

## The Science of Running

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RUNNING is the most primitive of all types of muscular activity. It is man's oldest racial movement. The effects of running are physiologically more far-reaching than any other form of physical activity. Running does not overdevelop or hypertrophy any muscular groups. It normally develops in the safest way the very dynamos of life, the heart, lungs and vascular system. Running awakens the most primitive urges and joys of life, because there still exist in the neurones of man the remnants of his ancestral flights in chasing, hunting and catching.

When youth and man run they wildly and joyously recapitulate the story of their long distant past. The recorded history of the art shows Pheidippides, the greatest runner of all time, performing a deed unbeatable up to modern times. Two great athletic deeds he is honoured with. Not only did he run from Athens to Sparta in two days, a distance of 152 miles, but he bore the message of the Greeks' victory over the Persians from the battlefield of Marathon to the City of Athens. It is not recorded in what time he did this 26 miles, but the distance was run so swiftly that it was the cause of his death, for he only had time to utter the words "Rejoice, we conquer" and he collapsed.

Long distance running is an exercise of endurance. In competitive athletics it may also function as an exercise of speed. Great runners like Ritola, De Mar, Stenroos, Nurmi, Hayes, Kolehmainen, El Ouafi, Paddock, Abrahams and many others have all been men of calm spirit, wonderful determination, and immense grit. The big men of the marathon track, like De Mar, Stenroos and Nurmi, have possessed a typical caste of physique. These men possess the stocky pyknic type of physique about 5 ft. 4 in. to 5 ft. 6 in. in height, and have weighed light in proportion to their height, often never over 140 pounds.

They possess strong abdominal muscles, powerful lower limbs, and wonderful heart and lung power. It is just the development of these latter organs which makes the art of running the most valuable of all physical activities. Why is it that the long distance runner has a stronger heart and bigger lungs than the gymnast or the weight lifter, tennis player, and perhaps every other athlete?

It is because these organs function more actively in running. What is the effect of systematic long distance running on the heart? It is one of the functions of the heart to deliver blood, laden with oxygen, to the tissues in action, and to drive it back to the air spaces in the lungs, loaded with carbon dioxide. When carefully trained by graded effort to its physiological limit, such as obtained in running, it increases in size and weight, its walls grow thicker, more muscular and stronger, and changes take place in its rhythm and pumping power. The heart of the marathon runner has been found to be larger than any other type of athlete. This "largeness" is a true development.

The efficiency of the heart is gauged by the amount of blood it can put out in a given time and its quicker recovery after severe work. These phenomena have been carefully measured. If we compare this type of efficiency in a non-athletic and an athletic type and give some data one will be able to realize the significance of the above assertions.

In some experiments conducted by Professors Henderson and Haggard, a non-athlete in a standing position showed a pulse rate of 70 per minute and a heart output of 4.7 litres of blood per minute. When working to the extent of 534 Kilogrammetres per minute the pulse rate increased to 152, the minute output ran to 17.2 litres of blood. A highly trained runner showed a resting pulse of 68, and a minute volume of 9.8 litres. When he did 1,500 Kilogrammetres per minute on a bicycle ergometer, his minute output ran up to 30.3 litres, and his pulse rate ran to 150.

The factors influencing cardiac development are the effects of muscular action on the venous return. The heart pumps out just as much blood as it receives. In terms of mechanical work, it is capable of performing approximately 20,000 Kilogrammetres of work in twenty-four hours in a resting state.

This enormous amount of work can be doubled during an active working day. The mechanical efficiency of the cardiac pump varies up to about 30 per cent., which is higher than that of the muscular system when it is working under its most favourable conditions.

When a large mass of muscular tissue is at work in any activity, the frequency of muscle contractions and relaxations are of a naturally rhythmic manner. A big load of blood is forced through the venous system and returned to the heart. It has been mathematically shown that the oxygen consumption per Kilogram of body weight per minute is greater in running than in any other exercise, hence the greater circulatory rate of blood. This is because running is completely evolutionary in its design. Mankind has been doing it for ages, and its actions are performed with the least expenditure of energy. It has become economical. Although it involves the largest muscle masses of the body, its movements follow nerve paths biologically old. Running secures better cardio-vascular nutrition than any other type of action.

On the other hand, many static muscular actions, such as those found in weight-lifting, hinder venous return. That is why such exercises are exhausting when compared with their energy expenditure. The result of this is that the net return of blood to the heart is delayed and there is a back pressure which pools the blood in the large venal channels. This often leads to a cyanotic state, especially in those who do a lot of such exercises.

Observations of blood pressures on speed runners show a slow steady rise in systolic and diastolic pressures during the effort. As the work continues, these pressures fall a little from the maximum, and then they drop below the normal after the exercise has ceased. McCurdy has shown that the systolic recumbent pressure may rise to 170 millimetres of mercury in the trained man. The greater the effort the higher the pressure. In endurance activities (ten mile run), where moderate speed effort is carried out, the systolic pressure may mount to 40 millimetres of mercury over recumbent pressure, and the diastolic pressure 22.5 millimetres of mercury.

Many investigators have observed that after severe and long distance efforts both pressures remain below the normal. This is probably due to vascular dilatation and cardiac fatigue.

The biochemistry of respiration in regard to running can only be briefly dealt with. Life involves gaseous interchange between an environment and an internal cellular structure. A constant supply of oxygen must replace a constant removal of carbon dioxide, otherwise life disintegrates. Exercise alters the gaseous equilibrium in blood and tissues. The oxygen consumption of a man in a standing position is about 350 millilitres per minute. This supplies all tissue needs. But as soon as man commences to move, his oxygen requirements increase. If he walks at the rate of 2.38 metres per second, his oxygen consumption rises to 2,732 millilitres per minute, and if he runs rapidly at the rate of 4.7 metres per second, he will consume 4,080 millilitres of oxygen per minute.

But this is not all. If a man be trained to move his muscles in the fastest possible manner, and he does this for a period of about 30 seconds, it is found that his oxygen consumption will rise to the enormous extent of 30,000 millilitres per minute. This is the absolute limit of human capacity, and is perhaps never reached outside the fast "running in place" of laboratory tests.

The relationship, then, between muscular activity and the gaseous respiratory function is definite and obligatory. Increased breathing movements always follow increased muscular activities. How is this breathing mechanism evoked into action? There is at the base of the brain a portion called the Medulla oblongata. Within this there is a small area called the respiratory centre. Flowing out of this respiratory centre are a number of nerve fibres which are keyed to the vagus, phrenic and intercostal nerves. These end in finely drawn branches to all the inspiratory muscles. This respiratory centre is very sensitive to the presence of acid metabolites, and when these are rushing through it it becomes very excited and sends out additional impulses to the breathing muscles to function. Hence increased respiratory activity.

This mechanism is not by any means a perfect one. If exercise be only moderate the heart and breathing machinery can cope with the oxygen requirements and the carbon dioxide elimination. The biochemical products of muscular activity are acidic in nature. As a result the H ion concentration of the blood rises, and a mechanism comes into action which endeavours to subdue this increased harmful activity, but before it can be quenched the acid metabolites succeed in getting into most tissues. If the acidity of the blood does not rise above a certain level, the body can keep what is known as a "steady state". But if the exercise increases in intensity and speed, a point is reached where, in spite of the best efforts on the part of the heart and lungs to eliminate the carbon dioxide and replenish the oxygen supply, acid production gets ahead of acid elimination. Since it is the oxygen which is required to oxidize lactic acid, and it cannot be supplied quickly enough the body runs into what is called an "oxygen debt".

The exercise has to be done on credit, and sooner or later nature makes one stop work and "pay up". Activity ceases and prolonged and vigorous respiration is continued until the body gets all the oxygen it requires. Every vigorous type of

exercise runs up an "oxygen debt", and recovery cannot be complete until all this debt is "liquidated". An athlete can incur a greater oxygen debt than a non-athlete, and pay it off much quicker when the exercise is over.

In speed and endurance running there is a well-known phenomenon which often occurs and in which breathlessness and acute abdominal pains supervene and almost inhibit the athlete from carrying on his race.

This distress is indicated by the symptoms of acute exhaustion. The athlete knows that this is the onset of "second wind", and if he has enough grit to continue, the body adjusts itself rapidly and the race goes on. The cause of this distress is the setting up of a series of new biochemical conditions which have to be adjusted. The acid-base balance of the tissues is disturbed. There is a greater lactic acid production within the muscles, vasomotor responses have to be made, a large quantity of the blood has to be shunted from the splanchnic area into the active tissues, respiratory adjustments have to be met, and increased heat manufactured. In addition, the primary and secondary blood "buffers" have to be called up and assembled. When all this machinery is brought into a state of equilibrium the cardio-respiratory apparatus becomes efficient to carry out its functions and the muscles act with renewed vigour. A man then gets his "second wind".

The point of interest is that the properly trained man does not ever develop this condition. Some ill informed persons have taught that the practice of "breathing exercises" preparatory to the athletic event will prevent this initial dyspnoea. But this is sheer bunk. The use of these exercises is dangerous and unscientific. They temporarily upset the respiratory centre. Oxygen cannot be stored in the body, and the respiratory functions are not improved by static "breathing movements".

As a net result of running practices, the athlete so improves his respiratory and circulatory powers that he can deliver greater quantities of oxygen to his tissues in a shorter time. His vital capacity increases considerably, and his tidal capacity goes up in quantity and down in rate. Professor Demyer showed that the respiratory rate of men who had been trained by running activities reduced from 14 to 10 per minute.

The mechanical factors involved in running are worthy of representation in this article. First of all, the runner is using practically two-thirds of his muscular system in violent contractions if he is a distance or speed runner. From the waist to the tip of the toes, both flexors and extensors of the body, the lower limbs are brought powerfully into action.

Outstanding development is noticeable in the gastrocnemius, soleus, quadriceps and "hamstrings". The glutei are always well developed and strongly marked in runners, and the abdominal muscles are usually strong and well developed also.

Man's anatomical system inhibits him from racing over the ground as fast as his mammalian contemporaries. This is due to his upright position and his lack of a fourth lever in his lower limb machinery. Quadrupeds have greater speed and springing power because their muscles are geared to four large levers linked to give great mechanical power. When these elongate with force greater speed ensues. It is axiomatic that the speed of a limb increases in proportion to the acuteness of the angles of the bones possible in motion and the number of bones forming its levers.

In running, there is a phase of the action when the whole body is off the ground. For a portion of each stride the body is unsupported. It is approximately one-third of the time taken to make a move from one foot to the other. The foot pressure on the ground is greater in speed running than endurance running. The frequency of footfalls increases with speed, and their duration diminishes. The chief characteristic of the run is the period of suspension between the two footfalls. This does not take place in the form of a leap, as some try to explain.

The actual forward thrust is made during the downward pressure of the foot. In other words, the body begins to rise when the foot touches the ground, and descends just as the other foot reaches the ground. Kinesiological analysis shows that the legs leave the ground by flexion just at the moment when the body is at its greatest height in the air.

In long distance running it appears that the heel touches the ground first and the foot performs a rolling motion, finishing at the first metapthalangeal joint. In addition, there is a wave-like motion through the spine and forward and backward oscillation of hips and shoulders.

The mechanical work involved in racing has been worked out by Marey and Demeny. The voluminous works of these Frenchmen have never been translated into English. So much for the low scholarly standards in English physical education. On the contrary, the American universities have made prolific use of such material. Demeny has shown that when a 64-Kilogram man is running about 145 steps to the minute, he is expending energy to the extent of 22 kilogrammetres per step. That is 3,190 Kilogrammetres in one minute. In faster running, where there are 300 steps per minute, it has been shown that 7,230 Kilogrammetres are expended in one minute's running. Professor Hill has shown that converting figures for oxygen consumption into mechanical units, a man running at the rate of 9.2 yards per second for 100½ seconds will expend sufficient total energy to raise his body weight 690 feet vertically upwards. Deducting losses due to mechanical inefficiency, of course this figure would be much less, but still quite an enormous expenditure. One can easily guess what the physiological cost of a marathon run would be.

One of Professor Hill's first-class 100 yards sprinters, weighing about 165 pounds, during a series of tests, actually propelled himself over this distance at the rate of 11.46 yards per second, and in so doing developed about 8.5 horsepower of mechanical energy. In doing the 100 yards at his best speed, he expended 40,000 foot pounds of work and incurred an oxygen debt of 6.7 litres.

It may be interesting to give some physiological tests and measurements of one of the best runners in the last decade, C. de Mar. He was famous for winning the American marathons in record time, and submitted himself to a number of tests several times to furnish data for physiological purposes.

The following scientific measurements give some indications of his remarkable physique :

Age	..	..	..	..	..	..	36 (April, 1924)
Standing height	..	..	..	..	..	..	173.0 centimetres
Sitting height	..	..	..	..	..	..	89.0 centimetres

Weight .. .. .	60.5 Kilograms
Predicted weight (Dreyer) .. .. .	65.5 Kilograms
Vital capacity .. .. .	5.5 litres
Oxygen consumption (resting) .. .. .	256.0 millilitres per minute
Ninth rib expansion .. .. .	9.3 centimetres
Pignet's index .. .. .	28
Sargent's index .. .. .	32
Pulse before race .. .. .	58
Pulse after racing 15 miles in 1 hr. 45 min. ..	116
Breathlessness after this test .. .. .	Nil
Heart resting minute volume .. .. .	8.2 litres
Heart resting stroke volume .. .. .	141 millilitres

The data given in the above articles furnish ground for investing the art of running with a sound scientific technique. Athletic coaches should know the main physiological points in any exercise art which they teach.

In the majority of instances they don't, to the detriment of their trainees. I have seen enough of athletic training in Australia to know that it is encumbered with a mass of traditional ignorance. The sooner those responsible learn scientific values in all athletic arts, the better.

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