The efficacy and design of strength training programmes for distance running events

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The design of a sports' strength programme is often founded on opinion and conception of the kind of training and exercise selection that will result in an event specific benefit. The problem with opinions and conceptions is that they vary between coaches. In my experience, this is very evident in the area of designing strength programmes for the distance running events, where coaches' ideas on what strength qualities need developing are diverse. Some coaches favour high volume strength endurance or circuit training, some believe in high intensity power training and some coaches believe strength training is not required for distance events, or should be limited only to the faster, middle distance events. These varied beliefs tend to be justified by coaches' perceptions of strength training or past training habits.

I contend that strength programme design is most effective when it is based on evidence and concepts rather than opinions and conceptions. Ideally, programmes will follow a proven method from the research literature. If empirical evidence is limited, as is often the case for elite athlete populations, then programmes need a sound theoretical basis. This ensures rational choices of training goals, modes and exercises are made for the event.

This article will summarise the small body of empirical evidence of strength benefits for distance running and discuss the theoretical basis for strength development required for these events. The scientific discussion aims to steer distance running coaches into making informed decisions about how to design strength programmes based on two potential areas for improved performance. The first is strength development related to maximum speed and the second is the strength development related to running economy.

The Maximum Speed Argument

Most coaches would agree that high levels of lower limb strength and power are important to optimise sprinting performance, and as such, the majority of elite sprinters complete strength programmes. Research has shown that maximal strength and sprint running performed concurrently in the training cycle improves sprint performance[6] and a programme of explosive weight training performed at maximal power loads improves sprint performance.[21] No studies have controlled the training programmes of elite athletes for long enough periods to prove definitively the best programme design, however, practise of international athletes suggests a multi-dimensional strength training programme running concurrently with the running and sprinting training yields good results.[5] The multi-dimensional programme would include high force, high velocity or explosive and



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stretch-shorten cycle (SSC) exercises, usually the commonly known weightlifting and plyometric exercises. Strength training for sprinting is also supported by the concept that one of the key limiting factors of sprint performance is the rate of force development in the vertical direction during ground contact.[19] This limiting factor can be specifically trained and overloaded with high vertical rate of force development produced in weightlifting exercises, such as the second pull of the power clean.[7] In addition, sprinting requires high levels of SSC elastic energy utilisation for propulsion forces.[5] This is a separate quality to muscle power and can be developed with plyometric exercises using similar contact times and movement velocities as the sprint action.

There is both empirical evidence and theoretical basis that strength and SSC training benefits maximal sprint running performance. Having established the efficacy of this kind of training upon sprinting with this brief review, we need to consider how much sprinting ability impacts upon distance running performance in order to establish the extent to which strength and SSC training would benefit the distance events.

The importance of maximum sprint speed is clear for the middle distance events. For example, elite male 800m runners would need to be capable of performing 200m sub 23 seconds to be able to run at 52–53 second lap pace during 800m races. Indeed, research shows that middle distance performances can be accurately predicted from max running speed combined with the running velocity at VO_2max.[1]

The need for excellent sprint ability for events of 5000 m and upwards is less obvious and many coaches believe that this is the reason why strength training is not necessary for the longer distances. However, evidence exists to show that maximal sprint speed during a maximal anaerobic running test along with the velocity at VO_2max intensity is a predictor of performance in 5000m.[17] This research suggests sprint ability is a neuromuscular and/or physiological factor that contributes to long distance running performance, although it will not be as significant as for the middle distance events. In addition, it is worth considering the competitive demands of these longer events, where the final 200m of a 5000m or 10000m track event can be completed in around 30 seconds for elite females and around 27 seconds for elite males. This shows the need for good sprinting ability and anaerobic power to be able to speed up sufficiently at the end of races in order to win.

The performance analysis of the events and the research showing that maximum running velocity is a strong predictor of performance supports the concept that sprinting ability is an essential quality for middle distance and an important quality for long distance athletes. This argument, combined with the previously established concept that strength training is beneficial for the development of sprinting ability, strongly supports the use of strength training for distance runners. The type of programme design that would be best for distance athletes is not established in the research. However, a multi-dimensional programme targeting improved leg power and SSC ability is the logical recommendation. The take home message of the maximal speed argument is that distance runners are best to follow similar modes of strength training to sprinters if they wish to improve maximum speed. The key difference is not the type of training or exercises performed, rather that distance runners will spend less training time per week on this area and the strength training volume and strength performance levels will be lower than sprint athletes.

The Running Economy Argument

Running economy is a very significant physiological variable for distance running performance. Research has established that what distinguished elite distance athletes in race performance was not VO_2max levels – which are

usually very high and similar in elite runners – but the VO_2 cost of running at race pace.[4] For example, Miryashita *et al*[11] distinguished between 5 km runners all with VO_2max of around 68 ml/kg/min. The economical athletes at sub 15 minutes performances and the less economical group ran around 16 minutes.

Interestingly, a key biomechanical difference existed between the two groups, in that the less economical runners had greater vertical displacement of their centre of mass (10 cm versus 6 cm per stride cycle), which meant more energy was being wasted propelling the body upwards instead of forwards. The less economical group in effect, were running, unnecessarily 'uphill'. This excess vertical displacement being inversely related to economy is supported by other studies.[20] Kyrolainen *et al*[9] showed that reduced horizontal braking forces during ground contact was the major biomechanical variable related to running economy. Runners who are better able to maintain horizontal velocity during the stance phase are likely to be more economical. Pre-activity co-contraction of the major leg muscles prior to ground contact and effective horizontal propulsion force of the hip extensors during ground contact will promote this quality. This brief discussion of the biomechanics of running shows the need to avoid excessive vertical displacement and excessive horizontal braking is key in optimising mechanical efficiency.

The research does not support the concept of a perfect running technique model for maximum efficiency, rather that economy is dependent on the interaction of all the individual's kinematic variables.[20] What the research does support is the fact that neuromuscular factors are related to running economy and performance. For example, Paavolainen et al[17] found that shorter contact times, greater pre-activation leg muscle recruitment and lower total muscle activation in high calibre 10 km runners versus lower calibre runners with similar VO_2max levels. Running velocity at VO_2max is a strong predictor of distance running performance[12] arguably better than VO_2max alone,[14] as by definition it represents both aerobic power and neuromuscular efficiency in achieving a certain pace at that VO_2 level.

Biomechanical and neuromuscular factors are related to running economy. Theoretically, these factors can be positively influenced by strength and plyometric training methods, by creating the correct muscle strength and inter-muscular co-ordination between the major leg muscles. For example, hip extension force during ground contact can be promoted with exercises to strengthen the gluteals and hamstrings and pre-activation of the leg muscles prior to ground contact can be practised with plyometric drills. In fact, optimisation of the SSC component of running is proven to be very important for running economy, with much of the mechanical propulsion energy resulting from the tendons.[2]

During running, the leg can be seen to act as a 'spring'. The stiffness of the leg spring is the ratio of the applied force and the spring deformation and in the running leg spring model, this is the ratio of peak impact vertical force to the displacement of the centre of mass. The stiffer the spring the more energy is released back and the less vertical displacement during ground contact occurs. Dalleau *et al*[3] showed that leg stiffness during treadmill running was significantly related to running economy. A good level of co-contraction of the leg muscles prior to and during the braking phase of ground contact, results in 'stiffer' ankle and knee joints, which in turn increases force potentiation in the push off phase.[9] The fact that stiffness is related to running economy, further explains the mechanism by which strength and plyometric training can influence economy. The neuromuscular and physiological factors relating to leg spring stiffness are the SSC elastic energy release, increased rate of force development, inter-muscular and intra-muscular neural recruitment. All these factors are proven to be improved through maximal strength, explosive strength and plyometric training methods.[18,8]

There is a sound theoretical basis for strength and plyometric training influencing distance running performance by directly enhancing running economy in terms of both neuromuscular and leg spring factors. To strengthen the case further, there are also a few intervention studies providing empirical evidence to show improvements in economy post strength training. Notably, Paavolainen et al[17] showed, in a well controlled study that the addition of sprinting and explosive strength training to the weekly running schedule resulted in an improvement in 5 km running performance independent of any change in VO_2max or lactate threshold. The running economy at sub max speed, the maximum sprinting speed and jump power improved following the nine-week training study in the experimental group, with no change in the control. The authors argued that the neuromuscular factors related to sprinting and jumping were also related to running economy and that the mechanism for improved economy following the explosive strength training was most likely increased leg spring stiffness. This argument is reasonable, given the discussion above. Other studies have also support positive changes in

running economy through strength or plyometric training. Johnston *et al*[10] showed a 10 week resistance training programme for the whole body resulted in better running economy in female cross country runners and Murphy[13] showed plyometric training resulted in increased economy and 3 km performance without changes in VO_2max and LT in elite female athletes.

The potential to improve running economy through strength and plyometric training has both a good theoretical foundation and a small body of empirical evidence to back up its use. On this basis strength training is strongly recommended for distance events as running economy is such an important performance variable. Even a small improvement in economy will be a competitive advantage at the elite level and is especially important for the longer distances.

I contend that this scientific discussion will dispel any perceptions that strength and plyometric training is only useful for the middle distance athlete. If strength training could only influence maximal running speed, then this would possibly be true. However, as strength training influences running economy, then distance athletes will surely benefit from including strength and plyometric methods into their training programme.

In terms of programme design, the evidence from the published research and the rationale of the leg spring stiffness argument suggests that, a combination of explosive strength and plyometric exercises is likely to have the most positive influence upon running economy. It is important to emphasise that the aim of the strength training is to influence the neuro-muscular system and not to develop muscle mass nor enhance the work capacity of the major leg muscles. To achieve gains in running economy, I would recommend following similar methods to develop maximum sprint speed, with particular focus on plyometric ability.

In summary, for both running economy and maximal speed improvements, strength training using weightlifting and plyometric exercises for the major leg muscles are recommended as having the most scientific foundation for improving distance running performance, either through supporting the development of sprinting ability – which influences middle and long distance performance - and/or through the improvement of running economy, which directly improves distance running performance. It is vital to remember – for injury safety – that whilst the mode of training is similar to sprint athletes, distance runners cannot perform strength and SSC training at the same level of exercise intensity, volume or technical complexity. A period of familiarisation and gradual progression of strength training is recommended.

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