On the Role of Muscle Relaxation and Elasticity in the Adaptation Process of Distance Runners

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ABSTRACT

The ability to run fast is generally considered to be connected with maximal strength and accompanying muscle hypertrophy. However, there are other important factors involved in distance running and the excessive or incorrect development of strength can have a negative impact on performance, not least because the coordination required for efficient movement and energy conservation can be compromised. A better approach would link the preferred development of muscles and connective tissues together with the application of elastic energy and moderate muscle hypertrophy. Good muscle elasticity requires the rapid alternation of muscle contractions and relaxation. The aim of this article is to analyse the possibilities for developing muscle elasticity and connecting it with the skill of relaxation in the long-term training and adaption process of distance runners. The authors review the existing literature and make the case for coaches to focus on developing the skill of fast voluntary relaxation. Although adaptive shifts are largely genetically determined, it is possible to achieve remarkable changes via targeted training. Further research and wide spread application in training will lead to a better understanding and the development of relevant training techniques.

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Introduction

Training for running events is an adaptation process aimed at improving the runner's competition result. The degree of structural and functional integration of the body through long-term training is directly related to genetic programming, which influences both the athlete's health as well as the development of his/her physical capabilities[1, 2, 3].

The latter was proven in a study on nine and ten-year-old children, which showed that the effect of metabolic reactions to muscular exercise is genetically determined in both trained and untrained young people. Already in the early stages of ontogenesis, the subjects showed differences in the level of development of anaerobic glycogenolysis. Based on the results of the 300m run used as a testing exercise, three types of metabolic reaction were identified and the following adaptation type classifications were made:

- Stayer – blood lactate level under 4mmol/l;
- Sprinter – blood lactate level over 8mmol/l;
- Mixed type – blood lactate level between 4 and 8mmol/l.

The study also showed that further training did result in some fluctuations, but the general adaptation type remained unchanged[4].

Studies of heart rate variability carried out on children from two to six years of age demonstrate that the development speed of regulatory systems has a defining effect on the body from an early age. By identifying the main types of heart rate regulation (central or autonomous), it is possible to predict the body's possibilities for adaptational development[5].

DENISENKO et al. have very interesting opinions about the role of relaxational preparation in the long-term adaptation in trained athletes. Through complex research at the full body level, the authors established that fast intentional muscle relaxation and a high level of activity in the breaking protection system lead to a positive shift towards the relaxational adaptation type. If, however, the speed and activity level of the aforementioned processes are low, there is a shift towards the hypertrophic, preferably force adaptation type[6].

To assess the functional state of athletes' neural and muscular apparatus, as well as their central nervous systems, researchers used the computer polymyography method. The important novelty of the research lay in the fact that positive shifts in fast voluntary muscle relaxation in the experimental group were achieved when using special relaxation exercise complexes in addition to ordinary training sessions. The athletes who achieved the relaxational reaction type were remarkably different statistically from the hypertrophic type athletes, in that they had better sporting results, improved fatigue resistance, a faster and more advanced recovery rate from work stress, and a more economic heart rate. They were able to perform physical exercise with smaller shifts in biochemical energy consumption and to cope better with physical overload and trauma risks[7].

Although the subjects of the aforementioned study were experienced football players, it is highly likely that using special relaxation exercise complexes can be applied to developing the skill of fast voluntary muscle relaxation in athletes practising other sports, such as runners. Although the value of good relaxation skill is generally recognised in all sports, new opportunities to increase knowledge of and purposefully develop myorelaxation processes are essential, and highly practical for athletes who find relaxation problematic.

The Phenomenon of Fast Voluntary Relaxation

The central nervous system has been shown to play an active role in the process of relaxing skeletal muscles from a contracted state. However, the neurophysiological mechanisms underlying voluntary muscle relaxation in humans are not well understood[8, 9].

A reduction of cortical motor output can be achieved by the activation of inhibitory cortical areas, and both primary and supplementary motor areas may be activated during voluntary muscle relaxation[10. 11]. The motor cortex is activated by the onset of both skeletal muscle relaxation and skeletal muscle contraction. The increased primary motor cortex excitability that is observed just prior to muscle relaxation indicates that active motor control is necessary to relax the skeletal muscle during contraction[12].

The activation of the cortical inhibitory pathway is important in skeletal muscle relaxation[13]. Inhibitory mechanisms can be activated at the spinal level by a pathway descending through the spinal cord. A neuronal population within the motor cortex can cause spinal presynaptic inhibition by activating inhibitory interneurons in the spinal cord[14]. These findings suggest that the control of skeletal muscle relaxation differs from the control of skeletal muscle contraction. Thus, the process of skeletal muscle relaxation requires specific changes in the excitability of the motor cortex and activity of the inhibitory motor circuit. Increased antagonist co-activation increases joint stiffness and could contribute to deficits in voluntary muscle relaxation.

The two main peripheral factors responsible for the rate of skeletal muscle relaxation are sarcoplasmic reticulum Ca^{2+} uptake and the rate of cross-bridge kinetics[15, 16].

It has been suggested that special motor control training for skeletal muscle relaxation might lead to significant improvements in motor performance through increase in motor cortex excitability, and that this can occur over a short period of time (only ten sessions). The acquisition of skeletal muscle relaxation control after motor control training was found to increase short-interval intra-cortical inhibition upon the termination of skeletal muscle release in both the agonist and antagonist muscles[9]. These results suggest that the neural modulation induced by the agonist and antagonist muscles is controlled by the completion of relaxation following motor learning.

Muscle Elasticity

Elasticity plays a substantial role in enhancing the motor output in different sport movements, including running[17, 18, 19, 20]. If a tendon or active muscle is stretched, the elastic energy is stored within these structures. This deformation energy is recoiled and used to enhance motor output in the concentric phase of the stretch – shortening or reversible muscle action. Tendon elasticity and the specific skill of using this elasticity in a running movement are important for elite athletes. A middle or long distance runner who runs a distance in a certain time reactively will demonstrate a totally different type of performance profile (energy expenditure and coordination) from someone who runs the identical distance in the same time using a technique that is poorly reactive and therefore energy wasting. It makes sense, therefore, that a reversible (contraction-relaxation) muscle action be learned or trained.

According to NOAKES, the best distance runners are predominantly small, but exceptionally powerful for their size. They also have very good speed qualities and a superior fatigue resistance[19]. These runners' individual degrees of fatigue resistance are predictable from the low rate at which their performance falls off with increasing distance. There are no better examples for this than Olympic champions Haile Gebrselassie (ETH) and Mohamed Farah (GBR).

NUMMELA et al. showed that distance running performance and running economy are related to the neuromuscular capacity to produce force and that a maximal anaerobic running test can be used as a determinant of distance running performance. They also demonstrated the importance of the anaerobic efficiency factor in the process of achieving results in distance running[21].

Good speed is usually connected with maximal strength and muscle hypertrophy. According to ZATSIORSKY maximal muscular strength and forces in fast reversible muscle action are not correlated in good athletes[18]. However, if the runner's resistance training has been built up in a methodically correct way and the optimal increase of maximal strength does not interfere with coordination or the speed and elasticity related qualities, it is definitely useful. This has been proven by the results of various studies[22, 23, 24]. Unfortunately, it is rather common in sports training that ignoring the aforementioned principles leads to a situation where the athlete's maximal strength increases, without guaranteeing an improvement in endurance.

Concerning muscle and tendon elasticity, an interesting finding is that the stiffness of the leg spring alters with changes in stride frequency[19]. At the same running speed, the leg spring becomes stiffer, the higher the stride frequency and the shorter the stride length. It must reflect individual differences in the elasticity of legs and be in good connection with the fast running rhythm of modern top class runners. An outstanding example is another Olympic champion, Kenenisa Bekele (ETH), who was able not only to utilise mechanical energy efficiently at a high running velocity but also, much like sprinters, to generate greater mechanical energy when necessary[25].

In running, the work produced by various muscles alternates quickly. A rapid exchange between tightening and relaxation in muscles is an important requirement for achieving a good level of performance[20]. The way in which reflex patterns work to make tension and relaxation possible should be incorporated as fully as possible in a variety of types of training, trying to maintain good interrelationships between coordination, the sensory system and the physical condition. It is likely that efficiency of the neural regulation allows a more economic use of the body's energy resources and increases the efficiency of all body systems. With regards to the adaptive protein synthesis, such exercises primarily affect the sarcoplasmic reticulum and contractile proteins, without causing excessive muscle hypertrophy. Starting from moderate base speeds, the resulting adaptation has great advantages because functional powers increase significantly, although the mass of organs and leg muscles only increases marginally[26].

The muscle hypertrophy phenomenon is often controversial and solving it requires a dialectical approach. According to MJAKINTŠENKO & SELUJANOV, runners' leg muscle hypertrophy is not only important to counter mechanical load in running, but also as a factor in increasing the aerobic output of slow twitch muscle fibres. They argue that excessive hypertrophy increases inert muscle mass, whereas the lack of it reduces the anaerobic threshold speed[27]. Therefore, extensive aerobic exercise that reduces the cross-section of leg muscles should be optimally connected with strength exercises that help maintain the cross-section of the muscles[28].

It is likely that middle and long distance runners, depending on the distance, have optimal hypertrophy of certain muscle fibres, which is directly related to the morphological structures that are responsible for the oxidation potential. Moreover, NEMIROVSKAJA et al. suggest a possibility that targeted training can result in the increase of muscle fibre strength as well as oxidation potential, thus leading to a maximally high potential in elite class athletes[29].

Training practice has shown that bounding and jumping exercises of average intensity and longer duration are an efficient method for developing muscle elasticity in distance runners[30]. Accordingly, it is important to concentrate on the sharp, impulsive contraction of thigh flexor muscles, followed by a fast relaxation whilst doing these exercises. The aim is not to focus on pushing away from the ground, but on lifting the feet off the ground rapidly. A pre-stressed foot acts like an elastic shock absorber or a spring in a fast, rapid-paced distance run. It receives the gripping, pushing movement of the foot, releases the saved elastic energy, and ensures the efficient use of the horizontal component of speed[31]. Thus, when achieving fast foot contact it is crucial to time the swing leg's work well and move it forward quickly.

Reactive strength exercises using light weights can also be very useful. The 1500m and mile world record holder Hicham el Guerrouj (MAR) used these exercises intensively during his preparatory periods[32].

Perhaps the fast relaxation acquired through elasticity training slows the rate at which central fatigue develops during distance running. In addition to the concurrent use of special voluntary relaxation exercise complexes and muscle-tendon elasticity exercises, it may be the programming of the subconscious that comes into play in maintaining a fast running rhythm during the entire distance and enables a fast finish acceleration.

The Transfer of Training in the Development of Muscle Elasticity

The conversion of training exercises into sport performance is called the 'transfer of training'. The essence of the concept and its scientific and practical treatment are covered in great detail in a monograph published by BONDARCHUK[33, 34]. Central to the concept is the well-accepted training principle of specificity, which states that adaptions are specific to the nature of training exercises. In order to successfully conduct the training process, it is necessary to select the appropriate exercises and the most effective variants and complexes of their combinations and successions in training cycles. It is also necessary for the training potential of the applied programme to increase continuously.

YOUNG has published a good review of how to identify the factors that contribute to the transfer of strength and power training to sports performance, as well as guidelines for resistance training. He stresses that the maximisation of transfer to sports performance requires the 'conversion' of powerful muscles to a coordinated sports skill[35].

Although strength abilities are closely connected to elasticity abilities, excessive strength training is harmful in many contexts[20]. For example, the usually applied maximal strength exercises are problematic because they lack the elements of fast muscle contraction and relaxation that contribute to the coordination needed in running. Excessive maximal strength increase can be accompanied by the emergence of dominant excitation centres in the brain, which can set off negative effects when really quick and well-coordinated movements have to be performed[20]. In addition, strength training only affects the connective tissue elements indirectly. The tendons and ligaments are weak and not ready to stand up to the anticipated muscle development leading to injuries and other negative deviations. Developing tendons and ligaments requires a considerably longer period of time than developing muscle mass.

Different exercises for specialised preparation and development create a basis for enhancing performance at each stage or period of the training programme. Their transfer effect depends, first of all, on their similarity with the competition activity and higher training potential[33].

In relation to developing tendon and muscle elasticity and the transfer of training, a concept set out by MJAKINTSHENKO & SELUJANOV deserves attention. Their principal macrocycle planning scheme highlights the following issues: increasing the elasticity and reactivity of the leg muscles' connective tissue elements → increasing the strength abilities of slow-twitch muscle tissues → increasing the aerobic potential of both type of fibres → integrated preparation → competition[27]. In this logical sequence, the previous type of exercise creates a morpho-functional basis to obtain the greatest effectiveness of the subsequent type of exercise at a higher functional level of the body. It is likely that this presented sequence also ensures a good training transfer.

The development of strength in runners over time can be divided into three phases. First, an increase in strength can be attributed to an improvement in inter-muscular coordination, second, there is an improvement in intra-muscular coordination, and third, an increase in strength results from hypertrophy[20]. Research on neural adaptations to resistance training indicates that inter-muscular coordination is an important component in achieving a transfer to sports skills[36]. These recommendations are in good accordance with YOUNG's findings that relatively large gains in power output in nonspecific movements (intramuscular coordination) can be accompanied by small changes in sport performance[35].

Squats and jump squats on both legs have been popular exercises for training strength and power. High resistance weight training of leg extensor muscles is effective for improving maximum strength in a squat but this has not transferred to sprint speed[37]. The poor transfer of such power training could relate to a lack of movement specificity to running, which involves unilateral contractions to the leg extensors, resulting in total body movement in a horizontal direction. That is why asymmetrical strength training using squats on one leg is recommended for jumpers and runners[38]. There are three stages in this system:

Strength: additional weight 2–5kg, 6–8 squats in one series, 6–10 second rest between series.

Speed strength: squats according to metronome, 55–56 times in one minute without additional weight, 35–40 times with additional weight of 5–10kg.

Jumping capability: jumps on one foot for power or for speed.

The ability of some plyometric exercises to transfer to sprinting might partially reflect the contraction velocity specificity. Bounding exercises have been found to possess ground contact times very similar to those of sprint running[39] and distance running[40].

ROMANOV's system for the development of muscle elasticity deserves special attention[30]. A typical peculiarity of the system is that all jumping exercises are performed in a position where legs should be lightly bent at knees and other joints. The natural idea in this is that such position maintains tendons and ligaments in the elastic state like in animals that are running fast[41]. All jumps need to be performed using the front part of the foot arch. These exercises can be grouped as follows:

- jumps on the same spot;
- jumps forward and in different directions;
- jumps using additional (light) weights which are held overhead with straight arms.

Such sequences are used both to teach these exercises and also to develop muscle elasticity. This ensures a gradual increase in difficulty where the initial focus on muscle elasticity is followed by an additional muscle strength development. This is in accordance with the requirements of training transfer.

CARROLL et al. showed that the physiological adaptions associated with resistance training can potentially produce a positive or negative transfer to sports performance[42]. A negative transfer can occur if there is an increased co-activation of antagonist muscles, whereas a positive transfer can occur if resistance training reinforces the optimal muscle activation patterns that are required in the fast execution of the sports skill[42].

Conclusion

Based on scientific sources and empirical training practice, our analysis showed that developing muscle elasticity can play an important role in performance enhancing the neuromuscular adaptation of distance runners. This adaptation type would comply with the requirements of modern high-level distance running – a fast pace and the ability to maintain and change it when required. Although adaptive shifts are genetically determined, it is possible to achieve remarkable changes via targeted training. Since the brain is the most important organ related to motor output, its role and nerve regulation should be seen as the determiners of efficient neuromuscular adaptation. Better understanding of fast voluntary muscle relaxation based on research and wide spread application will result in the further development of relevant training techniques.

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