THE EFFECTS OF VIOLENT AND PROLONGED MUSCULAR EXERCISE UPON THE HEART.

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THE following observations are based upon an examination of the contestants in the recent Marathon race, given under the auspices of the Boston Athletic Association, April 19, 1899.

Our thanks are due to the governing committee of the association and to Mr. John Graham, its athletic manager, without whose assistance the investigation would have been impossible; also to the athletes themselves, who, with one or two exceptions, lent their cordial co-operation.

A Marathon race is a road race, corresponding in distance and conditions to the course from Marathon to Athens. It was instituted at the ancient Olympic games in commemoration of the performance of the messenger who ran from Marathon to Athens after the great battle, to announce the victory of the Greeks. This race was revived at the recent Olympic games in 1896, and the course was laid out from the town of Marathon to the Stadium in Athens.

Since 1896 an annual Marathon race has been given by the Boston Athletic Association. The course extends from the town of Ashland to the club house in Boston, a distance of twenty-five miles, over smooth roads, up and down several hills, many of which are both steep and long.

The conditions are such that the contestant must cover the distance without the aid of other locomotive power than his own. He can walk or stop if he so elects, but he can receive no locomotive assistance. The winner is the contestant who performs the distance in the shortest time. Each contestant, in case of accident, is accompanied by a member of the ambulance corps of one of the militia regiments, mounted on a bicycle. In relief of possible apprehension, I would say in advance that no accident occurred in the present race except to a member of the ambulance corps, whose bicycle collided with a dog.

The weather on the day of the race was pleasant, but an easterly wind, which was a head wind, greatly impeded the runners. There was considerable dust. The mean temperature of the air was 44° F.

The time made by the winner was 2 hours 54 minutes 38 seconds, about a minute less than the Athenian record, but twelve minutes more than the Boston Athletic Association record of last year. The time of the winner thus averages a little better than a mile in seven minutes for the twenty-five miles, from which it can be seen that he did not avail himself of the privilege of walking or resting to any considerable extent.

The physicians associated with me in the examination were Drs. H. S. Dearing and H. W. White, of St. Elizabeth Hospital, and Dr. E. C. Stowell, physician to the Boston Dispensary, all of Boston, and all members of the Department of Clinical Medicine in the Tufts College Medical School. We are indebted to Drs. A. E. Austin and L. H. Coriat for the urinary analyses, and to Dr. Batchelder for the examinations of the blood.

Preliminary Examinations. Prior to the race preliminary examinations were made upon the athletes in training, before and after long practice-runs. The results of these examinations, apart from their enabling us to arrange a programme of procedure to be adopted on the day of the race, were interesting in themselves.

Blood-counts were made of two runners before and after long practice-runs, with the following results:

BLOOD-COUNTS.

No. of Runner.	Distance.	Before.	After.	Remarks.
1	10 miles.	6,700,000	6,000,000	Peripheral anæmia.
4	5 "	5,050,000	5,716,000	Peripheral hyperæmia.

The temperature of No. 1, before the run, was 97.5° F., and after the run, 97°. From these combined observations it was concluded that the athlete was approaching the condition technically known as "staleness"—*i. e.*, a condition of reduced bodily vigor, and the man was advised to temporarily refrain from further practice-running, and to partake of more carbohydrates in his food (his diet having been largely albuminous), with the result that on the day of the race his initial temperature was 98.2°, and that he was one of the winners of the race.

This fact goes to show the value of medical supervision in cases of this nature, as it is safe to say, in view of the facts to be described, that if this contestant had entered the race with a temperature of 97° he would have been unable to complete the distance in the time accomplished.

As a result of these preliminary examinations a uniform method of procedure was decided upon. It was further decided that the blood-counts did not justify the labor and difficulties involved. They were accordingly abandoned.

THE RACE. In the race itself there were seventeen entries; fourteen completed the distance. Notes were taken of thirteen. The contestants were examined in Ashland during the hour and a half preceding the race, and in Boston during the first few minutes after the race. The history was taken of eleven who finished. The oldest was twenty-eight years, the youngest nineteen years; average age, twenty-two years. The parents of all were living, with a single exception. The occupations of the contestants were: clerks, 4; plumbers,

2; blacksmith, 1; oiler, 1; printer, 1; steward, 1; cigar-maker, 1. Four had had scarlet fever; one typhoid; none rheumatism. Nine drank tea; 5 coffee. Three use tobacco (one a cigarette-smoker). None use alcohol. Eight were of neurotic temperament. Three had competed in Marathon races before. For two men it was their third competition.

TRAINING. The training was noted in 14 contestants: maximum, 7 months; minimum, 2 weeks; average duration, 2 months. With the single exception of an athlete who trained four and a half weeks, it may be said that those who trained under two months were least successful in the race. The training in all cases consisted of a mixed diet, with increased albuminoids and decreased carbohydrates, and practice-runs three or more times a week. One of the men was taking strychnine; one ate apples on the way. One man who had been training but two weeks dropped out.

PHYSICAL EXAMINATION. *General inspection* was altogether favorable. Each contestant appeared a healthy, vigorous young man. After the race the general inspection showed a greater or less exhaustion in every case. Three were dazed and confused; 1 cyanotic; 1 of an ashen color. Three had to be carried to the examining-room.

THE PULSE. The radial pulse was taken before and after the race in 10 individuals; after the race in 13:

PULSE.

	Number of athlete.[1]												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Before	72	...	...	70	80	72	72	78	85	88	...	80	88
After	120	120	104	108	120	112	120	70	60	112	112	106	108

Nos. 8 and 9, showing the lowest pulses, were the most exhausted men; in No. 8 it was intermittent, in No. 9 irregular.

[1] The numbers of athletes in these tables are not the race numbers, but are arbitrary numbers used instead of names to distinguish the athletes. In all the tables these numbers correspond.

Before the race the pulse was strong in all. After, it was very weak in all; in one the radial could not be felt for several minutes after the finish; in one it was intermittent.

TEMPERATURE. The temperature was taken in the mouth before and after the race in 11 cases; after, alone, in 3.

The temperatures in the following table marked 94—° show that they were below 94°. The thermometer employed (registered Yale) only registered temperatures above 94°. This complication of extremely low temperatures was not foreseen, otherwise another would have been provided. It would be of great interest to see how low it might go in these similar cases:

	Number of contestant.												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Before	98.°2	...°	...°	99.°4	99.°6	98°	99.°4	99.°4	99.°6	100°	...°	99.°8	100°
After	94—	97	94. 6	95. 5	94	94—	97—	94	94—	95	94	97	98

RESPIRATIONS. The respirations were noted in eleven cases:

RESPIRATIONS.

	Number of contestant.										
	1	2	3	4	5	6	7	8	9	10	11
Before . . .	20	...	...	24	24	24	26	20	24	24	
After . . .	26	40	34	24	36	32	40	36	28	32	30

The weight was noted in ten cases:

WEIGHTS.

	Number of contestant.												
	1	2	3	4	5	6	7-8	9	10	11	12	13	14
Before .	160½	...	...	117	125	126	143	115	139	...	116	133½	134
After . .	155	...	...	112½	122	122	139¾	112½	135½	...	114¾	132	127½
Loss . .	5½	...	...	4½	3	4	3¼	2½	3½	...	1¼	1½	6½

URINE was examined before and after in 6 cases; after, alone, in 1. It showed the presence of albumin and casts in every case after the race:

URINE.

	Number.						
	4	5	7	8	9	10	13
Before	Albumin trace; occasional blood-corpuscles.	Normal.	Normal.	Large trace.	Normal.	Trace; blood-corpuscles.	
After	Albumin, $^1/_{10}$ per cent.; casts.	Albumin, a trace; casts.	Trace; numerous casts.	Albumin, $^2/_5$ per ct.; casts.	A trace; casts.	Same; with numerous casts.	A trace; casts.

EXAMINATION OF THE HEART. Inspection of the chest before the race was made in thirteen cases. The points looked for included bulging of the chest-wall, abnormal pulsations, right ventricular heaving, retraction of the intercostal spaces, carotid and jugular pulsation, and the position and diffusion of the apex-beat.

Bulging was noted in nine cases, and consisted in a relative projection of the left costal cartilages of the fourth and fifth ribs as compared with the right. Other abnormalities were absent, with the exception of slight visible pulsation of the carotids behind the angle of the jaw in two cases and slight epigastric pulsation in one. In both cases these points were attributed to thinness and excitement. Inspection of the chest after the race was made in 11 cases. Carotid pulsation was noted in 8; jugular pulsation in 1; diffuse epigastric in 1.

PALPATION. Palpation before the race was noted in 9 cases. The force of the apex-beat was described as thrusting in 7; normal in 1; diminished in 1. The force of the impulse projected the left costal cartilage in 1. There were no thrills. After the race the apex-beat was noted in 5 cases: thrusting in 1, ticking in 2, and weak in 2.

PERCUSSION. By percussion we attempted to show the area of relative cardiac dulness, first as compared with the

normal chest, and second in order to compare this relative area in each individual before and after the race. The freedom of the chest-walls from adipose tissue rendered this examination easier and more exact than in the cases of ordinary men.

The method employed consisted in marking out the area of comparative dulness on the chest with water-color paint, after which a tracing was made upon tracing-paper. The paint was then removed, so that no lines remained on the chest to bias the judgment on the second examination. As this relative area differs so much in the percussion of individual examiners, each case was percussed in the "Preliminary Examination" by three examiners, and the results compared.

A reduced photograph of the superimposed tracings of three examiners upon one of these athletes shows how closely these observations coincided, and demonstrates the accuracy of percussion in a thin chest with an hypertrophied heart:

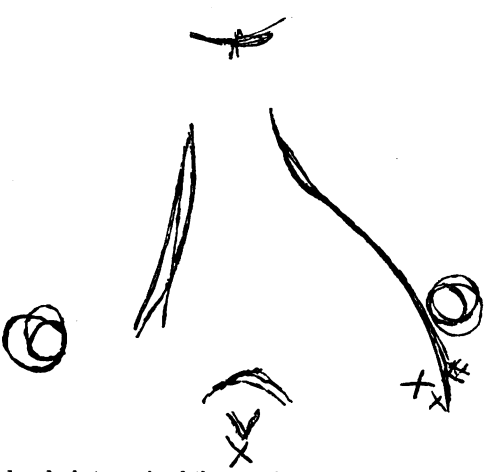

PLATE I.—Reduced photograph of the superimposed tracings of three examiners, showing area of comparative dulness.

This method was found to consume so much time that at the race each runner was percussed by only one examiner, in each instance the same examiner making the observation

PLATE II.—No. 12. Before and after. (Outside lines, after.)

PLATE III.—No. 5. Before and after. (Outside lines, after.)

before and after the race. In view of the fact of the close agreement in the percussion-dulness obtained by the three examiners, the constancy of enlargement is striking.

PLATE IV.—Before and after. (Left outside lines, after.)

Thirteen examinations by percussion were made before the race; 10 of these after the race. Of the 13 made before, 11 showed the area of comparative dulness relatively large as compared to the normal heart. Two showed a diminished or normal area. These two, showing the normal or diminished area, did not finish. One showed a relatively large area, but started with a temperature of 99.8°, and had a sore throat. He did not finish.

Of the ten observations made before and after the race, seven showed a relative increase of the cardiac dulness extending chiefly to the left, and corresponding to the position of the left ventricle, while two showed a decrease of the area of dulness in the same position. One showed nothing.

A comparison of the percussion-areas of one of the best with one of the poorest men, the men weighing the same, was

made. The man with the smaller area had only trained three weeks. He dropped out after running a few miles.

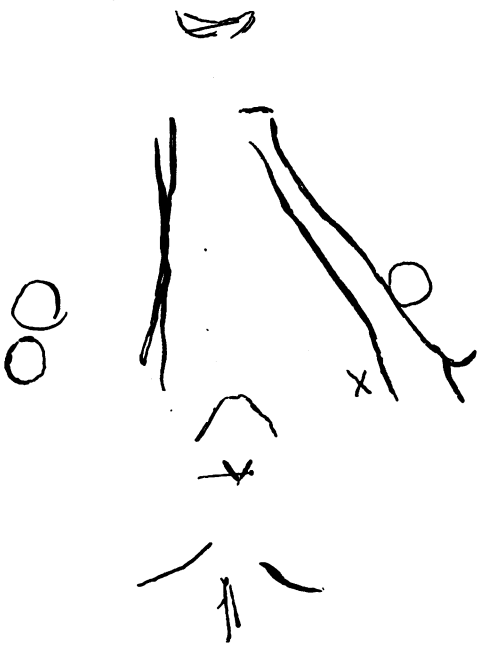

PLATE V.—Comparison of area of dulness of winner with one of the unsuccessful.

AUSCULTATION. Auscultation was practised in 11 both before and after the race; in 13 in all after the race. The heart-sounds were found normal in all examined previous to the race. They were unusually loud and full in all. As those who were not examined before the race succeeded in accomplishing a run of twenty-five miles, it would seem evident that their hearts were normal at the start, and that for the purposes of comparison the thirteen cases should be considered together.

After the race auscultation was practised with the binaural stethoscope immediately on the arrival of the men. They were brought to the examination-room in the elevator, and examined as quickly as their clothing could be removed from

the chest. The heart-sounds in all were weak. Of the 13 men so examined, in 2 there were no murmurs. In 11 cases murmurs were noted. In all cases murmurs were systolic in time, and their point of greatest intensity was at the base, slightly to the left of the sternum in the second interspace. They were in all instances transmitted downward to a greater or less extent in the line corresponding to the left border of cardiac dulness. In six cases this murmur was transmitted to the apex, in all of which it was heard in the back, between the left scapular angle and the median line. Accentuation of the pulmonic second sound was sought for, but was not distinguishable in any case, probably due to weakened action of the heart. These murmurs were ephemeral in character, and in all instances disappeared before the athletes left the examining-room.

SPHYGMOGRAPHIC TRACINGS. Sphygmographic tracings were taken of 10 before and after; of 13 after the race alone. If the capability of running twenty-five miles can be regarded as proof of a normal heart at starting, these 13 tracings can be considered together. The tracings before the race, considered as a whole, showed a series of strong regular pulses of high arterial tension. This was marked in 8; less marked in 1, whose tracing shows rather a low tension than otherwise; and exceedingly low in another who had been taking strychnine.

The 13 tracings taken after the race show exceedingly low tension in 10. Four of the tracings correspond with the pulse of mitral regurgitation. In all these cases the murmur above described was heard. In one there is a suggestive mitral regurgitation-tracing, but no murmur. This man did not complete the whole distance, but came in on a car. Possibly the murmur had disappeared before he presented himself for examination one hour after he stopped running.

SUMMARY. It is to us a source of regret that we cannot enter into the discussion of the tables in the limited time at our disposal. They are introduced here for the twofold pur-

pose of completing the report and showing the exhaustion of the men. Had the time been longer, it would have been of interest to have pointed out how greatly these results are at variance with the conventional statements of the text-books. For example, it is stated that the temperature of the body is raised during exercise (*American Text-book of Physiology*). We found it invariably lowered, varying from 5.5° to 2°. Albumin in the urine is spoken of as physiologic—we find it invariably associated with casts, thus forcing the conclusion that casts are in some instances physiologic, or that this albuminuria may at times exceed the physiologic limits. We are told that prolonged muscular exertion "enormously increases the blood-pressure in the arteries" (see Osler's *Practice of Medicine*, p. 736), whereas in the foregoing observations it is enormously decreased.

The results of these observations taken collectively show that general statements made in regard to the effects of muscular exercise may be misleading unless the character of the exercise and the condition of the individual are taken into consideration.

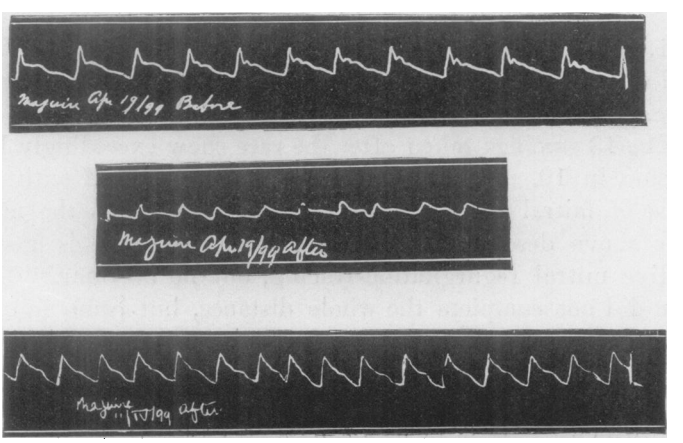

PLATE VI.—Sphygmograms of No. 4. 1. Before race. 2. After race. 3. After five miles' practice-run.

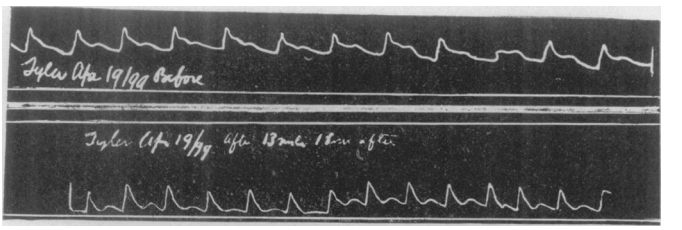

PLATE VII.—Nos. 1 and 7. Dropped out. Suggestive mitral sphygmogram.

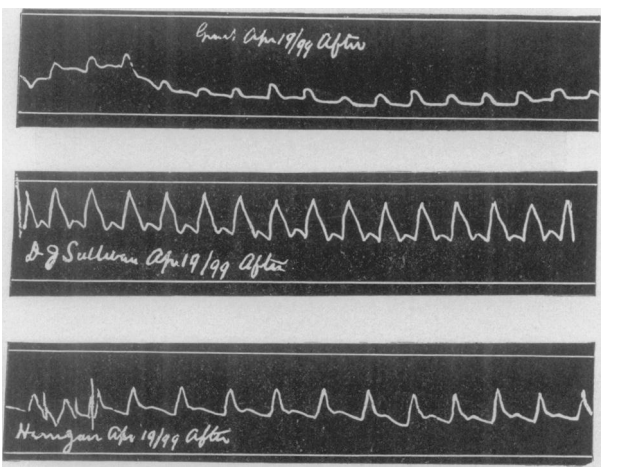

PLATE VIII.—Nos. 2, 7, and 11. After race, showing low arterial tension.

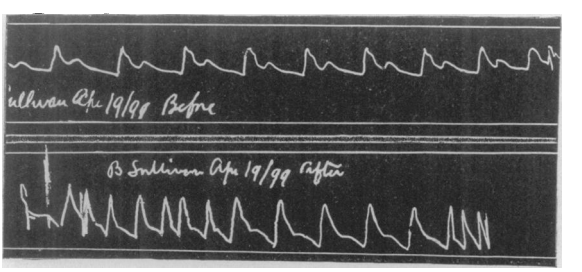

PLATE IX.—No. 3. Before and after.

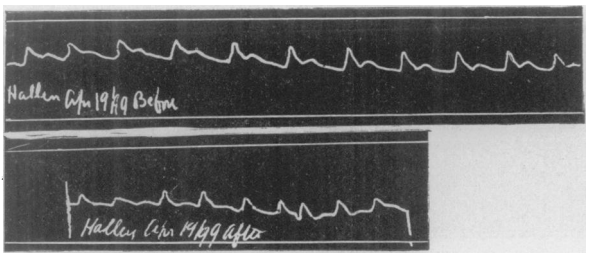

PLATE X.—No. 5. Before and after.

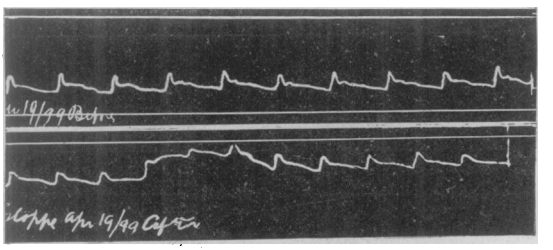

PLATE XI.—No. 6. Before and after.

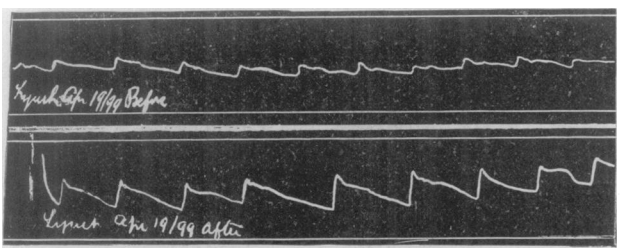

PLATE XII —No. 8. Before and after.

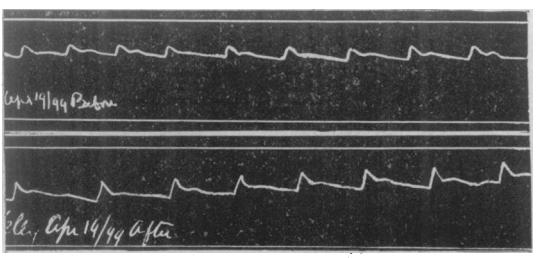

PLATE XIII.—No. 9. Before and after.

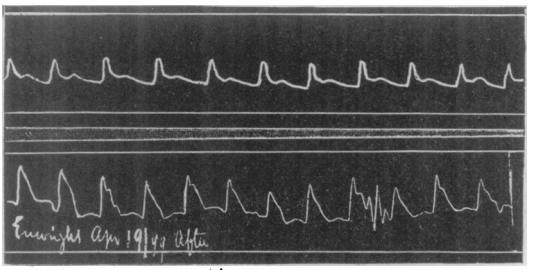

PLATE XIV.—No. 10. Before and after.

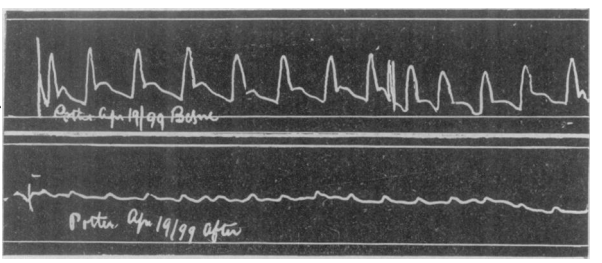

PLATE XV.—No. 12. Before and after.

That the effects as stated do result in individual cases, under certain circumstances and conditions, is undoubtedly true, but the logical fallacy of arguing from the particular to the general is in no way more strongly emphasized than in regard to these conclusions, drawn with respect to the effects of muscular exercise upon the heart.

The conditions existing in the case of a middle-aged sedentary man ascending a mountain and a carefully prepared athlete running a twenty-five mile race are no more similar than are those existing between a new and strong pump subjected to extremes of varying pressure and one which performs its monotonous but temperate function with a worn and leaky valve. In judging the effects of exercise upon the heart, every participating individual and every form of exercise should receive special consideration.

The case of No. 4, Plate VI., compared after a practice-run and after the race, is an excellent illustration of this truth.

After a practice-run of five miles he showed a temperature of 98°, pulse 100, respiration 32, a faint trace of albumin, and a sphygmographic tracing of high arterial tension. After the race he showed a loss of 4.9° in temperature and of $4\frac{1}{2}$ pounds in weight; respiration 24, $\frac{1}{10}$ per cent. of albumin, with numerous casts, and a pulse of 104 and of exceedingly low tension.

One of the most interesting of the conclusions of the examination is the evidence of the preparatory enlargement that the heart undergoes, showing the truth of Osler's statement that "no man becomes a great runner or oarsman who has not naturally a capable if not a large heart." This hypertrophy was shown in these cases by the bulging left intercostal cartilages; the thrusting force of the apex-beat; the enlarged percussion-area; the booming heart-sounds; the high arterial tension, and the increased area of cardiac dulness.

In drawing conclusions from the data given, remembering also that we are solely considering the effects of long-distance running upon the heart of healthy and strong men, and freeing our minds from preconceived notions and theories, the whole result of the examination can be summed up as showing an extreme condition of general muscular exhaustion. In this condition the heart, a muscular structure, participates with the other muscles. Its muscular valves, the mitral because of their most essentially muscular structure, are the first affected, and soonest fail to perform their function, thus permitting regurgitation of the blood into the left auricle. When this regurgitation is extreme, it may even go so far as to lead to backing up of the blood sufficiently to cause stress upon the right heart (*vide* the jugular pulsation which was present in one of the cases, No. 9, Plate XIII.).

In regard to the timing and placing of the murmurs heard in the position named, the anatomic situation of the heart-valves must be borne in mind. Anatomically, the periphery of all these valves can be included in the circumference of the large mouthpiece of the ordinary stethoscope. Anatomically, the semilunar, the mitral, and the pulmonic are included in

a still smaller circle, and the value of faint murmurs heard in the second left intercostal space must be judged by their transmission by the blood-currents and such other favorable sound-conductors as the hypertrophied muscular tissue of the left ventricle and the residual blood in its dilated cavity. The conduction of these murmurs heard in this position in the direction of the hypertrophied left ventricle and their systolic synchrony; the fact that in some instances they were conducted to the apex; that they were heard in the back; together with the increased dulness over the left ventricle, showing slight dilatation, and the sphygmographic corroboration afforded in the five cases, would seem conclusive evidence that the common-sense explanation of what happened in these fourteen tired and exhausted hearts was muscular incompetence of the muscular mitral valve, which was physically unable to perform its function because of its participation in the general muscular weakness. Another significant fact was that those winning first and second place had no murmurs, showing a greater relative muscular vigor of the heart.

In corroboration of this view the researches of Hesse are of value. Hesse has shown that during diastole the mitral orifice is too large to be closed by the mitral valves alone. The orifice must first be constricted by the sphincter-like action of the circular muscular fibres around it. Probably with the muscular incompetence of this sphincter there is also associated a muscular incompetence of the left papillary muscles, which muscles are much larger and stronger than those of the right side. Also, it is probable that the muscular fibres of the left ventricular wall, which is thicker and stronger than the right, bear their proportionate share in this relative muscular weakness. Indeed, it would seem that nature, which had constructed this valve after a distinctly more muscular pattern, had provided a physiological safety-valve for long-continued muscular strain. It is not our intention to enter into the discussion of Balfour and Russell upon the significance of murmurs heard in the so-called pulmonic area. Suffice it to say that while we agree with Balfour in his

deductions as to the significance of these murmurs, we must agree with Ball, of Philadelphia, in our belief that the anatomic basis of Balfour's deductions founded upon Naunyn's observations is "not proven." In other words, while we regard these murmurs as mitral we do not feel absolutely convinced that they are transmitted by the left auricular appendage. In these cases we believe them to be transmitted by the hypertrophied ventricular wall.

The dictum of Sansom, that a systolic murmur heard at the apex and in the back fulfils all the requirements of a mitral organic murmur, is a statement upon which we are ready to rest our case. Six out of eleven fulfil all the requirements of authorities as to mitral murmurs. Are we not justified by the premises and by the exactly similar conditions in the conclusion that the five other murmurs are also mitral, differing only in degree?

To sum up the significance of those heart-murmurs, it seems to me conclusive that they are simply to be regarded as the participation of the muscular mitral valves in the general muscular exhaustion.

With respect to the effect upon the individual of such contests, a question we are often asked, we can only say that we do not see how such a contest can be in any respect more injurious than any other form of exhausting muscular exercise, such as long-distance bicycle-riding, swimming, and the like. The injurious effects, if any, are due to the supreme stress of the contest and not to the nature of the exercise. Long-distance running under suitable conditions and without the contest should be beneficial rather than otherwise. Personally I regard it with the contest as far less injurious than other practices indulged in by exuberant young men.

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DISCUSSION.

DR. THOMAS DARLINGTON: I hope that Dr. Williams' paper will appear complete in the TRANSACTIONS of the Association, together with the drawings he has made. The paper is certainly a very valuable one, and worthy of careful study.

DR. NEWTON: I saw a boy who had acute dilatation of the heart from throwing a hammer. He recovered entirely, so far as I could learn. I would like to ask Dr. Williams if he has made any observations upon the subsequent condition of these men. I would also like to ask how long their depression lasted, as well as the temperature and heart-murmur.

DR. WILLIAMS: The murmur lasted only a very short time—from two to three minutes to half an hour. One of the contestants rode fifteen miles on his wheel after the race, while a second one took part in a one-mile race eight days later, and, although on that occasion he accidentally fell in rounding the track, he finished within two seconds of the world's record, which shows that he could not have been much injured by his previous race in Boston. Several of the men had been participants in previous races. The blood-count was so unsatisfactory that it was discontinued. The men when they came in were bathed in sweat, and they varied much in the degree of anæmia and hyperæmia of the skin.