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The Effects of Severe Muscular Exertion, Sudden and Prolonged, in Young Adolescents.

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IN any attempt to ascertain the effect of severe muscular exertion, it is necessary, first of all, to study the physiological changes set up in the body by moderate exertion.

Curiously enough, although the English are more addicted to athletic exercises than any other civilised nation in the world, no English physiologist, as far as I know, has ever systematically investigated this subject from a physiological standpoint and recorded the results of his investigations. The only works on the subject I am acquainted with are "The Physiology of Bodily Exercise," by Dr. Lagrange, written for the International Scientific Series, and "The Physiology of Sport," by Dr. George Kolb, a distinguished German athlete.

As I wish to make my paper as practical as possible, I will start by discussing the effects of exercise on two of the most important organs of the body, the heart and lungs.

Breathlessness.

One of the objects of respiration is to get rid of carbonic acid gas (CO_2) which is uninterruptedly manufactured in the body while life continues, and the accumulation of which in the body can cause death in a very short time. One of the results of muscular contraction is the production of CO_2 , therefore the greater the number of muscles contracting and the more rapidly they contract, the more quickly does this gas accumulate in the blood. It would appear, then, that the most important factor in the production of breathlessness is the saturation of the blood with this gas. A sleeping man, when the majority of his muscles are in complete repose and the manufac-

ture of CO_2 is at its lowest, breathes less deeply and less frequently than when awake. In hibernating animals the production of CO_2 is diminished to an extraordinary degree, and so is respiration. Lagrange states that CO_2 injected into the veins of a dog immediately quickens respiration, while a continuation of the injection brings on intense dyspnoea and all the usual symptoms of asphyxia.

We may conclude, then, that the respiratory need is in proportion to the quantity of CO_2 in the blood, and that in athletic exercises the quantity is rapidly increased by increased production. If now muscular work in a given time is so great as to produce a quantity of CO_2 greater than the lungs are able to eliminate the gas must accumulate in the system, and the respiratory distress will increase every moment, and will finally interrupt the work. Further, CO_2 has a weakening influence on muscular fibre, and causes its contraction to be less forcible and effective.

The amount of muscular effort necessary to produce breathlessness will vary with each individual and with the individual capacity of eliminating CO_2 by the lungs. The boy with large lungs, powerful heart, and an acquired knowledge of expanding his lungs to the best advantage will get rid of CO_2 much more rapidly in proportion to its manufacture than the boy with badly developed lungs, weak heart, and feeble chest expansion.

The Lungs.

The first effect of exercise is to increase the frequency and force of the heart's beat and quicken the blood current, more blood is sent to the lungs, and we get an active congestion. As a result of this active congestion the space occupied by the blood which swells up the pulmonary capillaries covering the air vesicles is no longer available for all the air in those vesicles. The lungs in consequence make an increased effort of expansion, and many of the air cells not usually in action at once expand with air to make good the deficiency. These changes occur especially about the apices of the lungs and along the free edges. As the muscular effort continues an increasing amount of CO_2 is thrown into the blood, stimulating the respiratory centre in the brain, inspiratory efforts become deeper and more frequent, and more air is drawn into the air cells, at once impeding the circulation through the pul-

monary capillaries; a fight for place is going on in the lungs between the blood and the air; the heart beats more and more quickly but each ventricular systole is less vigorous, and as a result passive congestion of the lungs follows, and with it a marked obstacle to the elimination of CO_2 . The exertion cannot be carried beyond a certain point, as increasing saturation of the blood with CO_2 in the end brings about the cessation of all effort.

We see here then at least two effects of severe muscular exercise either sudden or prolonged. A great strain is thrown on the air vesicles, leading to what may be described as physiological emphysema.

Let me take the case of a university athlete, let us say in his third year a man who has gone in vigorously for athletic competitions, rowing or running as a schoolboy, and keeping up, or probably increasing, his athletic competitions regularly at the university. In such a case you will often find the following signs of this physiological emphysema: (1) Absence of apex beat either on inspection or palpation while at rest; (2) absence of all superficial cardiac dulness, due to the fact that the enlarged emphysematous lung completely covers the heart and pushes it away from the thoracic wall; (3) on percussion a hyper-resonant note above the clavicles and along the edges of the sternum. Now if the muscular effort which has brought about this emphysema is repeated too often or kept up for too prolonged a period, it is quite easy to conceive that it becomes converted into a pathological emphysema, leading in later life to the same evil consequences that we have in the emphysema of old-standing bronchitis or chronic asthma.

Heart Strain in University Athletes.

A second effect is to throw a great strain on the right side of the heart, on the right ventricle and right auricle, as passive congestion of the lung implies over-distension of the right ventricle.

When we remember the enormous changes going on in the body of young adolescents, the rapid growth of the heart as well as all the other parts of the body, we should be safe in assuming that at no time during what may be called the athletic period, is the right side of the heart more liable to injury from over-distension. I think this

danger is a very real one, and I can recall several examples coming under my own observation.

A few years ago I was asked to see in consultation a public school boy, who had come to Oxford with a great school record as a mile runner. When training for the Freshman's sports at Oxford he found that he was not running nearly up to his form, and that the watch made him many seconds slower than he ought on his previous records to be.

On examination of the heart while at rest nothing unusual was noted. On making him walk fast round a large room two or three times marked epigastric pulsation was observed, which continued longer than usual, at the same time a very distinct systolic murmur was produced, heard over the middle of the sternum, especially along the left border. I had no doubt that this was a case of over-dilatation of the right ventricle, and advised his giving up long-distance running altogether. This patient was afterwards seen by Sir William Broadbent, who gave him the same advice, and sent him a sea voyage, where the temptation to do too much was removed.

I believe that Sir William Broadbent's explanation of the murmur was to the effect that in these cases the conus arteriosus—the upper conical portion of the right ventricle from which the pulmonary artery rises, usually covered by lung tissue—owing to the dilated condition of the ventricle, comes into actual contact with the chest wall, and during systole is more or less flattened out against it, thus forming an eddy in the blood current as it rushes through the pulmonary artery, producing a murmur systolic in time. Let me give you another example:—

From time to time I examined a very successful three-mile runner, and on one or two occasions, after comparatively slight exertion—walking round a room two or three times—I detected a soft systolic murmur over the pulmonary area. However, he was going so well that, after consultation with a medical friend, we decided that he might be allowed to compete in his next race; he did so, winning easily; two or three weeks later he ran again, winning his race with great ease.

The following year, on one or two occasions I detected the same murmur early in his training; but later, on training very carefully, the murmur was not brought out by exertion. He then ran a very hard race, intending, I believe, to make an exceptionally good time. When

about 300 yards from the finish, and running quite by himself, he collapsed, and with very great difficulty tottered to the tape, and was supported to the pavilion, where he lay for nearly three-quarters of an hour in a semi-conscious condition, and was a considerable time before he had sufficiently regained his normal condition to leave the ground. I was not present at the race, and so am obliged to fall back on his own statement.

A year passed, and he was most anxious to race again, but was obliged to confess that when it came to running hard many of the old symptoms, to which before his breakdown he had been a complete stranger, began to assert themselves, and in my own consulting room, I was now and again able to bring out the murmur to which I have referred.

I have no doubt that this was another example of the dilatation of the right side of the heart produced by prolonged muscular exertion. I might cite many other cases very similar to these which have come under my own observation.

Heart Strain in Girls.

I would here call attention to a form of heart strain by no means uncommon among girls and young women. We find it most frequently among young domestic servants who have a large amount of running up and down stairs, and it is generally associated with a certain amount of anæmia, and probably is due to an atonic condition of the heart muscle induced by the impoverished blood. The most prominent symptoms are breathlessness on exertion out of all proportion to the anæmia and excessive frequency and tumultuous action of the heart.

In these cases we may give iron in various forms for weeks with very little benefit; it is only when we insist on rest in the horizontal position for at least two or three hours in the day that our patients begin to make real improvement. Often it is necessary to keep them in bed for a time. The rapid growth of girls between the ages of 14 and 18, associated with marked functional changes, renders them, I believe, particularly liable to minor forms of dilatation of the right side of the heart. It is well to remember this, as in recent years hockey, swimming, cycling, and tennis have been taken up with such vigour by them, and are at times overdone, though on the whole the effect on the health is very beneficial.

The Effect of Severe Muscular Exertion on the Left Side of the Heart.

At the outset it would appear that authorities differ as to the condition of blood pressure in the systemic vessels during exercise. Lagrange, quoting Marey, says that the heart in spite of the increased frequency of its beat, does not give to the blood so powerful an impulse as in ordinary circumstances, and the blood pressure falls. On the other hand, Dr. Kolb shows by a number of sphygmographic tracings that during active exercise the blood pressure is raised.

It will be admitted that in the earlier stages of great muscular exertion the blood is thrown into the aorta with both increased force and increased frequency, and that one of the most constant and marked results of oft-repeated muscular exercise is what may be described as physiological hypertrophy of the heart. When I am asked to examine an undergraduate in his first year with reference to his fitness for running or rowing, I invariably find out from his past history what amount of exercise he has indulged in during his school career. If he has gone in vigorously for athletics—running, rowing, football—I expect to find some evidence of this hypertrophy; the apex beat will be found lower and more to the left than usual, in the mammary line or even external to it; the impulse will be strong and heaving in character, there will be some accentuation of the aortic second sound, and the pulse will be slow and strong. If during his university career he keeps up his athletic efforts, these indications of hypertrophy will become distinctly more marked and more unmistakable. This hypertrophied condition is, I think, a matter of little consequence as long as the efforts are not too often repeated. It is in the too frequent repetition of severe muscular effort or its continuance over too long a period of life that the danger lies.

More than thirty years ago Dr. Clifford Allbutt, in a paper published in the *St. George's Hospital Reports* on the efforts of overwork and strain on the heart and great blood vessels, showed that the chief danger lies in the aorta. He pointed out that oft-repeated muscular effort produced hypertrophy of the left ventricle, and that if continued the blood from the hypertrophied heart was constantly thrown into the aorta with abnormal force, and that the vessel gradually lost a certain amount of its

elasticity, became stretched and dilated. This change increased the capacity of the vessel and permitted a larger quantity of blood to be thrown into it at each contraction of the ventricle. In order to force it onwards the ventricle was compelled to beat with increased power. So little by little the distension was increased until the day arrived when incompetence was set up, either by stretching of the orifice from dilatation of the vessel, or from inability of the valves to support the column of blood above them. These changes, as Dr. Allbutt carefully pointed out, were very gradual in their progress, and did not as a rule induce the sufferers to seek medical aid until they had attained middle age. There is one troublesome symptom that I think is often associated with this form of physiological hypertrophy, and that is sleeplessness. I remember that when training for the University sports this troubled me very much, and in my fourth year I was obliged to give up training in consequence.

Prophylaxis.

It is easy to see how the dangers, as far as the heart and lungs are concerned, of severe muscular exertion, sudden and prolonged, in the case of young adolescents, may with a little care be avoided: (1) I think all boys before being allowed to compete in school sports, especially in running or rowing races or gymnastic exercises, should undergo medical inspection, and that the badly-developed, weakly, flabby-muscled boys should not be permitted to take part in these competitions, but they should most certainly be encouraged to go in for graduated exercises, as I believe with good medical supervision and a little encouragement many of these boys will grow into fairly broad-chested, muscularly developed, healthy men.

(2) Boys who are obviously growing with exceptional rapidity as occasionally happens, should be advised for a time to avoid exercises requiring great muscular exertion.

(3) On the other hand I should say that the healthy strong boys, who take part in all the school usual sports, football, paper-chases, or athletic sports, might well be examined once or twice a year to safeguard against overstrain, and here I might add one word, as to the examination of the heart. I believe it is impossible to form an accurate opinion as to the way the heart is doing its work without giving it a very definite amount of work to do. I in-

variably make a patient walk fast round a large room two or three times and sometimes run up a flight of stairs before expressing any opinion as to whether he is in a condition to train for a hard race, and am frequently unable to detect anything wrong until I have taken this precaution.

Cases of severe and sudden breakdown from muscular exertion in the case of well-fed public schoolboys and university men are exceedingly rare. I have known men in face of all advice row night after night in the bumping races at Oxford with well-marked valvular disease and yet not come to any sort of grief. Whatever changes are set up may be sufficient to make the athlete at the time short-winded, and perhaps cause precordial pain and discomfort, but do not produce any striking and alarming symptoms, the danger all lies in the future twenty years onwards.

Recommendations.

I am perfectly familiar with the late Dr. Morgan's inquiry into the "After-Health of the Oxford and Cambridge Inter-University Crews," extending over a period of forty years, and have often quoted the result he arrived at—namely, that the vast majority of these oarsmen were benefited rather than injured by their exertions, and that, as regards heart disease, there was little appreciable difference in the mortality from this cause among these University Oars and that which prevailed among other classes of men at a corresponding period of life. It is well to remember that Dr. Morgan was dealing with a very special class of men, who were as a rule medically examined as to their fitness for the contest, and who only competed after careful and prolonged training, and did not—and this is of the very greatest importance—compete very often. The points I would insist on, as far as school athletics are concerned, are as follows:—

(1) That before engaging in athletic competitions involving great muscular strain, the younger boys, however good they may be, should not be allowed to compete in the longer races—mile, half-mile, and quarter-mile—against boys two or three years older than themselves, and more especially this would apply to paperchases; here the strain is often very great. The paperchases should be graded.

(2) That the effort in every case should be preceded by a period of training and preparation.

(3) I would urge the school doctor to advise the successful athlete at school to make his athletic career a short one, giving up severe athletic effort within three or four years of his leaving school. It is in the frequent repetition of the muscular effort, or in the continuation of the athletic life over too long a period of years, in which the main danger lies.

Go to any of our great centres of the iron industry where the labourer has constantly day after day to lift heavy weights, or to make frequent and oft-repeated muscular exertion, and the percentage of heart troubles will be found to be enormously increased among these men, and their lives shortened by their efforts. Or learn the same lesson from lower animals, in those animals in which great muscular effort is frequently repeated, such as foxhounds, greyhounds, hunters, racehorses, diseases of the heart and blood vessels are especially common. I make these assertions on the authority of Mr. Fleming, the eminent veterinary surgeon.

For the boys who from one cause or another are not allowed to take part in the more vigorous games, such as football, paperchases, gymnastics, I hold that it is of the highest importance to provide some form of outdoor pastime. At Oxford I advise cycling, insisting on my patients walking hills and not attempting to ride on very windy days. Golf is my sheet anchor. As to lawn tennis, I advise them to play with a partner up at the net and go in for a volleying game. Leisurely rowing, sculling, or punting may also be indulged in.

After all, the danger of athletic strain is, I believe, not very great at our public schools, where boys are well looked after and have not the chance of doing too much; it comes later on when the successful athlete is encouraged to repeat his efforts far too frequently for his own good. Of this I am assured, and in the present day it holds good even for football.

I could say a great deal more of the evil effects of muscular strain on the lower middle classes, whose ambition in recent years has been stimulated in every shape and form to win pots and medals in all kinds of running and cycling handicaps. Fortunately, I believe, this craze is on the wane. I have now pointed out the dangers connected with muscular effort, but I do not close my eyes to the advantages gained by athletic competitions as carried on at our public schools. I hold that the advan-

tages to health are overwhelming. I believe the physique and general health of our public school boys owe an enormous amount to school games and the taste for healthy open-air exercise these games develop. I believe these tastes developed at school often stand a man in good stead for the rest of his life. I am not going to moralise on the beneficial influence of athletics in the building up of character. This influence has been described and dilated on by head-masters and laymen in better and more forcible language than I can command, and, I may add, in a very convincing and clearly written paper read a few years ago by Dr. G. Fletcher. I take only the physical side of man, and I assert that a taste for muscular exercises in the open air will do more than anything else to keep a man young in spite of his years and able to enjoy life in the best sense of the word.

Physical Standard for the Army.

I believe it is said that the standard of chest measurement, of height and weight in the army is too high. It has always seemed to me that to attempt to judge of a man or boy's fitness to engage in any athletic undertaking requiring a high level of stamina in this way is most unsatisfactory. As a rule, long-distance runners (from three miles onwards) are small, thin, wiry men; some of our best-known champions have been very small. The same holds good of long-distance walking. Weston, the American, who started the craze of long-distance races a few years ago, and who certainly was a man of extraordinary stamina, was a short, lightly-built man, about 5 feet 7 inches in height, 9 stones in weight. On many occasions he covered more than 500 miles in the week. Rowell, his opponent and conqueror, who on one occasion covered over 600 miles in six days, was a shorter and more stoutly-built man. I believe that Weston would never have passed into our army, his weight and chest measurement would have been against him, but I should imagine he was exactly the type of man best fitted for the work our soldiers are now being called on to do in South Africa.

If we look in another direction to a body of men who for a part of the year give themselves over to often very great feats of endurance—the guides in Switzerland—it will be found that some of the most active and enduring are small men, but equal to carrying their own weight and

all the extras that a guide is required to carry. The standard of height, then, ought to be a low one in the army. In my opinion your short wiry man is infinitely more able to stand the wear and tear of a campaign than your tall, finely-built man. With regard to chest measurement, I must own I am a great sceptic. It seems to me that those who attach so much importance to chest measurement overlook the fact that there are at least two very distinct types of chest—the broad chest and the long, narrow chest which cannot be measured. The lung capacity of two men of exactly the same height might be practically the same; yet their ordinary chest measurement might differ by inches. The tape only measures the horizontal diameter; it takes no cognisance of the vertical.

Lastly, with reference to weight: I remember a little more than a year ago being consulted by a young man who was coaching for the army. He was hoping to get into a crack cavalry regiment. He was well built and in excellent health. I would have unhesitatingly passed him as a first-class life for assurance. His only trouble was that he was a stone too light and he wanted to be fattened up. In other words, every effort was to be made to put a quite unnecessary stone of flesh on to a man who would be in every way healthier and more fitted for his work without it. I could not get the stone of extra flesh on him; but, as he passed well out of Sandhurst, I heard that they gave him his commission. Can anything be more absurd than this? It seems to me that if the matter of physical fitness for active service were left in the hands of competent medical men to decide each case on its own merits, without hedging them round with all sorts of standards, it would be far better. The result would be that very probably many small useful men would get in who are not now accepted, while others taller and finer in appearance might not. After all, in the matter of life assurance we get on very well without too many standards.

Intermittent Albuminuria.

To what extent I would ask does great muscular strain tend to produce or exaggerate those cases of intermittent albuminuria which are so common among young men? Let me take a typical case. An undergraduate, apparently in the very best health, seeks my opinion as to his fitness for rowing. I find all the organs healthy and the mus-

cular development good—everything satisfactory until I come to the urine, when I discover a distinct cloud of albumen with the ordinary tests. On further examination I find that after a night's rest no trace appears, that with slight exertion the amount is very small, but after a hard row the amount is very considerable. Often the effect of exercise is so marked that while the urine first passed after exercise will contain a very distinct trace, urine passed an hour or two later will contain either no albumen or only a very slight trace. I generally advise these patients to give up all competitions involving great muscular exertion, such as rowing in races and running in athletic sports, and to take to more moderate exercise in the form of golf or sculling or lawn tennis. Here again, if harm is done by muscular effort the injury will be of very gradual onset, and will not make itself felt for years. I take it that the explanation of this form of albuminuria is that there is some defect in the walls of the blood vessels which supply the kidney, that with the increase of blood pressure, which is the first result of muscular effort, the defective walls allow a certain amount of serum to escape, and the more often the muscular effort is repeated the more easy it becomes for the serum to transude. It would be very interesting by a systematic examination of the urine to ascertain the percentage of cases of this form of albuminuria in young adults at one or other of our large public schools. Certainly at Oxford I am, accidentally as it were, constantly coming across cases which probably existed undiscovered at school—undiscovered because the trouble gave rise to no symptom whatever. Treatment seems to do very little good. If they have albumen in their first year of residence they invariably have it in their fourth year, and then I lose sight of them.