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Science of champion runners: Inside the body of elite endurance athletes

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The 40th anniversary of the London Marathon takes place on Sunday, October 4 2020. Athletes will run on a closed-loop circuit around St James's Park before finishing on The Mall. This year's lineup includes current champions Eliud Kipchoge and Brigid Kosgei. These athletes can run for more than two hours at speeds an average person could maintain

for only a matter of seconds. So what makes them so fast?

Years of training have brought about bodily adaptations that enable elite endurance athletes to perform at the top of their game. Let's first look at the all-important cardiovascular system, which is adapted to enable a regular supply of oxygenated blood to the working muscles.

Strong heart

Regular training results in an increase in the thickness of the muscle forming the heart wall, in particular, the left side of the heart. This is the side of the heart responsible for circulating oxygenated blood around the body and to the muscles during exercise.

Increased thickness of the left ventricle wall (the lower chamber of the heart), enables endurance athletes to pump more blood out of their heart each time it beats. We call this the "stroke volume."

A regular adult, exercising at their maximum level, can have a stroke volume of 120ml. However, because of the increased thickness of the heart wall, endurance athletes have a stroke volume during maximal exercise of around 200ml.

An endurance athlete's heart can beat 200 times every minute during maximal exercise, resulting in these athletes being able to circulate close to 40 liters of blood around the body every minute. The amount of blood the heart pumps in one minute is called cardiac output. In elite endurance runners, it can be nearly twice that of an average adult during maximal exercise.

VO2 max

It is not just a strong heart that is key to these athletes' success. Getting enough oxygen to the working muscles is also vital.

Activities lasting longer than a couple of minutes mainly rely on aerobic metabolism (the process by which we use oxygen to turn fuel, such as fats and sugars, into energy), making a constant supply of oxygen crucial to success. Elite marathon runners can breathe around 200 liters of air per minute during maximal exercise. This combined ability of the lungs and heart to take in and transport oxygen means that elite athletes have a very high VO2 max—the maximum amount of oxygen the body can use in a minute. VO2 max is regarded as one of the key determinants of endurance performance success.

VO2 max values in an average adult are around 30-45 milliliters of oxygen per kilogram of body weight per minute. But in elite endurance athletes, VO2 max increases to 65-80 ml/kg/min.

Running economy

It's not only the size of an athlete's engine (VO2 max) that's important for success, just like a car, the economy of the engine also plays an important role. Most marathons are run at around 75-85% of VO2 max, meaning the ability to work efficiently at lower exercise intensities is also key to success. In running, this is measured by "running economy."

Athletes with good running economy need less oxygen to run at a given speed than their competitors, preserving vital energy for later in the race. Elite endurance runners display incredibly low running economy values, showing their ability to move at fast speeds while using a much lower amount of oxygen than the average person.

At a given speed, an average person may typically need 220ml of oxygen per kilogram of body weight to run one kilometer. Elite marathon

runners are more economical, perhaps requiring as little as 180ml of oxygen per kilogram of body weight to cover the same distance.

Lactate threshold

An important factor in running a fast marathon race is the ability to run at the fastest possible speed without becoming tired. This optimal speed or "threshold" is related to several changes that happen in our body as we exercise, including the build-up of chemicals in the blood. Blood lactate is one such substance that accumulates in the blood during exercise.

Lactate threshold is a term used in exercise physiology to describe specific changes (or breakpoints) to this substance during exercise.

Blood lactate is often incorrectly thought of as a waste product and mistakenly thought to be responsible for muscle fatigue, but it is now recognized as an important energy source. Still, exercise above the lactate threshold is associated with more rapid fatigue and, as such, the speed at lactate threshold is a powerful predictor of endurance performance.

A higher lactate threshold will enable a higher running speed to be sustained without blood lactate accumulating, enabling the running speed to be maintained for an extended period. Elite male and female marathon runners have reported lactate threshold speeds of 18-21km/h

As the runners lap St James's Park on Sunday, all the above factors will contribute to their success—they will be the key determinants of the runners' performance.