STUDIES ON "KANSETSU-WAZA"

(3) Physiologic Studies on "Kansetzu-waza", with Special Reference to the Reaction of the Nervous and Muscular Systems

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The term "Kansetsu-waza" (the art of bending and twisting the joints, bone-locks) in Judo is applied to a group of holds in which a joint of the opponent is held and fixed at an angle other than the optimum functional angle of that particular joint, thereby making it difficult for the muscle group which surround the joint to function efficiently, and thus enabling one to take an advantageous position over his opponent. A muscle group spanning a joint is capable of exhibiting its maximum efficiency, only when it is at its optimum length, and when the muscle is overstretched or contracted, its efficiency is very much hindered. In view of this fact, the "Kansetsu-waza" is of great interest physiologically—it is a technique by which one is able to hold his opponent in restraint without injuring the latter, a very ingenious application of physiologic restraint. However, in the performance of the "Kansetsu-waza" this condition is advanced one step farther, and by restraining free movement of the joint of the opponent, one assumes a position which enables him to apply the decisive blow. This is done by imposing on the joint whose free movement is restrained, a load in excess to its physiologic limit, as for example in the "Juji-katame" (Cross armlock), a condition of hyperextension, and in the "Ude-garami" (Entangled armlock), a condition of hyperextension and twisting are forced on the joint. Since the scope of motion forced on the joint exceeds its physiological limit, it naturally follows that pain is felt in the joint. This is accompanied by overstretching of the ligament, and if the process is carried farther, injury to the bone may result. However, when actually performing the technique there is no intent of causing injury to the joint; the main object is to restrain free movement of the opponent, so that when the "Uke" (the individual on whom the technique is performed) feels pain in the joint he realizes that he is overcome, and the "Tori" (the performer of the technique) also realizes that his technique has taken effect, and so immediately lets go his hold. In Judo as a sport it is not desirable to go further than the point where the "Uke" feels pain. However, sometimes the whole process of the technique proceeds too rapidly for either the "Uke" or the "Tori" to realize the danger point, thereby causing undue hyperextension of the joints, or some other unphysiologic effect. For this reason it becomes necessary to clarify the effect upon the human body when these conditions are imposed on the joints. The present study was undertaken with the view of investigating particularly the effect on the nervous and muscular systems.

METHOD OF EXPERIMENT

Two methods of experiment were employed: In one method, the "Tori" performed the "Kansetsu-waza" on the "Uke" who sat in a semi-supine position with the right arm on a supporting pedestal. In the other, the "Uke" took the same posture, but instead of the "Tori" performing the armlock, the elbow of the "Uke" was fixed as the fulcrum, and a mechanical load applied on the distal end of the arm. By the former method, an experimental condition very similar to that of the actual performance of the technique may be simulated, and by the latter method the relationship between the amount of load and the various physiologic changes which occur may be investigated.

Method I. Actual Performance of the "Kansetsu-waza"

Five Judoists (Sugiyama, Takamizawa, Kobayashi, Sato, and Yamagishi) were selected as the "Uke", and Y. Matsumoto (VIII Dan) performed the armlock. Four kinds of "Kansetsu-waza" were performed, and these were divided into performances in which the "Uke" offered resistance and in which the "Uke" did not offer resistance.

No. 1–2 Cross armlock, Type 1, without resist.; with resist.
No. 3–4 " " " 2, " " " "
No. 5–6 Entangled arml., Type 1, without resist.; with resist.
No. 7–8 " " " 2, " " " "

Cross armlock, Type I, was performed in a way so that hyperextension of the elbow would be produced with the palm of the hand facing up. Cross armlock, Type 2, was performed in a way so that hyperextension of the elbow would be produced with the thumb pointing up. Entangled armlock, Type 1, was performed in a way so that the arm would be twisted outward with the hand in supination, and the elbow joint flexed at an angle of approximately 90°. Entangled armlock, Type 2, was performed in a way so that the arm would be twisted inward with the hand in pronation, and the elbow joint flexed at an angle of approximately 90°. During performance of the technique, circular pad electrodes, 10 mm. in diameter, were placed at 3 cm. intervals, in line with the direction of the muscle fibers, on the skin over the deltoideus, biceps, triceps, flexor carpi radialis, and extensor carpi radialis muscles. From these electrodes the action current of the muscles was led through an amplifier to an apparatus which recorded the EMG. Simultaneously with this procedure, EEG was taken from lead electrodes applied to the frontal and occipital regions, and from an indifferent electrode placed on the earlobe. Also, ECG was taken from electrodes placed on the upper part of the sternal region, and on the region of the apex beat. Respiratory movement was also investigated by wrapping around the thorax a rubber tube filled with copper sulfate solution through which an electric current was passed, and the changes in electrical resistance of the solution due to respiratory movement were recorded.

The relative positions of the "Tori" and the "Uke" were as follows: The "Tori" sitting on one side of the "Uke" held the latter's right arm, whilst with the former's right hand fixed the "Uke's" upper arm, and held the "Uke's" forearm or hand with his right hand. This was the preliminary posture, after which the signal "Ready" was given, at which both parties got ready for the performance. At the signal "Begin", the "Tori" began to perform the armlock and continued until the "Uke" gave the signal "I surrender", at which the "Tori" immediately released his hold.

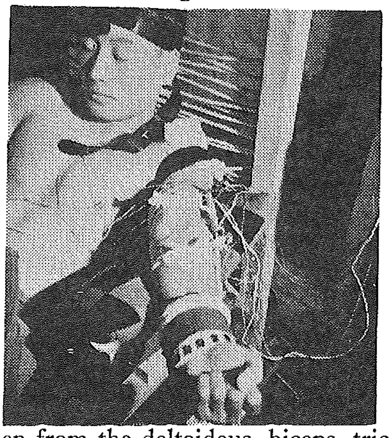
Method II. Application of Mechanical Load

In this procedure, instead of the "Tori" performing the armlock, a mechanical load was applied to the arm of the "Uke" to simulate the conditions of the cross armlock, Types 1 and 2, with and without resistance (following table)

No. 1–2 cross armlock, Type 1, without resist.; with resist..
No. 3–4, " " " 2, " " " "

The "Uke", i.e., the experimental subject was made to sit on an experiment chair, his shoulder firmly fixed, and with the elbow joint as the fulcrum, the arm from the shoulder was held horizontally. In this position the tension of the cable attached to the cloth belt around the wrist was gradually increased in order to produce hyperextension of the elbow until the signal "I surrender" was given by the "Uke". The reading at this moment, on the cable tensiometer was converted into kilograms by reference to a conversion table. Simultaneously with this procedure, EMG, EEG, and ECG studies together with an investigation on the psychogalvanic phenomenon were made; also, the angle of the elbow joint was measured.

Fig. 1



EMG recordings were taken from the deltoideus, biceps, triceps, flexor carpi radialis, and extensor carpi radialis muscles. EEG was recorded from leads placed on the frontal, parietal, and occipital regions. ECG was recorded by using the chest lead V_4. Psychogalvanic phenomenon was studied by using an electroencephalograph with electrodes placed on the dorsum and the palm of the hand.

By connecting an recorder to an electrogoniometer, changes in the angle of the elbow joint were recorded. The maximum load which the hyperextended elbow joint could tolerate (critical load) was measured by means of a cable tensiometer. The maximum arm strength when the elbow was flexed at 90° was also measured by means of a cable tensiometer. Furthermore, the time required for the armlock to take effect, i.e., the time between the signals "Begin" and "I surrender" was measured. The following Judoists participated as experimental subjects in the mechanical load experiment: Nakazawa (II Dan), Hamano (II Dan), Miyakozawa (II Dan), Haga (III Dan), Takamizawa (III Dan), Kataoka (IV Dan), Sato (IV Dan), and Asami (IV Dan). Their ages ranged between 18 and 25 years.

RESULTS OF EXPERIMENT

The results of the experiment may be divided into two groups: 1) Bodily changes which occur in the "Uke" during performance of the "Kansetsu-waza". 2) Results of measurements of the various factors which determine the tolerance of the "Uke" during preformance of the "Kansetsu-waza".

I. Physiologic Changes

1) EMG.

a) Actual performance of the "Kansetsu-waza". In the cross armlock, Type 1, without resistance, the greatest discharge was observed in the EMG of the biceps muscle, followed by the EMG of the flexor carpi radialis and the deltoideus muscle, whilst no discarge was observed in the EMG of the triceps and the extensor carpi radialis muscle (Fig. 2). In the cross armlock, Type 1, with the "Uke" resisting, markedly increased discharges were observed in the EMG of both the biceps and flexor carpi radialis muscles; and discharges were also observed in the EMG of the deltoideus, triceps, and the extensor carpi radialis muscle (Fig. 3). In this case the palm of the hand was facing up, and consequently, the full force of the load seemed to be on the flexor muscles. Conditions were somewhat different in the cross armlock, Type 2. When the "Uke" offered no resistance, very little discharge was observed in the EMG, and that only in the EMG of the biceps. When the "Uke" was resisting, somewhat marked discharges were observed in the EMG of the biceps and the flexor capri radialis muscle, however, only slight discharges were observed in the EMG of the triceps and the extensor capri radialis muscle. In Type 2 the flexor aspect of the elbow joint was facing up, and the thumb was also pointing up, thereby putting the forearm in pronation. Consequently, in this case the effect of the load was felt in the small muscle group and the ligaments relating to the wrist joint, rather than in the previously mentioned four muscles.

In the entangled armlock, Type 1, without resistance, marked discharge was observed in the EMG of the biceps muscle, and only weak discharges were observed in the EMG of the other three muscles. In Type 1, with the "Uke" resisting a similar phenomenon was observed, i.e., the discharge observed in the EMG of the biceps was the greatest, followed by that of the flexor carpi radialis, and then by those of the deltoideus and triceps muscles. In this case the arm was flexed at the elbow joint and supination was strongly forced upon the forearm.

In the entangled armlock, Type 2, without resistance, besides marked discharge in the EMG of the biceps muscle, strong discharge was also observed in the EMG of the deltoideus muscle followed in order by those of the triceps and the flexor carpi radialis muscle, but no discharge was observed in the EMG of the extensor carpi radialis muscle. In Type 2, with the "Uke" resisting a somewhat similar phenomenon was observed, but in this instance the discharge in the EMG of the deltoideus was the greatest. In this case, the arm was flexed at the elbow joint and pronation was strongly forced upon the forearm.

b) Application of mechanical load. In the cross armlock, Type 1, without resistance, marked discharge was observed in the EMG of the biceps, however, no discharge was observed in the triceps, flexor carpi radialis, and extensor carpi radialis muscles. In contrast to this, when the "Uke" was resisting (Fig. 5), marked discharges were observed in the EMG of the biceps and flexor carpi radialis muscles. Discharges were also observed in the EMG of the extensor carpi radialis and triceps muscles. This condition very closely resembled that of the experiment in which the cross armlock was actually performed.

In the cross armlock, Type 2, without resistance (Fig. 4), no discharge was observed in the EMG except in that of the biceps muscle. When the "Uke" was resisting, the most marked

Fig. 2 EMG, EEG and ECG in actual performance of cross armlock.

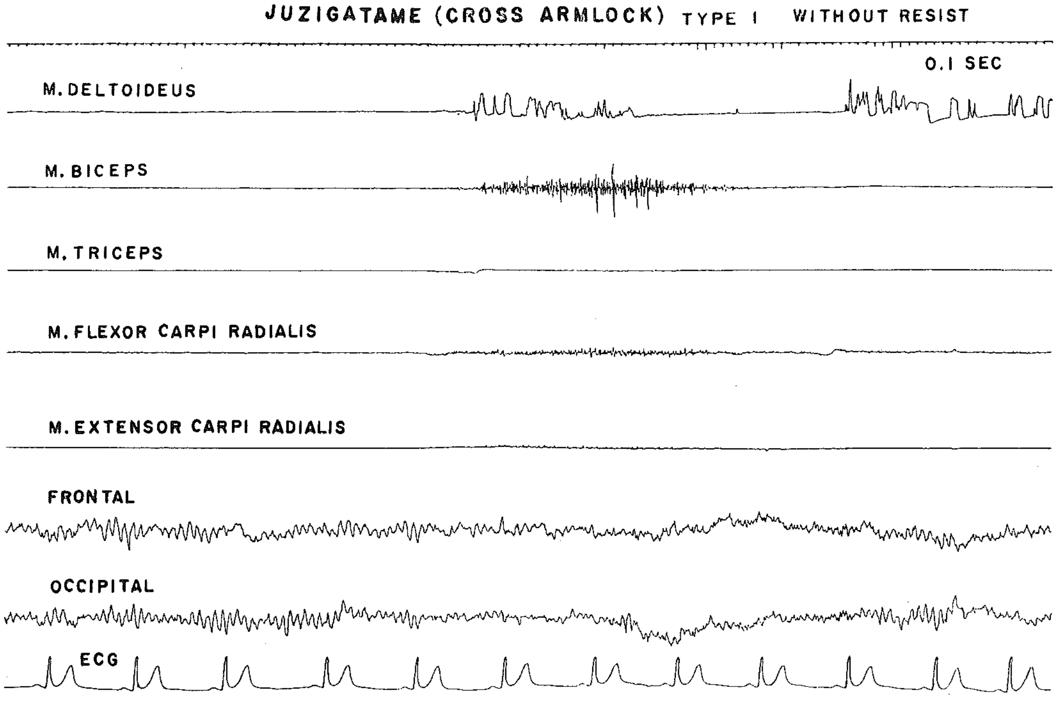
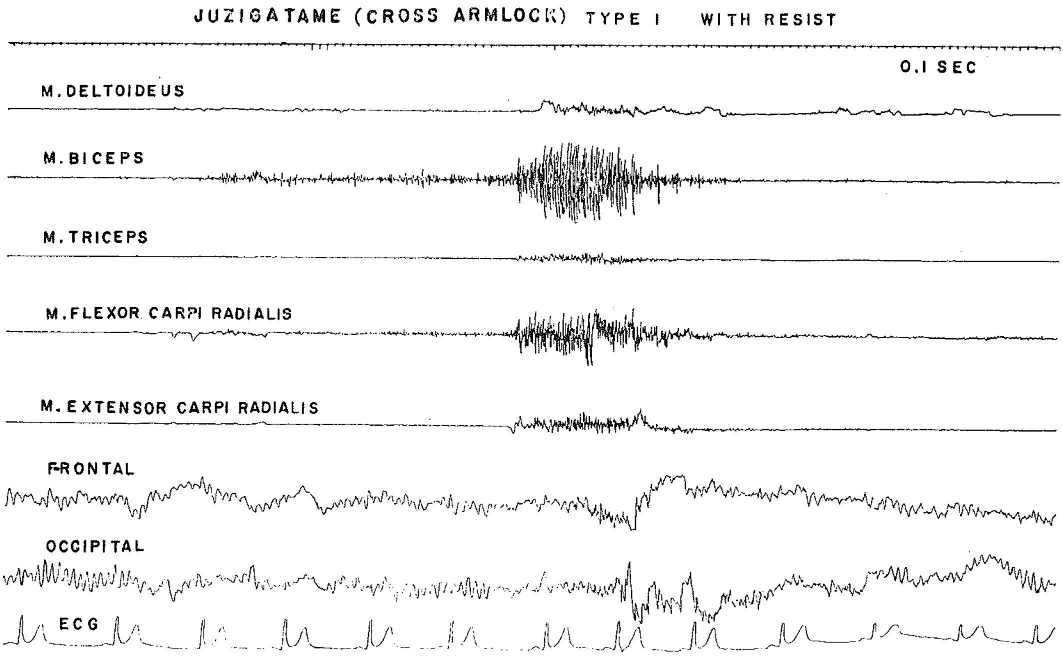


Fig. 3 EMG, EEG and ECG in actual performance of cross armlock.



Ffg. 4 EMG, EEG, ECG, PGR and goniometer (G) in mechanical performance of cross armlock.

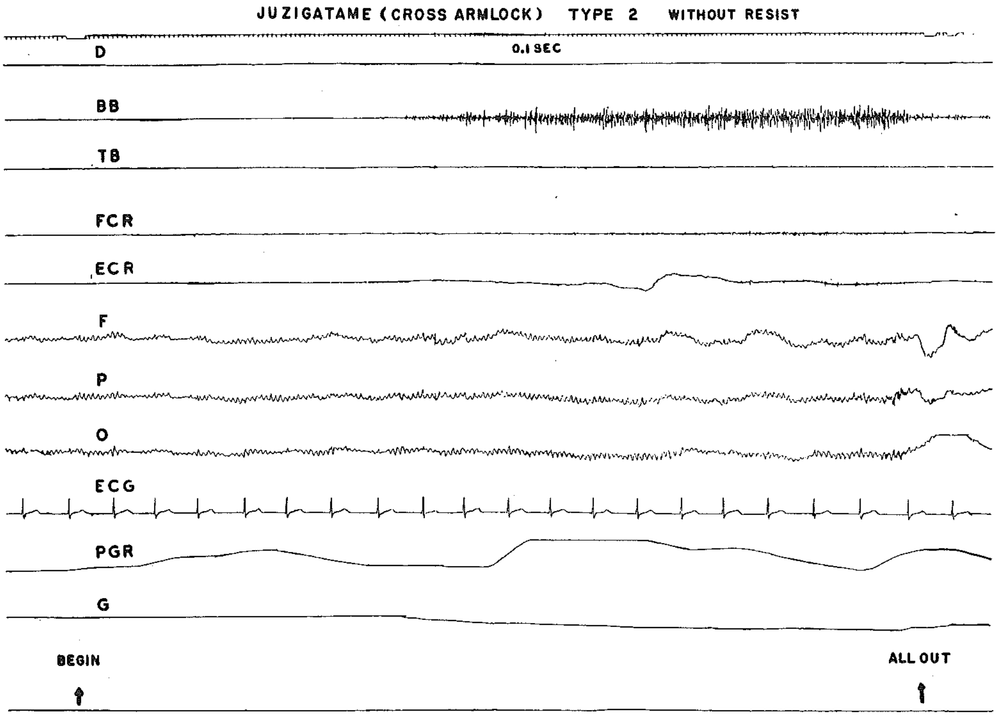
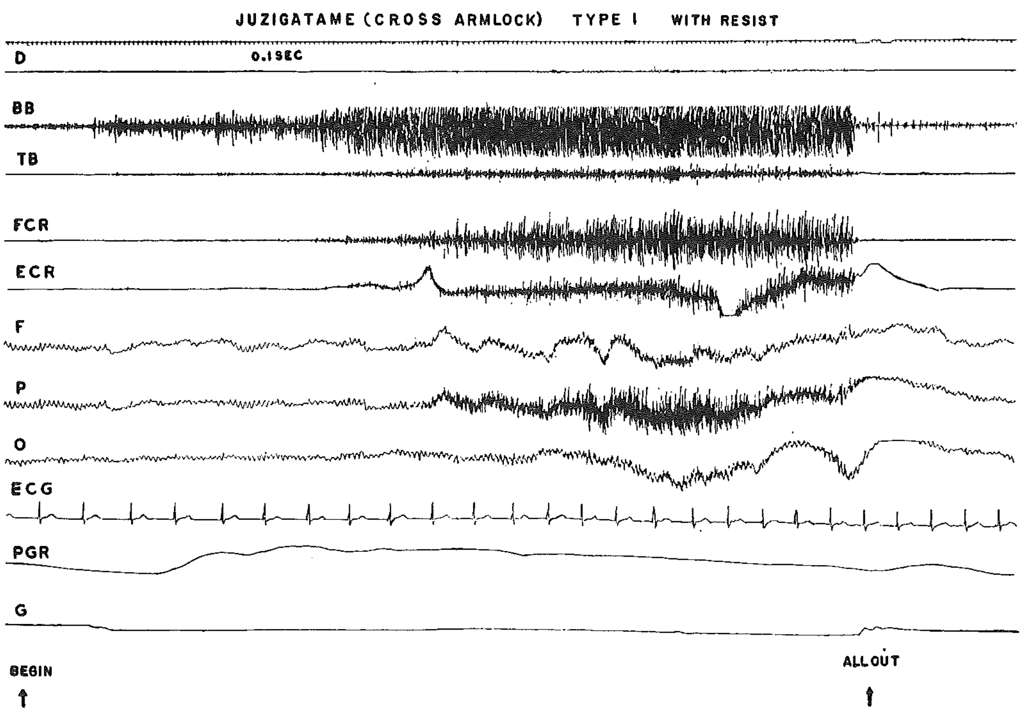


Fig. 5 Same as Fig. 4.



discharge was observed in the EMG of the biceps muscle, followed in order by that of the flexor carpi radialis muscle. Slight discharge was observed in the EMG of the extensor carpi radialis muscle, however, none was observed in that of the triceps muscle. In this case also the EMG findings were very similar to those of the experiment in which the cross armlock was actually performed. Entangled armlock was not simulated in the experiment using mechanical load.

2) EEG.

a) Actual performance of the "Kansetsu-waza". Changes in EMG findings of all the experimental subjects showed common tendencies, however, the EEG findings of each experimental subject showed much individual difference. Here, we shall discuss on one example (Fig. 2 and 3). EEG was taken with the experimental subject in a sitting position, and with his eyes closed. Monopolar leads placed on the frontal and occipital regions were used.

In the cross armlock, Type 1, without resistance (Fig. 2), the continuous alpha waves which had been observed until the signal "Ready" rapidly disappeared thereafter, and were replaced by beta waves. This condition lasted until 2–3 seconds following the signal "I surrender" after which alpha waves reappeared and alternated with beta waves for a period of a little over 10 seconds. This was followed by the appearance of continuous alpha waves. In the experiment in which the "Uke" resisted (Fig. 3), alpha waves sometimes disappeared and were alternated by beta waves even before the signal "Ready" was given. When the signal "Begin" was given, alpha waves rapidly disappeared, and at the time when the signal "I surrender" was given, waves with higher frequencies were observed. For a while after the "Tori" let go his hold, beta waves were predominant, however, thereafter, alpha waves reappeared.

In the cross armlock, Type 2, without resistance, alpha waves became scarce and were replaced by beta waves in the interval following the signal "Begin", however, after the signal "I surrender", alpha waves began to reappear and replaced the beta waves. In the experiment in which the "Uke" resisted, alpha waves disappeared and were replaced by beta waves even from the time the signal "Ready" was given. However, it is noteworthy that directly before the signal "Begin" was given, alpha waves were markedly observed in the EEG of the frontal and occipital regions, and by the time discharges were observed in the EMG during performanec of the technique, alpha waves disappeared and were replaced by beta waves. At the time the signal "I surrender" was given, the EEG revealed increased voltage and frequency. A few seconds following release of the hold by the "Tori" alpha waves reappeared.

In the entangled armlock, Type 1, without resistance, following the signal "Ready" and preceding actual performance of the technique, alpha waves were on the decrease, however, directly before the signal "Begin" there was a period in which alpha waves were markedly observed. This period corresponded to the intermediate period between the signals "Ready" and "Begin". In the experiment in which the "Uke" offered resistance alpha waves disappeared following the signal "Ready", however, alpha waves reappeared 2–3 seconds thereafter, and directly preceding the signal "Begin". Alpha waves disappeared and were replaced by beta waves by the time an increase was observed in the EMG due to performance of the armlock, however, 2–3 seconds following the signal "I surrender" alpha waves reappeared. In the entangled armlock, Type 2, without resistance, beta waves were observed even from the time the signal "Ready" was given. In the experiment in which the "Uke" offered resistance, the beta waves which had already replaced the alpha waves before actual performance of the armlock were in turn replaced by alpha waves, momentarily, directly preceding actual performance of the armlock, however, performance of the armlock caused beta waves to reappear.

From the foregoing observations, the following characteristics in EEG may be recognized: Alpha waves are replaced by beta waves during performance of armlock, regardless of the kind of armlock employed, and sometimes waves with higher frequency and voltage are also observed. After releasing the hold, beta waves continue to appear for 2–5 seconds, and are replaced by alpha waves. Also, after the alpha waves disappear following the signal "Ready", they reappear, momentarily, and markedly, directly preceding actual performance of the armlock.

In the case of the experimental subject, Sato, alpha waves were also observed, and were replaced by beta waves directly preceding actual performance of the armlock. When the armlock was put into effect, these were replaced by high voltage waves.

In the case of Sugiyama, large alpha waves were observed, and although these were replaced by beta waves in the interval preceding actual performance of the armlock, alpha waves were also momentarily observed, directly before the armlock was put into effect. After 1–2 seconds following the signal "I surrender", alpha waves rapidly reappeared.

In the case of Takamizawa, alpha waves were generally small, and in the interval preceding actual performance of the armlock, beta waves became the predominant feature. During performance of the armlock, these beta waves were replaced by waves with high frequency and voltage. Over 30 seconds were required for the alpha waves to reappear, following the signal "I surrender."

In the case of Kobayashi, alpha waves were frequently observed, especially in the interval directly preceding performance of the armlock. During performance, waves with high frequency and amplitude were observed, and were seen until 2–3 seconds after the "Tori" let go his hold, after which alpha waves were again observed.

b) Application of mechanical load. In this case, as shown in Fig. 4 and 5, EEG of the frontal (F), parietal (P), and occipital (O) regions were studied. The experimental subjects were in a sitting posture with their eyes closed.

In the case of the cross armlock, Type 1, without resistance, alpha waves were predominant, but as the load was increased with resulting oscillation of psychogalvanic phenomnon waves, the alpha waves became interrupted. However, when the load was further increased, alpha waves were again observed, and directly before (1–2 sec.) the signal "I surrender" was given, beta waves and fast waves were observed in the frontal and parietal areas. Alpha waves disappeared, and beta waves became predominant in 2–3 seconds following the signal "I surrender". At the time the signal "I surrender" was given, the psychogalvanic reaction waves were greatly oscillating.

In the case of cross armlock, Type 1, with the "Uke" resisting (Fig. 5), interruption of alpha waves which were alternated by beta waves were also observed in the frontal, parietal, and occipital areas following oscillation of psychogalvanic phenomenon. As the load was further increased, waves of high frequency and voltage were observed. Directly after releasing the load in response to the signal "I surrender", beta waves were observed, but were replaced by alpha waves in 1–2 seconds.

In the case of cross armlock, Type 2, without resistance (Fig. 4), alpha waves alternated periodically with beta waves during the interval when psychogalvanic phenomenon waves were observed, however, alpha waves were still observed in the interval directly preceding the signal "I surrender". Directly following release of the load beta waves were the predominant feature.

In the case of the cross armlock Type 2, with the "Uke" resisting, there was an interval in which a few beta waves were observed in the early stage of the application of the load. As the load was increased, and by the time oscillation of psychogalvanic phenomenon and increased discharges in the EMG were observed, high frequency and high voltage waves were observed in the EEG. Also, marked increase in voltage and frequency of waves were observed in the parietal areas. This tendency was also observed in the previous experiment (Cross armlock, Type 1, with resistance). Directly after the signal "I surrender", beta waves were predominant, however, alpha waves began to appear in 2–3 seconds and alternated with beta waves.

From the foregoing results the following tendencies may be recognized: In comparison to the experiments in which the armlock was actually performed, changes in EEG were not very marked in the mechanical load experiment, especially when the "Uke" was not resisting, and alpha waves could be observed almost to the time the signal "I surrender" was given. This may be due to the fact that the manner in which the load was applied was rather slow. As noteworthy changes, periodic interruptions of alpha waves by beta waves were observed, as the load applied was increased. Of the eight experimental subjects, very little change was observed in two, periodic alternations of alpha and beta waves were observed in two, and high voltage and high frequency waves were observed in four subjects. In all the experimental subjects, beta waves were predominant in the interval 2–3 seconds directly following the signal "I surrender".

3) Psychogalvanic Phenomenon

In the mechanical load experiments, psychogalvanic reaction was investigated. Electrodes were placed on the dorsum and palm of the hand. In most experimental subjects, oscillations were observed even before the load was applied, and with increase in the load the oscillation also increased in intesity disclosing emotional excitement. The oscillations rapidly ceased following release of the load. In both Types 1 and 2 of the cross armlock, oscillations were more intense when the "Uke" was resisting; also, oscillations were more intense in Type 1 (palm of hand facing up) than in Type 2 (thumb pointing up). Very little change in psychogalvanic phenomenon was observed in those subjects who showed only slight changes in EEG.

4) Respiratory Movement

Respiratory movement was recorded only in the experiments in which the armlock was actually performed. With the inception of the armlock, breathing stopped in inspiration, and directly following release of the armlock the subject expired for an instant after which respiration became augmented for a while, and then gradually resumed normal rhythm. The time required to resume normal rhythm was about 5–6 seconds.

5) Heart Beat Interval

a) During actual performance of armlock. Changes in heart beat interval during performance of armlock was investigated by means of an electrocardiograph using chest leads. Individual results were as follows: In Sugiyama's case (Fig. 6), minimum heart beat interval was observed during performance of the armlock. However, as the performance was being repeated several times, decreased heart beat interval began to be observed even before actual performance of the armlock. Generally after releasing the hold, normal heart beat interval was rapidly resumed. In Yamagishi's case (Fig. 7), rapid decrease in heart beat interval was observed at the moment of inception of cross armlock, Type 1, however, normal interval was resumed soon after releasing the hold. In cross armlock, Type 2, very little change was observed, however, marked bradycardia was observed after releasing the hold. As other types of armlock (entangled armlock, Types 1 and 2) were being performed one after the other, decreased heart beat interval began to be

Fig. 6 Actual performance

SUGIYAMA (4 Dan) HEART BEAT INTERVAL

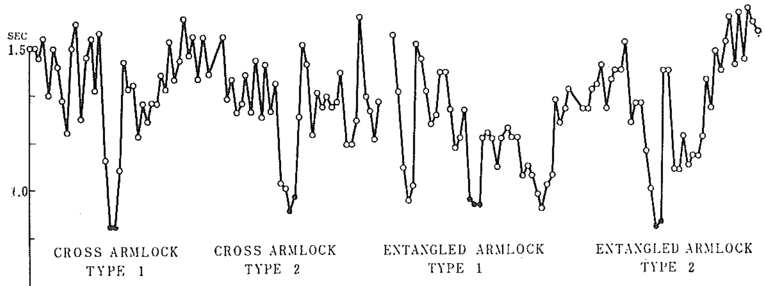


Fig. 7 Actual performance

YAMAGISHI (4 Dan) HEART BEAT INTERVAL

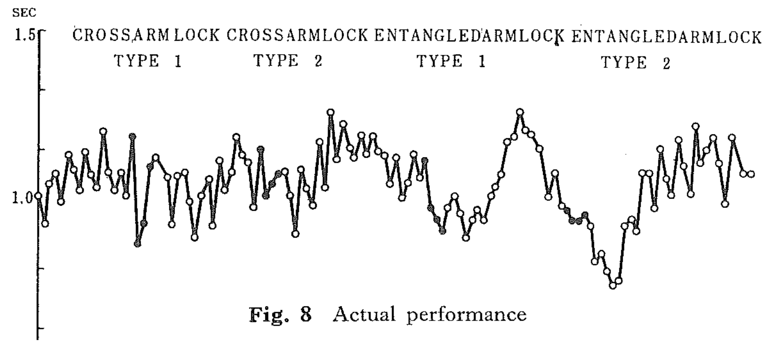


Fig. 8 Actual performance

TAKAMIZAWA (3 Dan) HEART BEART INTERVAL

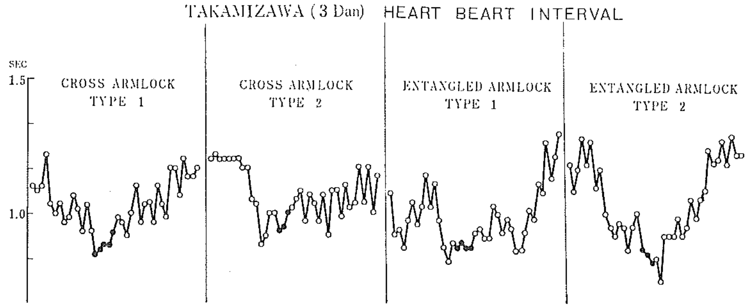


Fig. 9 Actual performance

SATŌ (3 Dan) HEART BEAT INTERVAL

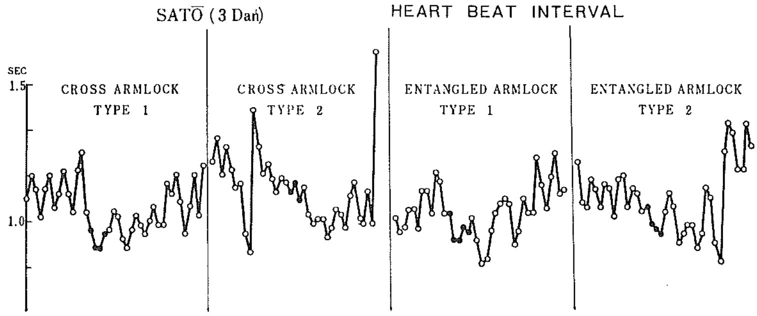


Fig. 10 Mechanical performance

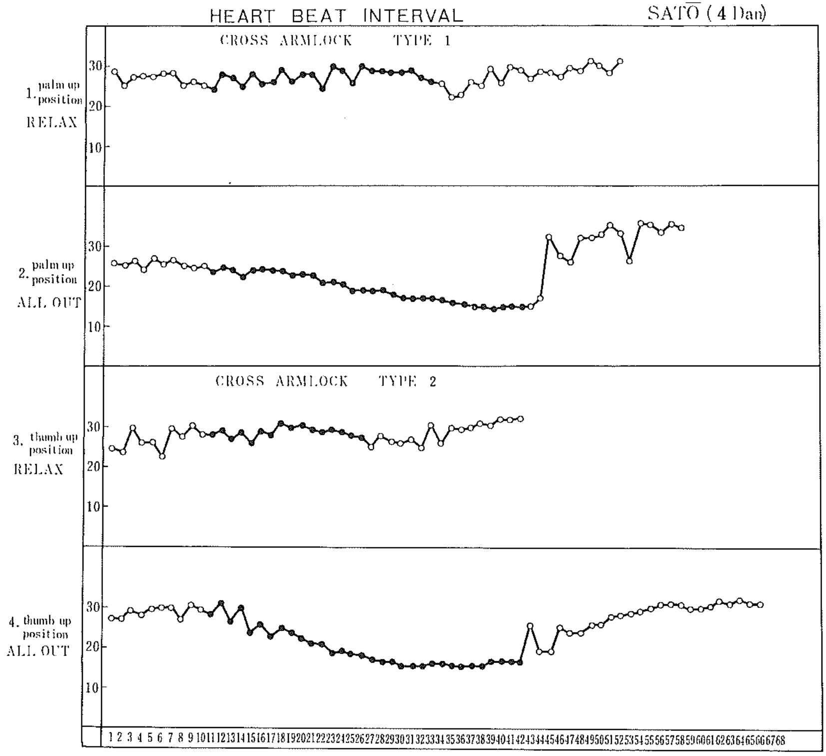


Fig. 11 Mechanical performance

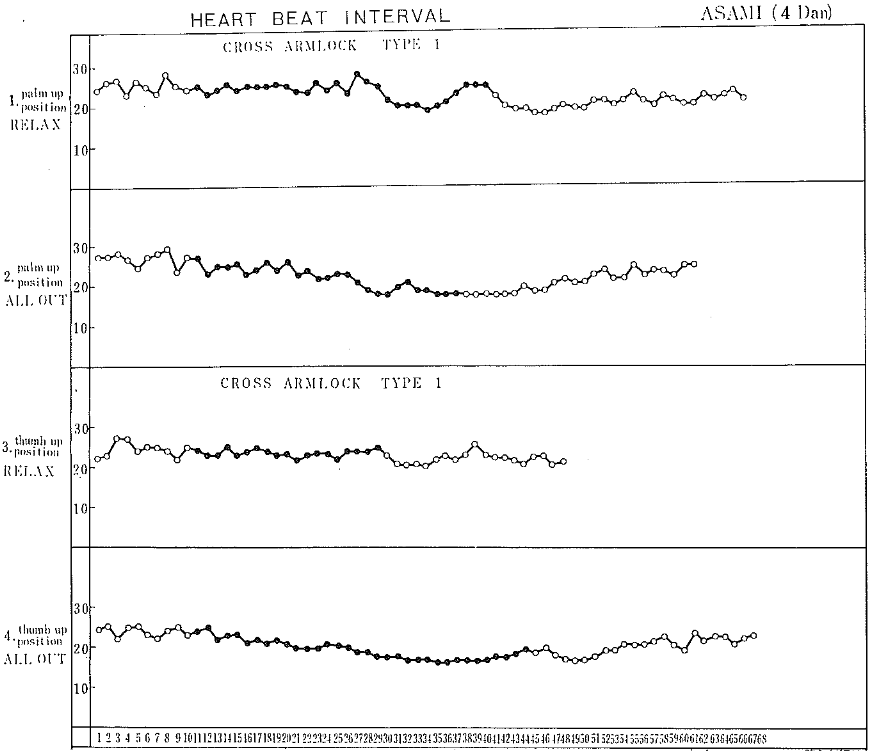
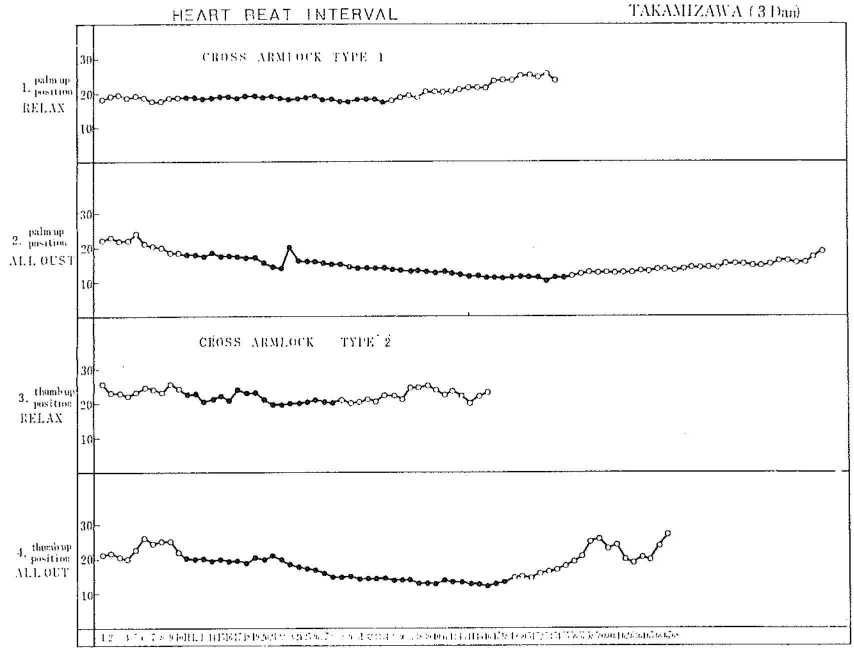


Fig. 12 Mechanical performance



observed even before actual performance, and the decrease in heart beat interval during performance became more marked. Observations on Takamizawa revealed results (Fig. 8) somewhat similar to Yamagishi's. In Yamagishi's (Fig. 7) case, few irregularities were observed, however, in general, results were similar to those of Takamizawa.

From the foregoing results, it is evident that in most cases heart beat interval became minimal at the moment the signal "Begin" was given, and that normal interval was rapidly resumed as soon as the hold was released. However, as the performance was repeated, decreased heart beat became evident even before the signal "Begin" was given.

b) During application of mechanical load. In this procedure, the load was applied gradually, and consequently, it took some time for the simulated effect of the armlock to become evident. As a result, the rate of decrease of heart beat interval was gradual (Fig. 10). In the Types 1 and 2 of cross armlock, with the "Uke" not resisting, the decrease of heart beat was only slight, but irregular. When the "Uke" was resisting, the heart beat interval gradually decreased with the increase in the load applied to the arm. Also, when the load was removed, the heart beat interval gradually decreased with the increase in the load applied to the arm. Also, when the load was removed, the heart beat interval rapidly increased. Fig. 11 shows data from another experimental subject, and in this case also the heart beat interval was greatly decreased when the "Uke" was resisting. However, in this case no rapid increase in heart beat interval was observed directly after removal of the load. In Fig. 12 results somewhat similar to the two previous examples may be seen.

From the foregoing results, it is evident that the decrease in heart beat interval was more marked when the "Uke" was offering resistance than when he was not resisting. Also, in the former case irregularities in heart beat interval was not so evident than in the latter.

6) **ECG**

Chest leads ECG disclosed a lowering of the height of R spike during performance of the armlock, i.e., before performance it was 0.90 mV, and during performance it was reduced to 0.65–0.70 mV. However, no significant change was recognized in the T spike. Also, when the "Uke" was not offering resistance, very little change was observed in the R spike. There was no change in the pattern of the ECG.

II. Factors Influencing the Effect of "Kansetsu-waza"

1) Time required for the "Kansetsu-waza" to take effect.

The time interval between the signals "Begin" and "I surrender" may be considered to be the time required for the armlock to take effect. By measuring this time interval the effect of the various forms of armlock may be compared.

a) Actual performance of the "Kansetsu-waza". The signals "Begin" and "I surrender" were recorded by means of a microphone and the time that elapsed between the two signals was measured (Table 1). From the Table it may be seen that in both the cross armlock and the entangled armlock, the time required for the techniques to take effect was longer in Type 1 than in Type 2, i.e., the cross armlock took effect quicker when the "Uke's" thumb was pointing up, and the entangled armlock took effect quicker when the forearm of the "Uke" was in pronation.

Table 1. Time required for the effect in actual performance.

	Cross arml. Type 1	Cross arml. Type 2	Entangled arml. Type 1	Entangled arml. Type 2
Sugiyama	1.8 sec.	1.5 sec.	2.1 sec.	1.0 sec.
Takamizawa	3.3 "	1.9 "	3.0 "	1.3 "
Kobayashi	1.0 "	0.9 "	1.2 "	1.0 "
Sato	3.2 "	1.7 "	3.5 "	1.9 "
Yamagishi	2.0 "	1.4 "	5.0 "	3.0 "
Average	2.2 "	1.5 "	2.9 "	1.6 "

Table 2. Time required for the effect in mechanical load.

	Cross arml, 1 Resist. (−)	Cross arml, 1 Resist. (+)	Cross arml, 2 Resist. (−)	Cross arml, 2 Resist. (+)
Sato	23.6 sec.	22.5 sec.	20.2 sec.	25.4 sec.
Hamano	25.7 "	46.6 "	13.9 "	29.7 "
Asami	27.6 "	22.6 "	18.3 "	24.5 "
Takamizawa	16.5 "	24.8 "	13.4 "	23.5 "
Miyakozawa	24.7 "	42.8 "	21.7 "	30.7 "
Average	23.6 "	31.9 "	17.5 "	26.8 "

b) Application of mechanical load. Since the load applied to the arm was gradually increased, it is natural that the time required for the simulated armlock to take effect was longer than in the actual performance of the armlock. Table 2 shows measurements taken during performance of cross armlock, Types 1 and 2, with and without resistance.

From this Table it is clear that the time required for the armlock to take effect was longer when the "Uke" was offering resistance, indicating that the "Uke" put in considerable effort to hold out. It is also evident that the cross armlock, Type 2 (thumb pointing up) required less time to take effect than the cross armlock, Type 1 (palm of hand facing up).

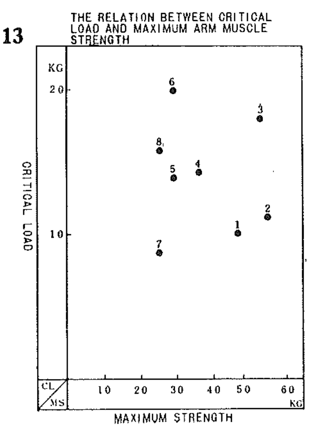
2) The "critical load" for the "Kansetsu-waza" to take effect.

It is technically difficult to measure quantitatively, during actual performance of the armlock, the force required for the armlock to take effect. This being the case, the mechanical load method simulating actual performance of the armlock was used. The reading on the cable tensiometer at the moment the signal "I surrender" was given was taken as the "critical load". The results are summarized in Table 3. For comparison, maximum arm muscle strength when the arm was flexed at 90°, of each experimental subject was measured. From the Table it is evident that cross armlock Type 2 required less force to take effect than Type 1, and that more force was required when the "Uke" was resisting. Also, considerable individual variations were found in the "cirtical load" values.

Table 3. Critical load and maximum arm muscle strength.

	Cross armlock, Type 1		Cross armlock, Type 2		Average critical load	Maximum muscle str.
	Resist. (−)	Resist. (+)	Resist. (−)	Resist. (+)		
Kataoka	5.0 kg.	17.8 kg.	8.7 kg.	8.7 kg.	10.1 kg.	46.6 kg.
Nakazawa	8.7	16.0	5.1	14.7	11.2	54.5
Haga	13.8	22.0	18.0	18.1	18.0	52.5
Hamano	7.3	21.0	6.0	22.8	14.3	36.0
Sato	5.3	23.8	5.8	20.7	13.9	29.0
Miyakozawa	19.3	25.6	12.5	22.6	20.0	29.2
Takamizawa	8.7	9.0	5.4	11.8	8.7	25.2
Asami	11.6	22.2	9.8	19.4	15.8	25.5
Average	10.0	19.6	8.9	17.4	14.0	34.1

Fig. 13



3) The relation between "critical load" and maximum arm muscle strength.

The relation between "critical load" and maximum arm muscle strength when the arm was flexed at 90° was studied. The results as summarized in Fig. 13 and Table 3 indicate that no correlation exists between the two. In other words, it does not mean that those individuals with stronger arm muscle strength are able to bear more of the effect of the armlock than those with weaker arm muscle strength. To site two extreme examples, Nakazawa, in spite of his comparatively large maximum arm muscle strength (54.5 kg.) could tolerate only up to 11.2 kg.; and in contrast to this, Miyakozawa whose maximum arm muscle strength was only 29.2 kg. could tolerate as much as 20.0 kg. Including the aforementioned two extreme cases, the averages indicate that without resistance on the part of the "Uke", the "critical load" was 1/3 of the maximum arm muscle strength, and with the "Uke" resisting, the "critical load" was 1/2 of the maximum arm muscle strength.

4) The "critical angle" for the "Kansetsu-waza" to take effect

The angle of the elbow joint of the "Uke" at the moment the signal "I surrender" was given was measured during the mechanical load experiments. As a result of these measurements, it was found that although the angle of the elbow at the inception of the performances differed in each individual—not all were uniformly 180°—the difference between the angle at the inception and the angle at the moment of the signal "I surrender" was 5°–8°.

Table 4. Critical Angle

	Cross armlock, Type 1		Cross armlock, Type 2	
	Resist. (−)	Resist. (+)	Resist. (−)	Resist. (+)
Katoaka	162°→163° (1°)	160°→164° (4°)	163°→164° (2°)	161°→165° (4°)
Nakazawa	187°→194° (7°)	186°→194° (8°)	188°→194° (6°)	187°→194° (7°)
Haga	150°→158° (8°)	153°→158° (5)°	150°→154° (4°)	150°→156° (6°)
Hamano	183°→191° (8°)	181°→191° (10°)	184°→190° (6°)	184°→191° (8°)
Miyakozawa	161°→165° (4°)	154°→158° (4°)	154°→162° (8°)	154°→162° (8°)
Takamizawa	162°→176° (14°)	160°→166° (6°)	160°→166° (6°)	162°→176° (14°)
Asami	188°→196° (8°)	186°→192° (6°)	184°→192° (8°)	186°→193° (7°)

DISCUSSION

As previously stated, two methods of experiment were used in the present study: One in which the "Kansetsu-waza" was actually performed under conditions very similar to those prevailing during performance of the armlock in a Judo tournament. The other in which a mechanical load was applied to the arm of the experimental subject, in a way to simulate as much as possible the conditions prevailing during performance of the "Kansetsu-waza", thus making it possible to make various measurements which were not possible during actual performance of the armlock.

We shall first dwell upon the physiologic changes that accompany performance of the "Kansetsu-waza" from the point of view of the common changes that occur during both the actual performance experiment and the mechanical load experiment.

One of the most important physiologic changes that occur in the "Uke" during performance of "Kansetsu-waza" is pain. It is this pain which prompts the "Uke" to give the signal "I surrender" regardless of whether he is offering resistance or not; and this inflicting of pain on the "Uke" by the "Tori" is the special characteristic of this technique. This sensation of pain will give rise to reflex action in the autonomic and the somatic nervous systems; also, it will change the level of excitation of the central nervous system, expecially the brain. Furthermore, this pain will give rise to a positive defensive action on the part of the "Uke" to resist the force which is putting the elbow in hyperextension. This defensive action is manifested by the increased muscle tension which occur both reflexly and voluntarily.

The mode in which the "Kansetsu-waza" takes effect will be now discussed from the point of view of the time required for the armlock to take effect. In the experiment in which the armlock was actually performed, it was found in all five experimental subjects that the cross armlock, Type 2 required less time to take effect than Type 1, i.e., the technique was more effective when it was performed with the "Uke's" thumb pointing up than when the palm of his hand was facing up. This is in agreement with the result obtained in the experiment in which mechanical load was applied to the arm. In the entangled armlock actually performed, Type 2 was more effective than Type 1. These results indicate that in the armlock, those techniques performed with the "Uke's" arm in pronation are more effective than those performed with the "Uke's" arm in supination. This difference in the effectiveness of the two types of armlock is due mainly to the anatomical structure of the elbow joint. Individual differences in effectiveness are mainly due to the differences in the strength of the elbow joint of each experimental subject.

The criterion of whether the armlock took effect or not is the pain felt by the "Uke" and after the pain is felt it is no more possible for the "Uke" to resist further. This pain is caused by the mechanical stimulation of the nerve receptors in the joint tissues as a result of hyperextension. This pain stimulus is transmitted to the central nervous system, part of which reaches the cerebral cortex where it is interpreted as pain; and the other part passing through the thalamus and hypothalamus stimulates the autonomic nervous system and gives rise to changes in the circulatory system and the sweat glands. Although it is an indirect method, investigation of changes in heart beat reveals changes in the nervous system. The changes in heart beat are thought to be the result of pain reflex. Two processes are considered to be taking part in this: One is the result of pain sensation felt by the cerebral cortex, and the other is stimulation of the autonomic nervous system via the thalamus and hypothalamus. Fig. 6, shows a very conspicuous instance of change in heart beat interval. In this case the armlock (actually performed) took effect very rapidly ("I surrender" signal in 1–2 sec.), and consequently, the rate of decrease in heart beat interval was also very rapid. The respiratory movement at this moment stopped in inspiration. This also has an accelerating effect on heart beat, however, it is of secondary importance. Since no significant difference in the degree of change of heart beat was found between the experiment in which the "Uke" was resisting and that in which the "Uke" was not resisting, the acclerating effect on heart beat of the effort put in by the "Uke" to resist is of secondary importance. Therefore, the decreased heart beat interval, in this case is thought to be mainly due to a reflex action induced by pain. However, in some cases, when the performance was repeated several times, a rhythmical decrease in heart beat interval was observed even before the armlock was actually performed (Fig. 7). This is thought to be due to a delayed conditioned reflex brought about by repeated sensation of pain felt at fixed intervals. The decrease in heart beat interval in this case is due to decreased TP interval (diastolic) in the ECG.

In the experiments in which mechanical load was applied to the arm of the "Uke" to simulate the armlock, the decrease in heart beat interval was only slight. This is because the manner in which the load was applied was gradual. When the "Uke" was resisting, the degree of decrease in heart beat interval was more marked than when the "Uke" was not resisting. Consequently, in this case, the emotional excitement due to the voluntary effort to resist played an important role in decreasing the heart beat interval. It is also thought that the increased muscle tension due to the "Uke's" effort to hold out augmented the auto-receptor reflex, and increased the sensation of pain. After the armlock was released and the heart beat interval rapidly increased, in some cases, the interval became even longer than that of the rest period. This is thought to be caused by relaxation of the sympathetic nerve due to relief of pain, and also caused by increased tension of the vagus nerve. In some instances, further decrease in heart beat interval was observed after releasing the hold (Fig. 11). This is thought to be caused by the conjoint action of the cardiac accelerating effect due to the effort to resist, and the cardiac accelerating effect due to pain.

As already described, it is evident that in spite of the fact that the same technique was performed on each experimental subject, the individual pattern of reaction differed considerably. This may be ascribed to the individual difference in the excitability of the thalamus and hypothalamus to mechanical stimulus from the joint. However, decrease in heart beat interval was a change common to all, and the manner of change in heart beat may be taken as an index for the effect of the armlock.

Changes in psychogalvanic phenomenon are assumed to be the result of the action of emotional excitement on the vasomotor nerves via the thalamus and hypothalamus. These changes are not always observed, and also cannot be clearly differentiated. In some cases, considerable oscillation was observed even in the preparatory stage preceding the actual performance of the armlock. However, as the armlock was put into effect and the load increased, the oscillation definitely augmented. Changes in psychogalvanic phenomenon were very often observed even before changes in heart beat interval or EEG became evident. However, changes in psychogalvanic phenomenon were observed even as a result of very slight stimuli, and as referential consequently cannot be utilized as an index for the effect of the armlock—they can only be used data, together with changes in EEG.

Electroencephlography is one of the most adequate methods of quantitatively investigating reactions that occur in the cerebrum due to stimuli of varying degrees from the elbow during performance of armlock. As previously stated, although there were some differences between the EEG taken during actual performance of the armlock and that taken when mechanical load was applied to the arm of the experimental subject, both showed a common tendency in that the alpha waves were gradually replaced by beta waves, and as the armlock or the application of load proceeded further, waves with higher voltage and frequency appeared. Although these waves with higher voltage and frequency were considered to be excitation waves further studies are required to verify this, because there is the possibility of the EMG having an influence on the EEG. Since, when the "Uke" was not resisting, alpha waves continued to appear almost to the time the signal "I surrender" was given, it may be assumed that changes in EEG when the "Uke" was resisting were due to the voluntary effort put in by the "Uke" to resist. In general, the order of appearance of the different waves was as follows: As the performance proceeded alpha waves were replaced by beta waves, which were in turn replaced by excitation waves. When the hold was released, beta waves reappeared and were followed by the reappearance of alpha waves. The above mentioned order of change in EEG reflects the progress of change in sensation in the joint.

In the actual performance of armlock, in all the experimental subjects there was an interval, directly following the signal "Ready", in which alpha waves disappeared momentarily and then reappeared in 2–3 seconds. This reappearance of alpha waves may be interpreted as being due to a feeling of ease, following the signal "Ready" or to the relief following the first alarm reaction. It would naturally seem that directly following the signal "Ready", the emotional excitement of the "Uke" would be increased in anticipation of the performance of the armlock, and one would not expect the reappearance of alpha waves. However, as already mentioned the reappearance of alpha waves was noted in all the experimental subjects indicating the presence of a period of relief from tension. If the appearance of beta waves in the interval directly following inception of performance of the armlock were to be interpreted as being due to excitation in the cerebrum, the reappearance of alpha waves in the interval directly preceding the inception of performance may be assumed to be due to cerebral inhibition. This view is very similar to the one Ikai (5) proposed in assuming the momentary cessation of muscle electric discharge directly preceding voluntary muscle action as being due to a phenomenon of inhibition. In other words, directly preceding inception of performance, there seems to be a moment in which tension is relieved. This condition helps strengthen the defensive attitude. Generally, desynchronization in EEG implies excitation in the cerebrum (2,7). On the other hand slow synchronous EEG is said to correspond to reticular inhibition (3). Needless to say, it is not possible to comment in detail on the mechanism of the cerebrum only from data obtained by electroencephalography, however, it may be presumed that the appearance of alpha waves in the interval directly preceding actual performance of armlock implies inhibition in a large part of the cerebral area. Furthermore, this may be interpreted as negative induction of the cerebrum, and this is assumed to be a preparatory measure for the concentrated excitation of the motor analyzer area which must be put into action the next moment (i.e., the moment the armlock is put into effect) (5). There is a similarity between this view and that given by Ikai and Steinhaus (6) in interpreting the increase in the level of muscle strength by sound stimulus or by shouting. According to them, the mechanism involved in this is assumed to be due to the concentration of muscle strength by inhibiting other areas of the cerebrum. This concentration of muscle strength according to Ikai and Steinhaus is due to desinhibition of the cerebral area.

In many instances, it was noted that beta waves were predominant for even 2–3 seconds or 3–5 seconds following release of the hold or the load. This is ascribed to the continuation of pain even after releasing the hold or the load.

Generally, when the change in EEG was marked the change in heart beat interval was also marked. However, during the incepient stage of the performance of the armlock, or when the mechanical load applied to the forearm was light, the two did not always show a parallel relation.

This is to be expected, because, although the afferent stimulus is the same, after passing through the thalamus, cerebral excitation due to efferent impulse is not necessarily the same as the excitation of the hypothalamus due to afferent impulse. The same principle may be applied to the psychogalvanic phenomenon, making the synchronous measurements of the three changes (EEG, heart beat interval, and psycohgalvanic phenomenon) very significant. From the aforementioned results, it is assumed that the "Kansetsu-waza" produces considerable reaction above and below the thalamus, and therefore is quite a stress on the body. This fact implies that the "Kansetsu-waza" should not be practiced on those individuals who have not yet attained the age of full development of the nervous system. Also, it is safer not to practice on those individuals whose heart beat shows any irregularity. However, on individuals who have attained full skeletal, muscular, and nervous development, the technique may be applied quite harmlessly and leaves no after effects.

In the actual performance of armlock or in the mechanical load experiment, the arm was first placed in natural extension. With the inception of the performance of either the armlock or application of mechanical load, the arm muscles began to be extended further. At this moment, when the "Uke" was not resisting, and when the load applied to the arm was still light, practically no electric discharge from the flexor muscles was noted. However, as the process proceeded, and when the armlock took effect, a rapid increase in electric discharge was noted. This is ascribed to reflex muscular contraction due to pain stimulus from the joint. When the "Uke" was offering resistance, electric discharge was noted from the inception of the performance. This is assumed to be due, not to pain stimulus from the joint, but to voluntary increase in muscle tension through the medium of alpha fibers, and also to increase in muscle tension as a result of secondary excitation of muscle spindle. The latter is brought about through the medium of gamma fibers (1). As the process proceeded further, and the load increased, and pain began to be felt in the joint, muscle contraction due to pain reflex was also added, thus increasing the electric discharge from the muscles involved. Judging from the voltage of the EMG, the excitation level of the motor unit of the biceps muscle at this moment was equivalent to the maximum muscle strength (30–45 kg.) of the biceps muscle of the same individual flexed at 90°. However, this form of excitation of the motor unit when the armlock has already been put into force is ineffective as a defensive action. This may be understood from the aforementioned fact that no interrelation was found between maximum muscle strength and the "critical load", making resistance, when the arm is in extension, of very little effect regardless of how strong the maximum muscle strength may be. This is also quite evident from the fact that a muscle must be in optimum length in order to manifest maximum strength. Therefore, it is of primary importance for the "Tori" to manipulate the arm of the "Uke" so that it will be in a position to put the defensive muscle at a very disadvantageous length. On the other hand, the "Uke" must always be careful to maintain optimum muscle length so that the muscles may be able to manifest maximum strength.

In the foregoing lines, the term "hyperextension" was used in relation to the condition of the elbow when the armlock was put into effect, but was it really so? In order to clarify this an investigation was undertaken, the result of which is shown in Table 4. As shown in the Table, at the inception of the armlock, some individuals showed a joint angle of 150°–160°, indicating a wide individual variation. These angles were not determined by the anatomical structure of the joint, but by the feeling of each individual that he had his arms stretched out straight. The angle at the moment the signal "I surrender" was given was 2°–14° more in extension than at the inception of the performance. There was no interrelation between the angle at the inception of the performance and the angle at the moment of the signal "I surrender", i.e., the smaller the angle at the inception of the performance did not always mean that the joint had to be extended more for the armlock to take effect. From the aforementioned, it is to be understood that the term "hyperextension" used in this report does not necessarily mean that the joint was extended beyond 180°. It is hyperextension based on the natural feeling of extension of each individual.

Although, the literature in regard to the extent of the motion of joints is scarce, according to the table of body measurements of the Japanese (8), the maximum extension of the elbow joint is 190°, and the minimum extension 180°, with an average of 184.4°. Consequently, when the angle at the inception of performance was 180°, the angle at the moment of the signal "I surrender" would be about 185°–188°. In the cross armlock, Type 2 (thumb pointing up, and without resistance) the difference between the angle at the inception of performance, and the moment of the signal "I surrender" was the smallest revealing that in this case the extent of joint movability was the smallest.

From the results obtained in this investigation, it is concluded that the various physiologic changes observed in this study were the result of the stress applied to the elbow joint, and that these changes took place within the limit of the physiologic movability of the joint, and may be performed with safety on those individuals who have attained full development of the joints.

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