists.

6) The respiratory patterns from the *Kake* to the *Nage* are identical in the Kata performance and in the favorite technique performance, however, the respiratory patterns differ during the *Kuzushi*. This is thought to be due to the fact that the inhibition of respiration before the *Kake* is stronger in the favorite technique performance than in the Kata performance.

7) In the *Renraku-waza*, an expiratory phase is inserted in the connecting period between the first *Waza* and the second *Waza*. The inferiority in effect of the *Renraku-waza* is thought to be due to the fact that a shift to the inspiratory phase is made before expiration reaches the last phase.

8) The timing of the interruption of breathing at the *Kake*, and the respiratory phase during execution of the technique were identical in the trainee and non-trainee. The difference lies in the regulation of breathing from the *Kuzushi* to the *Kake*.

A further study is being planned in order to elucidate the relation between execution of the technique and respiration, by recording the respiratory phases of the *Tori* and *Uke*.

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## 10. REGULATION OF RESPIRATION DURING NAGE-WAZA IN JUDO (2)

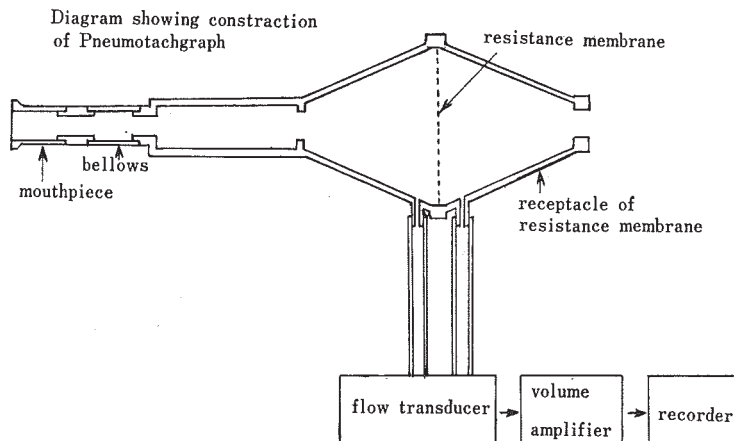
Y. Matsumoto, and T. Asami (Tokyo University of Education)

We presented a paper dealing with a study of the regulation of respiration during performance of Judo techniques at the 15th Convention of the Society of Physical Education. In the said study an investigation was made into the respiratory pattern during the series of action from Kuzushi (unbalancing the opponent), Tsukuri (preparatory action taken by the Tori against Uke in order to effect technique), Kake (execution of technique) to Nage (the throw) in a Kata (formal performance) performance of the throwing technique. A thermister was used to record the respiratory pattern and serial photographs were taken, simultaneously, in order to investigate the relation between the various actions and the respiratory pattern.

In the present study an investigation into the regulation of respiration during a Randori (free exercise) was made, and a pneumotachgraph was used in order to compensate for the deficiency of the thermister, thus enabling measurements of the respiration time, respiration velocity, and respiration volume besides the respiratory pattern.

### METHOD OF INVESTIGATION

A differential transformer was used as the transducer of the pneumotachgraph employed in the present study. As illustrated in the accompanying diagram, when the experimental subject is made to breathe into the mask connected to the mouthpiece the respiratory air current passes through the container holding the resistance membrane. When the air passes the resistance membrane a



difference in pressure is created. The difference in pressure is transformed into difference in electrical flow which in turn is recorded by an oscillograph.

The reliability of the current curve obtained by this method was certified by a compressor. In order to investigate whether the volume obtained by integrating the current curve was proportionate to the actual respiration volume, the air which passed through the pneumotachgraph was collected into a Douglas bag and was measured by a gas meter. As a result it was found that the two were proportionate to each other.

The experiment was conducted on 2nd August, 1964 in the Judo hall of the Tokyo University. The experimental subjects used in the study were one IV-dan Judoist and three III-dan Judoists, all members of the Judo Club of the Tokyo University of Education.

A mask connected to the pneumotachgraph was applied to the face of the experimental subject and he was made to perform the techniques freely in the usual manner.

Table 1

		4	3	2	1	breath- holding	1	2	3
respiratory time (sec)	inspiration	1.09	1.12	1.10	0.55	0.89		1.09	1.12
	expiration	1.26	1.24	0.87			0.70	1.15	1.13
velocity of respiration (cc/sec)	inspiration	1319	1305	1389	1615	0		1450	1454
	expiration	1065	1052	1260			1349	1245	1260
respiratory volume (cc)	inspiration	1178	1191	1157	642	0		1251	1310
	expiration	962	935	774			631	1021	1017

Table 2

order of shortness of breath-holding time (sec)	Ouchi-gari	De-ashi-harai	Tai-otoshi
	0.68	0.74	0.83
order of shortness of inspiratory time (sec)	Okuri-ashi-harai	De-ashi-harai	Ouchi-gari
	4.47	0.50	48
ratio to inspiration of 3 previous respiration (%)	44.3	48.5	0.51
order of smallness of inspiratory volume (cc)	Okuri-ashi-harai	Hiza-guruma	De-ashi-harai
	511	608	623
ratio of respiratory volume of previous respiration (%)	44.5	59.0	50.5
ratio of respiratory volume of 3 previous respiration (%)	41.5	60.5	53.0

A serial photographic record was taken from the moment of Kake by a camera equipped with an electrical contact point. Signals were indicated in the records for the convenience of interpreting the respiratory curves.

Because of technical difficulties measurements during performances of Seoi-nage and Tsurikomi-goshi were not possible and the techniques used in the study were limited to Hiza-guruma, Sasae-tsurikomi-ashi, Uki-goshi, Tai-otoshi, Harai-goshi, De-ashiharai, Okuri-ashiharai, O-sotogari, and O-uchigari. After a practice exercise, each technique was performed twice during which measurements were made.

## RESULTS AND DISCUSSION

The pneumotachgraphic curves of the experimental subjects at rest in a standing position and while grappling were plateau-like. The curves obtained immediately before and after Kake were dome-like or peak-like. Noteworthy changes were observed especially in the inspiration preceding the Kake and the expiration immediately preceding this inspiration, and also the expiration immediately following Kake. Of the 76 performances by the 4 experimental subjects the techniques were executed while holding breath in the inspiratory phase in 72 cases, and in the remaining 4 cases the techniques were executed while holding breath in the expiratory phase. The averages of respiration time, respiration velocity, and respiration volume during performances are indicated in Table 1. Table 2 shows the duration of inspiration time, and the volume of inspired air during the Kake of each technique.

Table 1 shows that the average breath holding time during the Kake was 0.89 seconds, the average inspiration time immediately preceding the Kake was 0.55 seconds and the average volume of inspired air was 642 cc.. Assuming that the inspiration time and volume preceding the Kake by three respiratory cycles represent the inspiration time and volume of the rest period, then the above values show decreases in 50% and 45% of the inspiration time and respiration volume, respectively. Among the nine techniques that were performed, those with short breath holding time were in the order of O-uchigari, De-ashiharai, Tai-otoshi, and Okuri-ashiharai. These techniques, it will be noticed, are those with short Kake time.

Table 2 (continued)

Okuri-ashi-harai	Hiza-guruma	Harai-goshi	Sasae-tsurikomi-ashi	Osoto-gari	Uki-goshi
5.87	0.90	0.93	0.94	0.99	1.15
Osoto-gari	Harai-goshi	Tai-otoshi	Sasae-tsurikomi-ashi	Hiza-guruma	Uki-goshi
0.53	0.54	0.55	0.57	0.59	0.70
51.5	50	51.5	46.8	49.5	65
Osoto-gari	Tai-otoshi	Osoto-gari	Sasae-tsurikomi-ashi	Harai-goshi	Uki-goshi
629	644	676	686	697	711
55.5	53.2	54.5	55.8	61.0	68.0
53.2	52.0	53.5	58.0	60.5	60.0

The techniques with short inspiration time immediately preceding the Kake were the foot techniques, such as, Okuri-ashiharai and De-ashiharai. The inspiration time was rather long in such techniques as the Uki-goshi or in the foot techniques which do not sweep the foot, but use it only as a support in throwing. Regarding the inspiration volume, also, the Ashi-harai showed the smallest value, and the Harai-goshi and the Uki-goshi showed the greatest value. These results indicate that the smaller the technique the more inhibited the inspiration directly preceding the Kake. Also, there is a tendency, in the smaller techniques, for the inspiration time to be shortened and the inspiration volume to be decreased before interruption of breathing, and in the larger techniques, as the action becomes larger, the inspiration time becomes longer and the inspiration volume larger.

Consequently, if we consider the decrease in respiration volume and respiration time in the interval immediately preceding the moment of execution of the technique as inhibition of respiration, then it may be said that there is more inhibition of respiration in the foot techniques than in the hip techniques. According to Takahashi, breath is held at 156% of the usual respiration volume at the moment of maximum grip strength, and at 143% of the usual respiration volume at the moment of maximum back strength, however, these are respiration amounts during measurements of muscle strength in a stationary condition and do not necessarily represent the respiration volumes in other sports. In the present study, it was found that breathing was interrupted after a respiration volume of approximately 55% of the volume at rest. However, as it is evident from the difference in respiratory volume between small techniques and large techniques, the intensity and speed of actions, and also the intensity of strength put into the actions greatly influence respiration, thus making a stereotyped explanation somewhat difficult.

#### CONCLUSION

1) By using a pneumotachgraph, the respiration time, respiration velocity and respiration volume were measured while the experimental subject was performing various Judo throwing techniques.

2) In 72 performances out of a total of 76, the Tori held his breath in the inspiratory phase at the moment of execution of the technique, and in 4 performances the breath was held in the expiratory phase.

3) The shortest breath holding time was recorded in O-uchigari (0.68 seconds), followed by De-ashiharai (0.74 seconds) and Tai-otoshi (0.83 seconds). The longest breath holding time was recorded in Uki-goshi (1.15 seconds). The average breath holding time was 0.89 seconds.

4) The average inspiration time immediately preceding execution of technique was 0.55 second and was found to be shorter by 50% of the value at rest in a standing posture. This reduction in inspiration time was the most pronounced in the foot techniques, such as, Okuri-ashiharai and De-ashiharai, and the least pronounced in the hip techniques, such as, Uki-goshi.

5) The average inspiration volume immediately preceding execution of technique was 642 cc., i.e., 55% of the value at rest. Just as in the inspiration time, the smallest values were those of the Okuri-ashiharai, De-ashiharai, and Tai-otoshi. The largest values were obtained in the Harai-goshi and Uki-goshi.

6) The average maximum respiration velocity immediately preceding execution of technique was 1615 cc/sec., and corresponds to 122% of the value at rest.

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