THE SIGNIFICANCE OF PHYSICAL EDUCATION IN HUMAN HEALTH AND FITNESS

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We are living in an age of technology. This is a mixed blessing, since it has brought advantages as well as disadvantages. Amongst the latter, there are the diseases arising from lack of exercise. They have been given the medical term of "hypokinetosis". As a result of our comfortable mode of living, our bodies are not subjected to sufficient physical strain. Hence, trophic processes may develop which, at first, may mean no more than a reduction of physical capacity. Later on, however, functional and regulatory disturbances will result, which finally will lead to permanent damage to the organs. There is no method of prophylaxis other than to restore normal physical activity.

This is also true likewise for functional disturbances and reduction of capacity. These conditions may be cured by occupational therapy and by rehabilitation.

At present, internal medicine is faced with two major problems: the struggle against cancer, and against the diseases of the heart and circulation. In the western civilisation, cardiac and circulatory diseases have become Public Enemy Number One.

It is not the inflammatory conditions which are predominant in this field, as was the case only 30 years ago, but the functional disturbances which, at a later period, lead to organic diseases. When once organic damage has developed, the physician can do no more than give symptomatic treatment. As yet, there are no drugs by means of which organic damage may be cured. For this reason, prophylaxis is the aim of internal medicine, i.e., the endeavour to avoid, from the beginning, the development of cardiac and circulatory disturbances. This may be achieved only by individually prescribed occupational therapy. It is the task of sports medicine to make a detailed investigation of occupational therapy and establish the laws accordingly. Sports medicine, therefore, can be regarded as prophylaxis or preventative medicine, the latter being one of the two pillars of internal medicine.

Physical Training

What form of physical training is required for this purpose? Here we must distinguish between three forms of training:

(1) Speed training;
(2) Strength training;
(3) Endurance training.

From a medical point of view, speed training is of lesser importance as it only demands co-ordination between the muscular and nervous systems as well as strength in the particular muscle groups. By speed training, we understand sprint training. The factors limiting the achievement in a 100 metre dash, for instance, are the trunk-limb leverage, the co-ordination of the nervous system and the musculature, the viscosity of the nerve fibres, and the muscular strength. This training however, does not affect the internal organs. Thus, for example, even an Olympic champion in sprinting like Hary, shows a heart volume barely equal to that of the average trained individual.

Strength training, from the medical point of view, is more interesting, even though its effect is of no importance on the internal organs. The cross-section of the individual muscle fibre is increased by strength training. However, there is no increase in the *number* of muscle fibres. Although there is an enlargement of the muscle fibres, it is important to remember that the blood supply remains practically unchanged. There is no increase in the number of capillaries, and these are the only area of metabolic exchange.

Thus, the passage of the diffusion of oxygen on its transport to each individual muscle fibre is lengthened. The increase in the circumference of the individual muscle fibre consequently makes the blood-supply more difficult. This explains the difference in achievement between endurance and strength athletes. The endurance of a muscle is proportionate to its blood supply. The more blood per unit of time, that can be supplied to the active muscle, the more oxygen thus offered to the cells, the higher the endurance capacity of the muscle will be. I should like to quote an example: a few years ago, a so-called "Mister-World-competition" was held at Munich. The so-called best developed man in the world was to be elected. The persons chosen were men with exceptionally large muscles, but they could hardly execute normal movements. I had the opportunity, subsequent to the election, of examining the first three prize-winners. They were able to work a turn-mill with a load of 700 to 800 watt for a period of one minute. A well-trained physical education student can, for instance, manage 300 to 350 watt. These muscle-men, however, were not able to endure a load of 120 watt over a period of 10 minutes, which can easily be accomplished by any well-trained *female* student of physical education. The reason for this discrepancy lies in the fact that in strength training, the individual muscle fibres will gain in size, whereas the supplying blood vessels, and particularly the capillaries, will not increase. Such strength training has no effect on the internal organs, and particularly none on the heart. The size of this organ remains unchanged. An action which lasts for one minute only can be performed on pure muscular strength. But when an action lasts longer than three minutes, the limiting factor lies in the heart and blood circulation. This is the reason why the muscle men could perform the extraordinary feat of strength of 800 watt per minute, but were unable to perform the relatively easy work of 120 watts in 10 minutes. They admit that they exercise each muscle individually. These men can, therefore, be compared with a motor-car with too heavy body-work. The cylinder-capacity of its motor and the cross section of its petrol pipes are too small. The car, therefore, will only develop a minor capacity. These relations are the same in the human being. The small cylinder capacity is the heart which has remained small, the too narrow petrol pipes are the capillaries which likewise have not developed. Their capacity, therefore, is not sufficient for offering the necessary amount of oxygen to the working muscle.

Endurance Training

The Heart

From a medical point of view, it is only the endurance training which is of particular interest. Its influence spreads to the most important internal organs. First of all, the heart must be mentioned. It is a well and long-known fact, that in the course of time, large athletic endurance achievements leads to an enlargement of the heart. In the medical literature, this condition has been called the "athletic heart" or the "sport heart". Until only a few years ago, the athletic heart was considered to be a condition with a bad prognosis. It was said to be the result of a pathological process of adaptation of the myocardium to excessive strain. The persons concerned were said to have a decreased life expectation.

In the last years, however, examinations using the most modern scientific methods have taught us that the athletic heart is a completely healthy heart. In an athlete who is working his way up to the world-class in endurance achievement, a heart of this size is a basic organic prerequisite. It is comparable to a motor the piston displacement of which has been increased, and the capacity thereby has been improved.

The development of the large athletic heart is brought about by two factors: the increase in the heart muscle, and the increase in the volume of the heart cavities. The studies conducted by LINZBACH has shown that the growth of the heart muscle is a harmonious process. The individual heart muscle fibres gain both in length and in width. However, the so-called "Critical weight" of 500 grams of the heart is never exceeded. The critical weight of the heart is based on the following conditional factors: for anatomico-physical reasons which can be mathematically proved a healthy human heart may grow to a weight of 500 grams without any impairment of its blood supply. When this critical threshold is exceeded, disturbance of the blood flow automatically occurs. For now, the growth of the capillaries can no longer keep in step with the growth of the myocardial fibres. In the past 20 years, we have learned from the autoptic findings in athletes who had been killed in accidents, that the critical heart weight had never been reached, not even in the largest athletic hearts. The average heart-weights ranged from 430 to 450 grams. Moreover, the electrocardiograms of star athletes with large athletic hearts have never shown symptoms suggestive of disturbance in the blood supply. If the contrary were true, these hearts certainly would not be able to accomplish such high achievements.

For a long time, the enlargement of the heart cavities has been considered as a pathological change. The enlargement may arise from a pathological increase of the pressure within the heart, this is the co-called tonogenic dilatation, or by a failure of the heart muscle, this is the so-called myogenic dilatation. By heart-catheterization in star athletes under strain, we have been able to demonstrate that neither a tonogenic nor a myogenic dilatation is present in the athletic heart. Completely normal pressure values were noted right up to the limit of physical capacity. Therefore, pathological dilatation of the heart cavities could reliably be excluded.

REINDELL and DELIUS mention a regulative form of dilatation. In all probability, this is a decrease of physiological nature in the tone of the heart muscle which gives rise to an enlargement of the interior space of the heart.

The increase in the muscular volume and the enlargement of the heart cavities enable a large athletic heart to promote a large output even against high pressure without having to fall back on its physical reserves. Due to the large amount of blood which can be supplied with each beat, the athletic heart is able to work at a lower rate. The studies conducted by GOLLWITZERMEIER and American authors, moreover, have shown that the oxygen requirement of the myocardium grows in proportion to the beating rate, apart from the pressure. Thus, a slower beating heart will work more economically. By means of experiments using heart catheterization, we have actually established a markedly lower oxygen-requirement in the athletic heart. This fact reduces the danger of nutritional disturbances occurring under stress.

Thus, the oxygen requirement in the athletic heart is reduced by the bradycardiac action and the economical regulation. The so-called arteriovenous oxygen difference, i.e., the difference in the oxygen levels in the arterial and in the venous blood, gives information on the extent of oxygen utilization. In the resting heart muscle, and under physical strain with a rise of 12 to 14 volume per cent, the arterio-venous oxygen difference remains almost unchanged. If however, in the accomplishment of a certain achievement, the heart muscle requires less oxygen, a larger oxygen reserve will result. Thus, the so-called coronary reserve increases. Since, according to the investigations carried out by SABISTON and GREGG, the blood flow in the myocardium only travels in the diastolic phase, and since, in the slow-beating trained heart the diastole is prolonged, there will result in an improvement in the blood flow in the trained heart muscle.

By means of the modern method of interval training, it is possible to achieve an optimal enlargement of the heart within a period no longer than six weeks. When a trained athlete is put to bed for a fortnight, however, he will loss 200 to 300 ml of his former heart volume during this period.

The Skeletal Muscle System

Endurance training likewise has an effect on the skeletal muscle system. Here, it is especially capillarization which is improved. This means an increase in the number and in the calibre of the capillaries. An improvement in the blood supply, and thus in the oxygen supply of the muscles will be the result. This is a most important factor. Heart, circulation, and respiration are not more than the servants of metabolism, and it is their task to satisfy the metabolic requirements. If, however, the muscle, due to the improved capillary distribution, is able to withdraw more oxygen from the blood streaming by, this will bring about a decrease in the demand on the heart. Please, let me quote a practical example: in an untrained person, the resting arterio-venous oxygen difference on an average amounts to 5 per cent, in a trained person, it will amount to about 7 to 8 per cent, thus permitting a reduction of the output per minute of the heart. The resting output per minute of the heart of an untrained person actually amounts to 5 litres, as compared with an output of 3 to 4 litres in an endurance trained athlete.

This can be illustrated by the following calculation: the resting heart of a poorly trained man in his thirties has to perform an achievement of approximately 10,300 mkg within 24 hours. Within the same period, the achievement of the heart of an endurance-trained athlete is no more than 5,500 to 6,000 mkg. Even if a daily training period of 2 hours, and an expenditure per hour of 1,500 mkg is taken as a base, the performance of the trained heart at work is still lower than that of the resting untrained heart.

Endurance training improves the capillarization both of the skeletal muscles and the myocardium. This has been clearly demonstrated by ECKSTEIN in experiments on dogs. Thus, prophylaxis of myocardial infarction may be exercised by adequate training.

The Blood

Endurance training likewise markedly influences the blood. The total amount of blood increases. The maximum increase in the blood hitherto reported in the medical literature is from 5 to 7 litres. At the same time, there is a rise in the haemoglobin level. The highest rise in haemoglobin hitherto reported was 240 grams. Even more significant than these two factors is another symptom. During physical stress, the blood coagulation time decreases to an extent of 300 to 400 per cent. When pathological alterations of the walls of the vessels are present, the formation of thrombi may easily occur. In an athlete trained for endurance, the clotting time is reduced to a much lesser extent. Thus, there will be much less danger of thrombus formation under physical stress. Here, a "practical anticoagulant therapy" may be spoken of.

Respiration

The effect of endurance training on respiration, too, is clearly demonstrable. Respiration may be subdivided into three main functions: ventilation; diffusion and perfusion.