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"Training methods to improve running economy are constantly sought after by athletes, coaches and sport scientists."

What is it, why is it important for distance runners and how can it be improved?

IN PREVIOUS ISSUES OF THE SCIENCE SECTION THE TOPIC OF RUNNING ECONOMY HAS BEEN BRIEFLY RAISED SEVERAL TIMES. THE CONCEPT CAN BE A COMPLICATED AND DIFFICULT ONE TO GRASP, AND IN THIS ISSUE WE WILL TAKE A STEP BY STEP APPROACH TO DESCRIBE WHAT IS RUNNING ECONOMY AND HOW IT CAN BE IMPROVED.

RUNNING economy is the energy cost required to run at a given speed, and it is represented by the oxygen consumption (VO2) measured at a particular running pace. At the same speed, runners with good economy use less oxygen than runners with poor economy. Running economy can vary by as much as 30% among athletes with a similar VO2max, and there is a strong association between running economy and distance running performance. Accordingly, it is likely that improvements in running economy will be associated with improved performance in distance runners[11].

RELATIONSHIP TO RUNNING PERFORMANCE

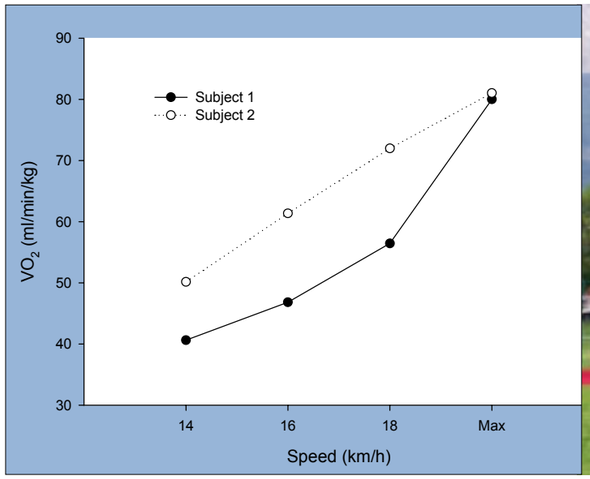
The relationship between running economy and performance is well documented. Research comparing elite American distance runners (VO2max 79 ml/min/kg) with sub-elite American distance runners (VO2max 69 ml/ min/kg) indicated that the elite runners had better running economy than good runners[9]. It has been demonstrated that a 5% increase in running economy induced a 3.8% improvement in distance running performance[3]. It has also been demonstrated that running economy is a good predictor of performance in runners of comparable ability[1]. In one study 12 highly trained male distance runners (VO2max ~72 ml/min/kg and 10 km performance ~32 min) were tested for physiological capabilities on a treadmill 3-6 days after they had competed in a 10km race. Race performance was significantly correlated with running economy at running speeds of 14, 16 and 18 km/h with the more economical runners performing the best. Approximately 65% of the variation in race performance was attributed to differences in running economy. A good example of the relationship between running economy and performance is described in a case study of American mile record holder Steve Scott[2]. In a six month period of training, Scott improved his VO2max by 3.8% (74.4 to 77.2 ml/min/kg) and running economy by 6.6% (48.5 to 45.3 ml/min/kg) at a running speed of 16 km/h. The combined improvement of VO2max and running economy reduced the relative intensity of running at 16 km/h by 10.0% (65.1% to 58.6% of VO2max) and was associated with improved performance during this period. Scott broke the American records for both 1500 m (3:31.96) and the mile (3:49.68) during this period with his improvement in race times paralleling his improvements in physiological capacities.

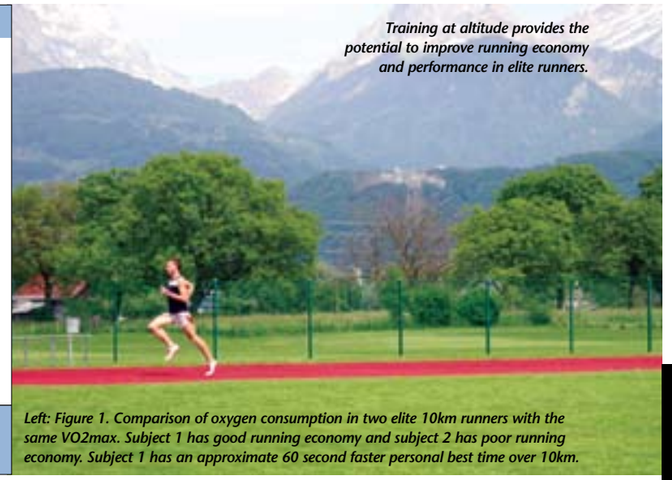
INTERVENTIONS TO IMPROVE RUNNING ECONOMY

Training methods to improve running economy are constantly sought after by athletes, coaches and sport scientists. Interventions that are easily incorporated into an athlete's training are desirable. Two that have received recent attention are strength training and altitude training. It has been suggested that strength training may allow the muscles to utilise more elastic energy, which reduces the amount of energy wasted in braking forces. Strength training may also improve running mechanics and muscle recruitment making running more efficient. Also, altitude exposure may modulate discrete metabolic aspects of working muscle, which facilitates more efficient use of oxygen and therefore improves running economy. A third intervention that may improve running economy, although it has been researched to a lesser extent, is training in warm to hot conditions.

1. Strength Training

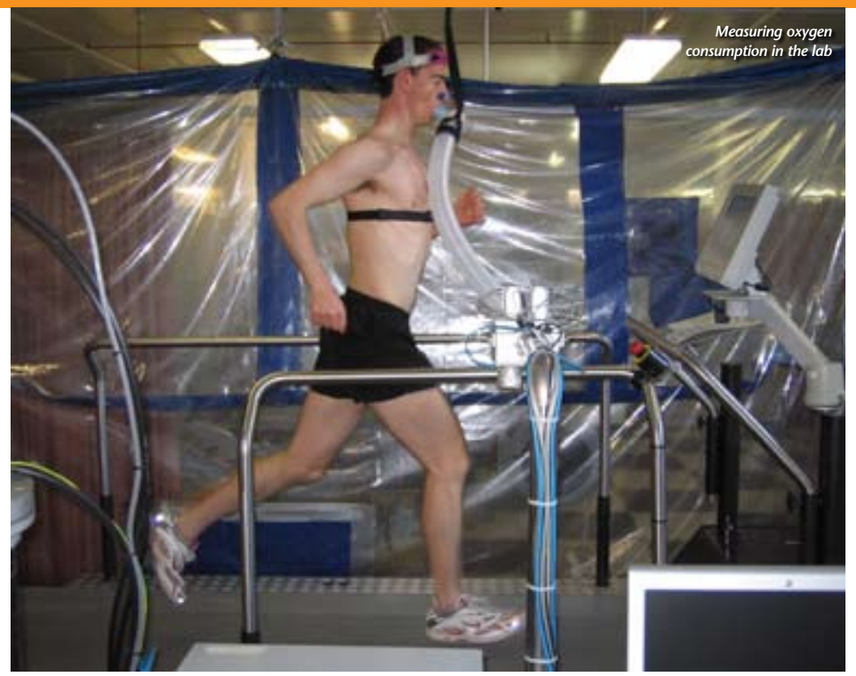
Strength training helps improve anaerobic characteristics such as the ability to produce high levels of lactic acid as well as the production of short contact-times and fast forces[7]. Recent work has shown that a combination of heavy-resistance training (traditional weight training) added to regular endurance training resulted in improved running performance and an enhanced running economy in well-trained triathletes[8]. Plyometric training is a specific type of strength training that utilises activities such as bounding, jumping and hopping. Plyometric training invokes specific neural adaptations such as increased activation of the motor units (nerve and group of muscles innervated), with less muscle hypertrophy than typical heavy-resistance strength training[5]. Plyometric training has the potential to enhance the muscles' ability to generate power by exaggerating the stretch-shorten cycle and increasing the stiffness of the muscle-tendon system, which allows the body to store and utilise elastic energy more effectively[12]. Both these adaptations could conceivably improve running economy by generating more force from the muscles without a proportionate increase in metabolic energy requirement. Alterations in running mechanics that allow for better coordination and timing of ground force application as well as better recruitment of muscle groups important for running are another way that plyometric and other forms of strength training can improve running economy. As mentioned in Issue 2 of R4YL, several research groups around the world have found 3-8% improvements in running economy and ~3% improvement in running performance after a period of specific strength training. Issue 2 also includes plyometric exercises that can be used by distance runners in their weekly training.





Training at altitude provides the potential to improve running economy and performance in elite runners.

Left: Figure 1. Comparison of oxygen consumption in two elite 10km runners with the same VO2max. Subject 1 has good running economy and subject 2 has poor running economy. Subject 1 has an approximate 60 second faster personal best time over 10km.



Measuring oxygen consumption in the lab

2. Altitude exposure

Altitude training results in central and peripheral adaptations associated with the lower percentage of oxygen in the air, which improve oxygen delivery and oxygen utilisation in the muscles and improve running economy, at least when exercising at altitude. There is evidence to suggest that running economy is also improved at sea level, with numerous research studies demonstrating an improvement in running economy and performance after various forms of altitude training (See Issues 3 and 4 of R4YL). Plausible mechanisms for improved running economy at sea level after a period of altitude exposure are:

- An increase in the energy production per mole of oxygen used[6],
- A decrease in the energy cost for each muscle contraction[10],
- And/or a decrease in the cardiorespiratory cost of oxygen transport[4].

The latter mechanism is supported by the reduction in heart rate at three submaximal running speeds coinciding with improved running economy after 10 elite distance runners slept at a simulated altitude of ~3000 m and trained at normal altitude for a period of ~50 days.

3. Training in the heat

Heat acclimatisation results in lower core body temperatures and an increase in plasma volume, which is accentuated by acute and chronic bouts of exercise in warm to hot temperatures. These changes may attenuate the magnitude of the thermoregulatory response (increased ventilation, circulation and sweating) and reduce the increased energy requirements associated with heat stress[13]. It follows that blood viscosity (internal friction of the blood caused by the percentage of blood cells in relation to total plasma volume) would be reduced from training in the heat due largely to an increase in plasma volume. A decrease in blood viscosity has been shown to have positive effects on endurance performance[14]. Adaptations from training in warm to hot conditions may also allow runners to run at any given speed with a lower heart rate and core body temperature, both of which are associated with improved running economy[15]. These findings support the premise that training in moderate heat may improve running economy and performance at normal temperatures, although insufficient data precludes drawing any firm conclusions.

SUMMARY AND FUTURE DIRECTIONS

Although extensive research has been conducted on running economy, and its importance to running performance is unquestioned, there are still relatively few documented training methods that have been shown to improve running economy in highly trained distance runners. Both the use of resistance training and altitude exposure appear to have potential in improving the running economy of highly trained distance runners, but further research into this area is required. Training in warm to hot conditions is another intervention that has the potential to improve running economy in distance runners, but again intervention studies investigating the effect training in the heat has on running economy are limited, and further research is needed in this area. Given that well-designed strength training programs, exposure to moderate altitude and training in warm to hot conditions have other benefits besides the potential to improve running economy, it would seem sensible for coaches to utilise these training methods where possible.

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