Physiological Studies on "Choking" in Judo

Part II

X-ray Observations on the Heart

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Forword

Previously a report was made on the physiological investigations on "choking" in Judo, in which the influence to the various physiological processes were studied. The effect of "choking" on the circulatory system was studied by investigating changes in blood pressure, heart rate, electrocardiogram, and peripheral blood vessels (3). According to this report the heart rate is increased in the getting ready position, decreased when the subject loses consciousness and increased upon awakening. The systolic and diastolic pressures are slightly increased in the getting ready position, and markedly increased upon awakening. Blood pressure measurement during the unconscious stage was hindered due to convulsions, and could not be ascertained. The reactions of the peripheral vessels during "choking" are manifested by contractions in the skin blood vessels and dilatations in the muscle blood vessels (1, 2, 3).

These phenomena may not have a direct relation to the unconsciousness resulting from "choking". On the other hand, however the fact that in highly sensitive individuals the stimulation of the carotid sinus causes unconsciousness, it cannot be affirmed that there is absolutely no relationship.

Ikai et al (3) state that the unconsciousness resulting from "choking" is caused by anoxia in the cerebral cortex, and that the manifestations in the circulatory system are attendant phenomena. In the present study in order to analyse the mechanism of the various circulatory manifestations, investigations were made on changes in the span of heart beat, thereby determining the cardiac output.

The changes in the circulatory system which occur during "choking" depend upon the part where the pressure is applied. Since it is difficult to determine the exact spot where the pressure is being applied, the same individual was used to perform all the "choking" act, and always in the same manner. The reactions in the circulatory system appeared in the heart, and in the peripheral blood vessels. The changes in the peripheral blood vessels were determined by means of the plethysmograph, and those in the heart by means of the electrocardiograph. Electrocardiographic studies revealed that the elongation in the heart rhythm is due to changes which occur during the diastolic period, and not during the systolic period. From the voltage of the R crest it was known that in the Okurieri-shime and the Katajuji-shime the heart approaches the vertical position. Blood pressure was found to be increased after awakening. To fully understand the above results it is necessary to know the changes in the return flow of blood to the heart, and also the cardiac output during the whole process of being "choked". To make these measurements directly is impossible under the circumstances, therefore resort was made to X-ray cinematography, whereby changes in the size of the heart, and changes accompanying each heart beat could be determined.

Experimental Method

Messrs. H. Katayama, Y. Ito, Y. Sato of the Tokyo University of Education, all fourth grade holders, were selected as experimental subjects, and Mr. Y. Matsumoto (seventh grade) of the Kodokan performed the "choking".

The subjects were made to lie in a supine position on an X-ray table. The "choker" taking his position on the left cephalic side of the subject, performed the "choking" very similar to that of the Okurieri-shime.

Photography was conducted by Dr. A. Inoue (Chiba Univ.). The X-ray tube was placed below the table, and the cardiac silhouette projected on the fluoroscope which was placed over the breast was photographed with a 35mm camera.

With the subject in the supine position the movements of the heart were photographed for ten seconds prior to the performance, followed by photography during the whole procedure until 20 seconds after awakening. This was followed by a two minute interval after which photography was resumed and continued for ten seconds. The speed of photography was 16 frames per second. The films were developed and each frame enlarged to a continental size, and measurements were made therefrom.

The following criteria were selected: 1) Entire transverse width. Here the transverse width was not divided into the left and right, but as seen in Fig. 1 A, measurements were made on the upper and the lower halves. The part designated as the upper half was from the border of the right extremity of the heart and the great vessels, to the border of the right extremity of the heart and the diaphragm. This upper half comprised about 30 % of the length of the heart, and the lower half about 85 %, and were designated as T1 and T2, respectively.

2) Right and left transverse widths. Here, the usual transverse measurements were employed. The maximum transverse width to the right and left of the midsternal line were taken and designated as T_R and T_L, respectively (Fig. 1 B), in which T_R corresponds to the right auricle and T_L to the left ventricle.

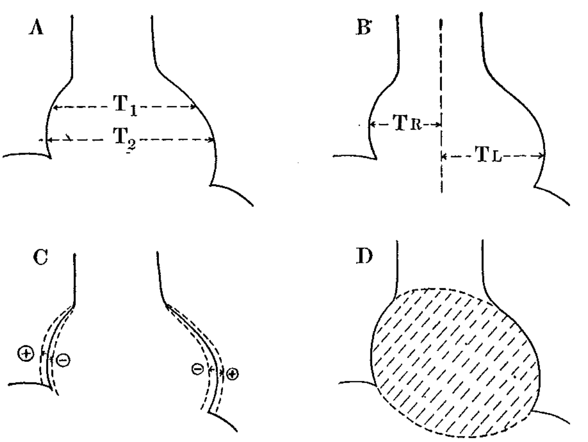


Fig. 1. Indeces for the measurement of heart Roentgenogram

A: Total width. B: Left and right width.
C: Transition of left and right extremieties.
D: Area.

3) Changes in position of the heart. As a means of determining the changes in position of the heart, the right and left borders of the heart at the inception of photography were fixed as the bacic points. A medial shift from these points were marked with a negative sign, and a lateral shift with a positive sign. According to this, a negative sign on the right border and a positive one on the left border would indicate a leftward shift of the heart. The shift of the left and right borders accompanying each heart beat may be considered to indicate the span of heart beat. However, when there is a marked change in the heart as when the subject is being "choked", the shift is a combination of the positional change and span of heart beat (Fig. 1 C).

4) Area of cardiac silhouette. In order to ascertain the volume of the heart indirectly, it is necessary to find the area of cardiac silhouette. This was done by using a planimetre over the cardiac silhouette (Fig. 1 D).

5) Movement of the diaphragm. According to a previous report (3) the movement of the diaphragm was recorded by means of a manschette and tambour, however during the unconscious stage accurate measurement was hindered due to the increased tension in the breast muscles. In the present study, the movement of the diaphragm was investigated by means of X-ray photography, thereby clarifying the form of respiration, and also the role played by the diaphragm in regard to the changes in position of the heart. A horizontal line was drawn through a fixed point below the border of the right extremity of the heart and the great vessels. The distances from the right and left sides of the diaphragm to this line were designated as RD and LD, respectively. The points of measurements on the diaphragm were, on the right, the border of the highest point of the right diaphragm and the right extremity of the heart; on the left the transition point of the left extremity of the heart and the diaphragm.

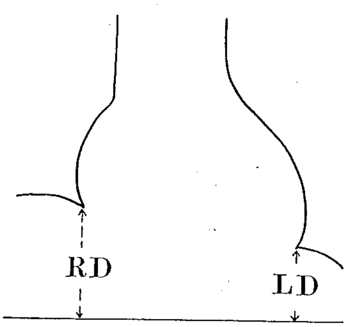


Fig. 2. Height of diaphragm.

Results

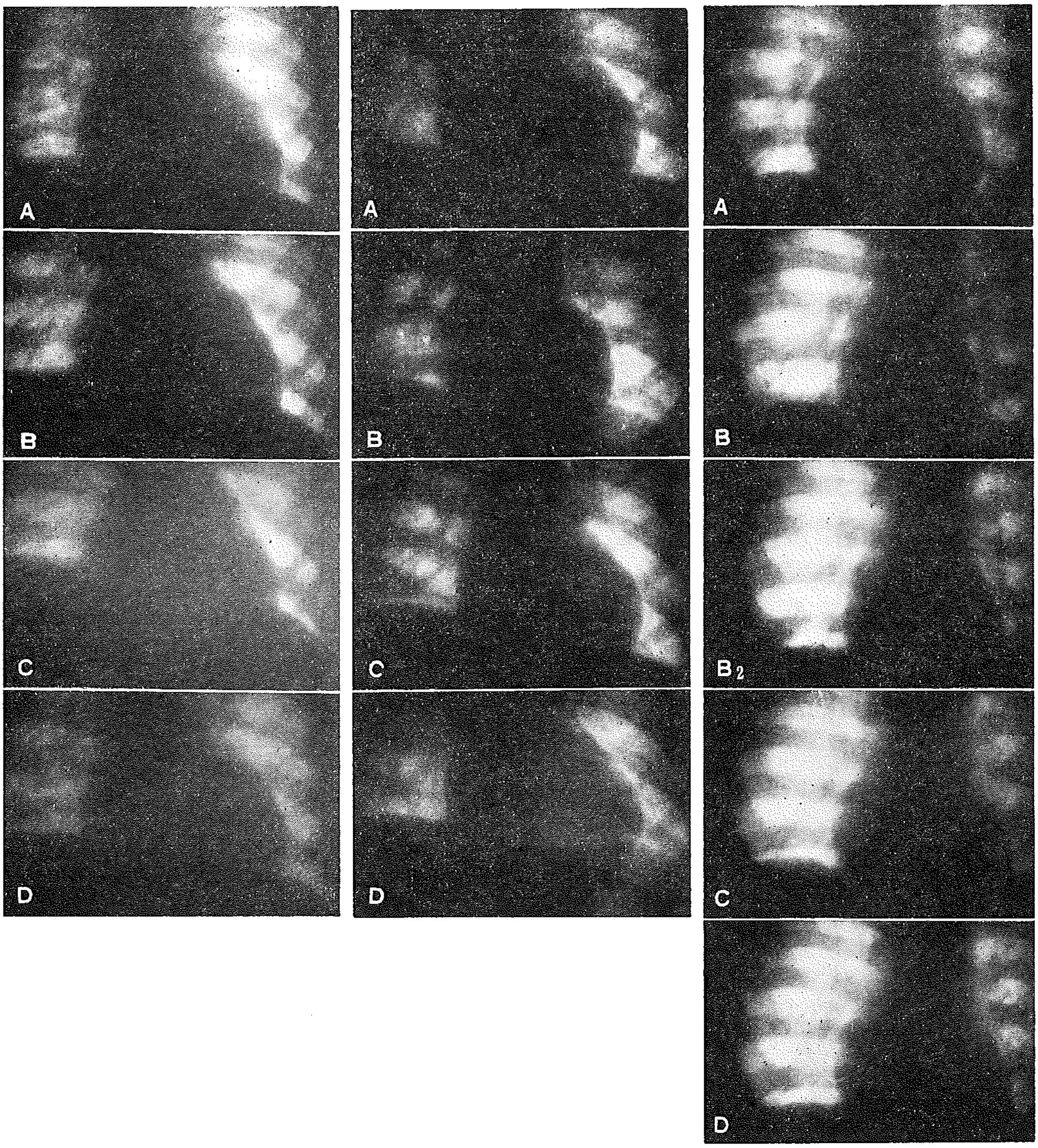
1. Changes in form of the heart. The serial photographs taken were enlarged and the changes in the form of the heart during the whole procedure of the "choking" performances were observed.

Although there were individual variations in the form of the heart at the resting period, in all the subjects a reduction in the form, especially on the right was observed. During the unconscious stage the reduction was greatest, and the silhouette of the right extremity became very thin. After awakening the form approached that of the resting stage (Fig. 3).

2. Changes in transverse width of the heart. As mentioned above, two kinds of criteria were selected for measurements. a) The upper transverse width (T_1) and the lower transverse width (T_2) showed identical changes, i. e. when the subject was being "choked" both widths became reduced, and further reduced when the subject lost consciousness. In general, the changes in T_1 were more pronounced than those in T_2. However, during the unconscious stage the reductions in T_1 and in the heart beat span were very pronounced.

Fig. 3. Effect of choking on heart Roengenogram

(A) H. K. (B) Y. I. (C) Y. S.



(A)

A. At rest.
B. Choking.
C. Unconscious.
D. After awakening.

(B)

A. At rest.
B. Choking.
C. Unconscious.
D. After awakening.

(C)

A. At rest.
B. First stage of choking.
B_2. Intermediate stage of choking.
C. Unconscious.
D. After awakening.

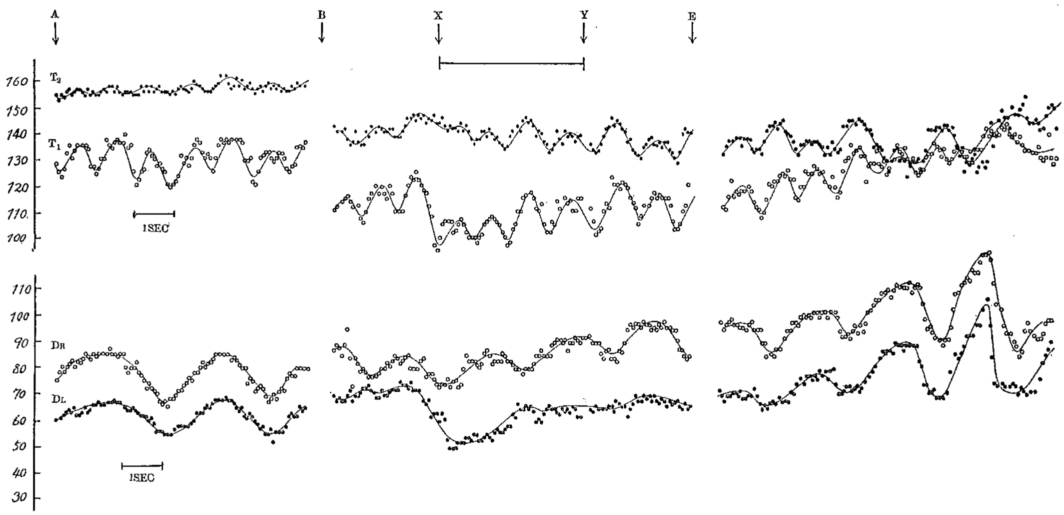


Fig. 4 The effect of choking on the changes in the total width of heart Roentgenogram and the height of the diaphragm.
T_1 T_2: total width. D_L D_R: height of diaphragm. A: at rest. B: choking.
X-Y: unconscious. E: after awakening.

After loosening the strangle hold the heart beat span immediately increased, but the T_1 and T_2 widths as compared to those at the resting period were still reduced. Ten seconds after awakening the T_1 and T_2 widths speedily increased and approached those at the resting period. The increase in T_1 was particulary pronounced, and as shown in Fig. 4, the two drew near toward each other, after which the conditions at rest were approached.

The interval of the heart beat at rest was approximately one sccond, at the inception of "choking" it became less than one second, at the unconscious stage it slightly became longer, and after awakening it again became less than one second.

b) Transverse widths, left and right (Fig. 5). At rest the increase or decrease in T_R and T_L were in identical directions, T_L showing greater changes than T_R. When the "choking" commenced both T_R and T_L began to decrease together with the decrease in the heart beat span. Thereafter an increase in T_L was observed, while T_R continued to decrease showing a leftward shift of the heart in relation to the midline. At this period

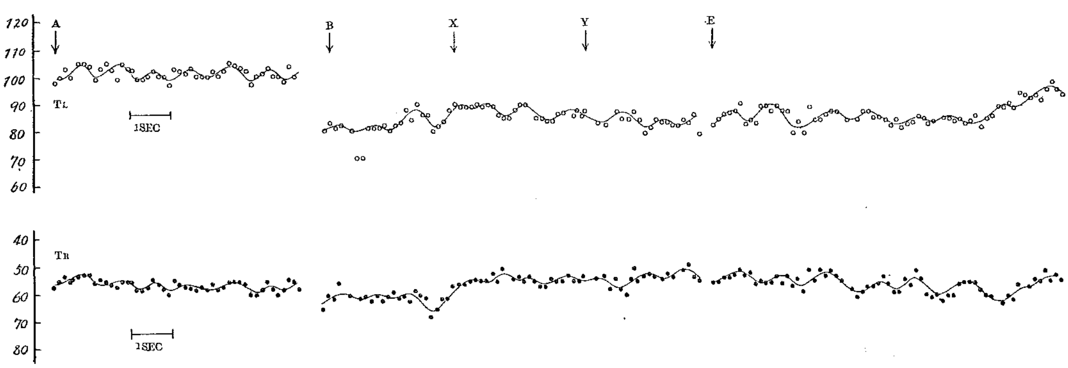


Fig. 5. The effect of choking on the right and left widths of heart Roentgenogram.
T_L: left width. T_R: right width. A: at rest. B: choking. X-Y: unconscious.
E: after awakening.

the changes in T_R accompanying each heart beat became very vague. Directly after loosening the strangle hold both T_R and T_L increased. This period corresponded to the period in which T_2 increased in Fig. 4. Ten seconds after awakening both T_R and T_L returned to conditions at rest.

3. Changes in position of the heart (Fig. 6). As the "choking" progressed the right edge pulsatingly shifted medially, whilst the left edge showing indentical pulsations shifted laterally. The changes observed were very similar to those of T_R and T_L in Fig. 5.

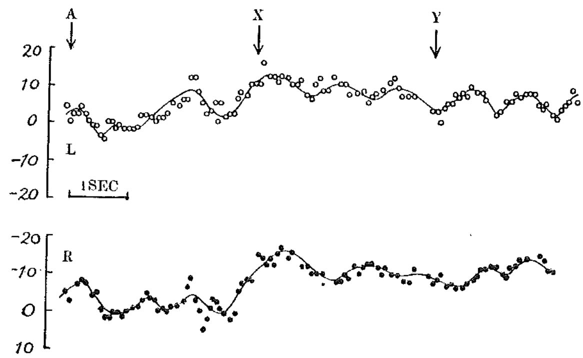


Fig. 6. The changes in the positions of the right and left extremities of the heart due to choking
L : left extremity. R : right extremity. A : choking
B-C : unconscious

4. Area of cardiac silhouette (Fig.7). At rest the cardiac silhouette increased or decreased regularly with each heart beat. As the strangle hold progressed the area decreased, and further decreased when the subject fell unconscious. At this stage the heart beat span was markedly small. When the strangle hold was loosened the heart beat span immediately increased, and after about ten seconds a rapid recovery was observed. Detailed observation showed a temporary increase in the heart beat span as the "choking" progressed into the unconscious stage. Among the changes observed in the heart when being "choked", those in the area of the cardiac silhoutte were the most conspicuous. The decrease in area as compared to that at rest was 15%. Fig. 8 shows the relative values of the cardiac silhoutte areas of three subjects during the four stages of, at rest, "choking", unconsciousness, and awakening.

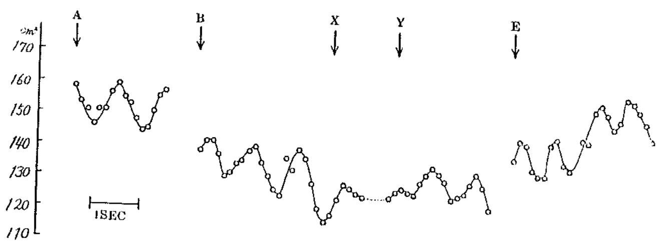


Fig. 7. The changes in the area of heart Roentgenogram due to choking.
A : at rest. B : choking. X-Y : unconscious. E : after awakeing.

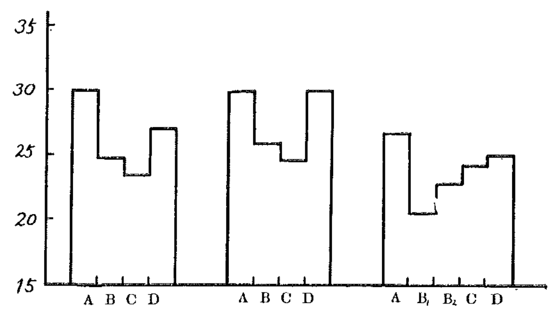


Fig. 8. The individual differences of the changs in the area of heart Roentgenogram dua to choking.
Axis of ordinates indicates relativ values of area.
A,B,C,D, atrest, choking, unconscious, awakening, respectively.

5. Changes in heart beat. A cinematographic study of the heart beat during the unconscious stage revealed a finding similar to auricular fibrillation. Further details regarding this phenomenon will be published in a forthcoming report.

6. Changes in movement of diaphragm. The changes in D_R and D_L during the four

stages of, at rest, being "choked", unconsciousness, and awakening are shown at the bottom of Fig. 4.

At rest the changes in height of the diaphragm on both the right and left were identical. In Fig. 4 both D_R and D_L are shown. Since the fluctuations of the heighest point of the right diaphragm were identical with that of D_R, no illustration is given here. During the stage of being "choked", the width of the respiratory fluctuation of D_R dereased and the height increased as the process approached the unconscious stage. When the strangle hold was loosened the width in the fluctuation of the height of the diaphragm increased, and after 10 seconds further increased. At this stage the entire transverse width, and the area of the heart were markedly increased. During the stage of being "choked" the width of the respiratory fluctuation of D_L showed an abrupt decrease, and as the "choking" progressed further, a marked difference between D_L and D_R appeared, i. e. D_L instead of increasing decreased, moreover its respiratory fluctuation became very small. In other words at this stage the height of the left and right sides of the diaphragm were different, and further their respective movements were not congruous. However, when the strangle hold was loosened, recovery was quick, and the behaviours of the right and left sides of the diaphragm became similar.

Discussion

The unconsciousness resulting from "choking" in judo, viewed physiologically, may be explained as being in a state of shock, primarily caused by anoxia in the cerebral cortex, with the changes in the cirulatory system as incidental causes. The present paper is a complemental study to that of a previous report (3), and an attempt was made to investigate the behaviour of the heart when an individual is being "choked".

The nature of shock is not quite clear, and it is a term given to a syndrome (6). Hitherto, studies on the behaviour of the heart during shock was chiefly made by investigations on cardiac volume, intracardiac pressure, cardiac output, and elctrocardiography (6).

Kohlstaedt and Page (4) have observed that during continued haemorrhage in experimental animals the volumes of the ventricles decreased. Kondo and Katz (5) have made X-ray observations on the heart of experimental animals whose veins in the hind legs had been blocked. They made recordings of the cardiac silhouette at diastole from both sagital and frontal directions. According to their observations, at the inception of shock the size of the heart is reduced, and as the shock deepens the rate in reduction becomes constant, and if further deepened a slight enlargement is noted. This reduction in the size of the heart is due to the decreased return flow from the veins. The enlargement is due to the decrease in the contractile power of the heart, which results in a dcrease in the output of the heart.

The conditions accompanying the unconsciousness from "choking" are somewhat different from those observed in a clinical or experimental shock, thereby making it difficult to compare the results of the present study with previous reports on shock.

As a result of the present study, during the stages of being "choked", unconsciousness and awakening, the volume of the heart dcreases as the process progresses and as the strangle hold is loosened the volume recovers its normal capacity. The heart beat span dcreases during the "choking" stage, and reaches its minimum during the unconscious stage and increases as the strangle hold is loosened. The criteria employed were, the area and the trnasverse width, both of which are two dimensional and not the volume itself. Also, since the direction of the X-ray was frontal only, it was difficult to deduce the exact measurements of the cardiac volume. However, it may be inferred that when there are marked changes in the transverse width and the area of the heart, there results a marked change in the volume of the heart. Since the cardiac silhouette on the right extremity is a silhouette of the right auricle, and on the left extremity that of the left ventricle, the changes in the transverse width and area of the heart correspond to the sum of the volume changes of the auricles and the ventricles. Consequently, the changes in the transverse width and area of the heart cannot exactly be said to correspond to changes in the output of the heart. However, among the criteria taken for the different transverse widths, the left transverse width is the most closely related to the output of the heart. As shown in Fig. 5. the change in the left transverse width accompanying each heart beat, resulting from "choking" are not very pronounced, however as the absolute value of the width is small, it is inferred that the output of the heart has been decreased. Of further note is the decrease in the change of the right transverse width accompanying each heart beat, which means a decrease in the return flow from the veins.

From the above it is presumed that decreases in the return flow from the veins, and cardiac output result from "choking", and for the causes of which the following may be taken into consideration. Previously it was reported (3) that a plethysmographic investigation of the forearms during "choking" showed an increase of blood flow in the muscles, and a decrease in the skin. Also, it is highly probable that the return flow of venous blood from the veins in the neck is reduced, due to the pressure applied to neck in "choking". These factors contribute to the decrease in the return flow of venous blood to the right auricle. Furthermore, during "choking" the thorax expands, and the diaphragm descends, resulting in a lowered intrathoracic pressure which in turn causes an increase in pulmonary blood flow. This results in a decrease of the return flow of blood to the left auricle. The above mentioned decreases in the return flow of the heart naturally cause a decrease in the output of the heart.

Since, as mentioned above a decreased output of the heart results, a reduction in arterial blood pressure is expected. However, a marked rise in blood pressure was observed after awakening (blood pressure measurements could not be taken during the unconscious stage due to convulsions). Although directly after awakening the output of the heart, as mentioned above, was still low, the contraction of the peripheral blood vessels in the skin is presumed to be the cause of the rise in blood pressure. Also it is knowm from previous studies (7) that during asphyxia, or cerebral anoxia, adrenaline is secreted and causes a rise in blood pressure. Moreover, the pressure applied to the common carotid artery decreases the internal pressure of the carotid sinus, and thus reflexly causes a contraction of the peripheral blood vessels, resulting in a rise in blood pressure (7). Another factor which may be taken into consideration, is the convulsion which appears during the unconscious stage. The convulsions offer resistance to the blood flow in the muscles, and contribute to the rise in blood pressure. From the above it may be understood that in spite of the reduced output of the heart during "choking", there is actually a rise in blood pressure. After awakening the increased rate of heart beat serves to compensate for the decrease in cardiac output.

The shift to the left in the position of the heart while being "choked", results from the contraction of the right auricle, however this phenomenon was not always seen in every subject studied. As shown in Fig. 3, when there is a decrease in the left transverse width of the heart, an increase in the right transverse width takes place. This is not the result of the difference in volumes of the left and right sides, but is presumed to be due to the rotation and forward shift of the heart during systole.

The asymmetry of the heights and movements of the right and left sides of the diaphragm is probably due to the disturbance in the control of the phrenic nerve. The decrease in the span of movement accompanying the decrease in height of the diaphragm is presumed to be caused by an increase in tonus.

Conclusion

As a sequel to a former report in which a physiological study was made from various angles during "choking" in judo, the present study deals with an X-ray photographic investigation on the changes appearing in the heart. Photography was done with a 35 mm camera with a speed of 16 frames per second. Each frame was enlarged to a continental size, and from them a careful analysis of the whole process of "choking" until recovery was made.

The criteria used for the study were, the entire transverse width, the right and left transverse widths of the cardiac silhouette, the positions of the extremities of the heart, and the area of the cardiac silhouette. Furthermore the height of the diaphragm was also studied.

The results obtained are as follows:

1. The transverse widths of the heart decrease during "choking", and recover normal conditions 10 secs. after awakening. The area of the cardiac silhouette decreases as the "choking" progresses, and reaches its minimum when the subject loses consciousness. Recovery of the normal area is completed in 10 secs. after awakening. From the above it is inferred that the cardiac volume decreases during "choking".

2. From the changes in the transverse widths and the area of the cardiac silhouette accompanying each heart beat during "choking", and from their absolute value it is inferred that decreases in the return flow of blood to the heart and cardiac output take place.

3. The tonus of the diaphragm during "choking" increases and take the inspiratory position. The above behaviour of the heart during "choking" is discussed from the standpoint of the changes in resistance in the peripheral blood vessels.

During "choking" aside from unconsciousness, which is an important change in the physiology of the body, it was found that a marked change in cardiac volume also takes place. From this standpoint it is safer for the individuals undergoing training in judo to have their cardiovascular function examined. However, in a healthy individual the effects of "choking" last only 10 secs., after which there is no observable residual effect.

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