Rapid dynamic training: challenging the limits to sprint performance

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Abstract
The search for more running speed had brought an abundance of training methods and combinations thereof. However, the benefit to sprint improvement of these methods does not compare favourably against the value of sprint training itself for which sprint running has the exact specificity. The rapid dynamic training exercise in this experiment is intended to isolate the muscles that contract rapidly when sprinting. EMG analysis of the vastus lateralis muscle during the exercise revealed an average muscle activation time of between 100 and 110 milliseconds. This method of exercise allows those muscles that can activate in a short time frame, as would be applicable to sprinting, to be developed progressively. Therefore, the specific muscles required for sprinting can be developed preferentially.

Introduction
Athletes are always in search of more speed. Running speed is an essential component of most major sports, and can be the determining factor in the outcome of a sporting event (Corn & Knudson 2003). It is for this reason that athletes undertake training programs to improve their individual speeds. In order to gain a performance advantage, athletes are always in search of newer methods. A number of researchers have found that commonly used training methods such as high resistance, over-speed, ballistics, plyometric training and resisted running are not substantially better than sprint training alone (Delecluse et al.1995, Rimmer & Sleivert 2000, Majdell & Alexander 1991, McBride et al. 2002, Kristensen et al.2006, Spinks et al.2007). Most strength improvements will occur when the specific movement pattern is used in training, even when different exercises involve identical muscle groups (Weiss 1991). Also, the greatest strength gains have been found by Behm & Sale (1993) to occur at or near the training velocity. Wiemann & Tidow (1995) say that the velocity in sprinting is directly related to the movement of the legs for which the movement of the joints that make up the legs are the functional result of activating muscles (Kyrolainen et al.1999). Therefore we need to make our muscles activate quicker to move our legs faster, which would result in higher running speed. However this principle will only apply if the force produced by the leg remains the same.

How much force is needed to run fast?
Muscles need to produce 797N or 81kg of force in the vertical direction, and 312N or 32kg of force in the horizontal direction during the propulsive phase of sprinting at 9.96 m/s (Mero et al.1992). The magnitude of the force generated in sprinting seems small compared to the weights that sprinters are known to lift. Perhaps success in sprinting is related to power which is equal to the product of force \times velocity.

How fast must my legs be moving to run fast?
The running action involves the leg moving rapidly from the front of the body to the back. The backswing velocity of the leg is directly related to the velocity of the runner at full speed (Wiemann & Tidow 1995). At 9.9 m/s Kivi et al. (2001) measured the thigh moving backward relative to the hip at a speed of 666 °/sec. During the forward swing the thigh moves at 726 °/sec. Furthermore, the knee extends at 1165 °/sec and flexes at 1083 °/sec. When running at 9.4 m/s, Kivi et al. (2001) reported the thigh moving backward at 626 °/sec and during forward swing moving at 727 °/sec. Other measures around the knee joint at 9.4 m/s include extension at 1156 °/sec and flexion at 1058 °/sec. Therefore, to increase your speed from 9.4 to 9.9 m/s, you will need to increase the speed at which you extend your thigh by an extra 40 °/sec. In order to run at 9.9 m/s or faster, the thigh must be able to extend 89 ° in 0.13 seconds at least. If the athlete cannot move their thigh back at that speed, it seems fundamental that they train to do so. Additionally, the athlete must develop a fast extension of the knee, the fastest biomechanical movement observed in sprinting.
How do I move my legs faster?

The muscles accelerating the body forward in sprint running must contract at an increasing speed as the sprint velocity increases according to Cavagna et al. (1971). Sprinters running at 9.23 m/s do so with their vastus lateralis (responsible for knee extension) muscle activating within a time frame of approximately 145ms (Nummela et al.1993). This activation occurs prior to and during the ground contact time of 107ms. Similarly, Kyrolainen et al. (1999) reported ground contact times of 115ms at maximal speed with the vastus lateralis activating over 142ms.

Kyrolainen et al. (1999) also reports the gluteus maximus to be activated for 168ms (responsible in part for thigh extension) and the biceps femoris to be activated in two bursts totalling approximately 265ms, once during stance and once prior to the leg making contact with the ground in backswing. If the aim is to run at speeds greater than this, the muscles that move the legs must contract in less time, thereby moving the joint quicker. By moving the legs quicker the sprinter will run faster.

Does a method exist to benefit sprint performance?

Training with plyometric methods improves the initial phase of sprinting within the first 10m although beyond that distance Delecluse et al. (1995) and Rimmer & Sleivert (2000) find it to be no more effective than sprint training itself.

The most specific of the plyometric exercises to sprinting is said by Young (1992) to be maximal bounding. Mero & Komi (1994) found the speed of maximal bounding to be slower than in maximal sprinting, although still faster than the speed measured by Hunter et al. (2005) in the early acceleration phase of sprinting. In addition, Mero & Komi (1994) found the ground force production times of maximal bounding to be longer than that of maximal sprinting although shorter than that reported by Mero (1988) and Murphy et al. (2003) in the early acceleration phase of sprinting. Taking this into account, the velocity specificity principle (Behm & Sale 1993) suggests that bounding would impose demands on the same muscles used during the early acceleration phase of sprinting. If these demands caused an adaptation of those muscles, sprinting performance would be enhanced in the early acceleration phase.

Rimmer & Sleivert (2000) found that plyometric training was able to reduce the ground contact time by 7 milliseconds in the early acceleration phase with this reduction being maintained near maximal speeds. The result is improved sprint performance through decreasing the amount of time touching the ground.

Can a better method be developed?

Shorter ground force production times would save the runner time on the ground, resulting in improved sprint performance provided the same velocity was achieved after each step. Murphy et al. (2003) suggests that ground force production times may be the difference between fast and slow runners over 10m. Kunz & Kaufmann (1981) related shorter ground force production times with elite sprint performance. They attributed this to a greater average backswing acceleration of the thigh. If shorter ground force production time is the mechanism that will enable faster running speeds, then this must be achieved through faster moving limbs either during or prior to the foot making contact with the ground.

The theory of rapid dynamic training is based on the notion that in order to increase the movement velocity of a particular limb, in this case the legs for sprinting, the muscles that move the limb must be trained to activate in less time but with the same or greater amount of force. Therefore, the exercises are designed to activate the muscle within the time frame needed to produce quicker action.

How can we activate our muscles quicker?

Muscles move our limbs. In order to move our limbs faster, such as our legs to make us run faster, we need to speed up and strengthen the muscles that will be recruited for the movement. For example, only the muscles in the vastus lateralis that can be activated in 145 milliseconds when sprinting maximally (Kyrolainen et al.1999, Nummela et al.1993) need to be developed. This may require those particular muscles to be taught to contract faster through practice. It is the objective of this paper to verify the muscle activation times of a fast repetitive movement belonging to the rapid dynamic training method so that this technique can be used as a method to speed up and strengthen the muscles recruited in the movement that may be applicable for sprinting.

Where did the idea come from?

The idea is based on studies of animal behaviour. Studies on cats show the recruitment of slow ankle extensors is maintained during locomotion and jumping (Smith et al.1977). During a medium paced walk of 0.8m/s muscular contractions lasted 300-400ms, whereas during a slow-paced gallop of 2.5m/s they lasted 100-125ms. Activity during ballistic jumping tasks consisted of bursts of muscular activity of 100-150ms for the lowest jumps and 150-200 ms for the highest jumps (Smith et al.1977). In contrast during rapid paw shakes, elicited by the attaching of masking

Rapid Dynamic Training
tape to the paw of the cat plus the immersion of the cat’s paw in shallow water, Smith et al. (1980) found the slow ankle extensor is silent whilst the fast ankle extensor is selectively recruited. The muscle contractions lasted an average of 88ms during rapid paw shakes (a reflexive action by the cat in an attempt to discard the tape and/or water from its paw) which is considerably shorter than that during locomotion and jumping tasks. For such a rapid activation rate in humans, recruitment of fast twitch fibres would be essential.

It would be of interest to athletes and coaches to reproduce a similar response in human locomotive muscle in terms of time of muscle activation as a rapid paw shake in a cat, because of the association with fast twitch fibres and athletic performance (Potteiger et al.1999, Mero 1985). Unfortunately unlike cats, most humans do not have an aversion to water and tape on the foot. Therefore an alternate method must be invented. If our goal is to run faster, we need to isolate the muscles that will be required to contract within the 145 milliseconds that the vastus lateralis contracts at maximal speed (Kyrolainen et al.1999, Nummela et al.1993) and impose demands on the isolated muscle. This should result in an adaptation by the isolated muscle to whatever stimulus is provided, such as progressive resistance.

Method

The experiment was conducted with only subject, a male aged 37 years of 172 cm in height and weighing 79 kg. The subject was familiar with the procedures and any risks of the test. In the experiment the subject was required to perform a fast repetitive exercise with an external load resistance of 20 kg equivalent to 971N of force including body weight.

Surface EMG recordings were collected using Noraxon MyoResearch (Noraxon U.S.A. Inc.) telemetric EMG system. Bipolar electrodes were placed over each muscle belly, with a reference electrode placed at the ankle. Signals were sampled at 1500Hz. EMG skin preparation procedures of shaving, abrasion and cleaning were completed and electrode placement was performed on 10 muscles of the subjects’ right leg including the vastus lateralis, gluteus maximus, biceps femoris, and tibialis anterior.

The data was analysed using an Excel spreadsheet (Microsoft Office Professional Edition 2003). In the absence of force platforms to verify movement, the activation of the tibialis anterior was taken as indication of movement of the right leg away from the ground. EMG data was rectified and displayed. Data referring to the vastus lateralis (VL) muscle was separated for analysis.

Figure 1: EMG data of these muscle groups in the rapid dynamic training exercise.

Static levels were calculated from the first 500 milliseconds of the analysis as this time frame represented quiet standing. The average static level was subtracted from the entire length of the experiment. Each step was identified from the time display of EMG peaks referring to the VL muscle. Determination of the start of each peak was enabled using a formula that recognized the change in EMG over time. The software was programmed to recognize the beginning of each peak through the identifying of a change of 50uV and 100uV. The data representing 16 separate steps was combined to form one average waveform.

Statistical analysis

Each data point from the beginning of the waveform representing a step was combined to form one average. The standard deviation of each average was calculated.

Results

Frequency of alternating movement

The EMG measurements displayed of the gluteus maximus, biceps femoris, vastus lateralis and tibialis anterior show the rate of steps (figure 1). From this the number of steps per second with the right leg is approximately 7.5 per second. This equates to an equivalent step cycle of 450 steps per minute.
Muscle activation time

The experimental evidence shows the average muscle activation time of the vastus lateralis to be less than 110 milliseconds (figure 2). Peak averaged raw EMG occurs approximately 15ms from the beginning of muscle contraction. This value differs slightly from the polynomial trend-line of best fit (R=0.92) where the peak occurs around 20ms from the beginning.

Peak EMG

The averaged rectified EMG peak for the VL muscle during the rapid dynamic exercise was 1330uV compared to the peak EMG of the VL during the hopping task, which was 439uV (figure 3). Also, the activation time during the rapid dynamic exercise (110ms) is observed to be shorter than that during the hopping task (400ms).

Discussion

Observations seen in the EMG of the vastus lateralis include:

- Muscle activation time of approximately 110ms
- The greatest amplitude at the beginning of the EMG waveform
- Peak EMG during the rapid dynamic exercise is 3 times greater than during the hopping task.

What does this fast activation rate suggest?

A muscle activation time of 110ms may suggest that fast-twitch muscle fibre is preferentially recruited. Smith et al. (1980) showed in experiments with rapid paw shakes in cats, that fast muscle is recruited whilst the slow muscle remains silent. In humans, Linnamo (2000) said that during rapid movements an increased

Rapid Dynamic Training
activation of fast motor units or decreased activation of the slow ones may occur. This is also the conclusion of Citterio & Agostoni (1984) who evaluated the fast fibres of quadriceps muscle to be selectively activated as cycling speed increased from 50 to 100 cycles per minute. By comparison, the movement speed in our experiment is closer to 450 cycles per minute. At such a high speed of movement as in our experiment, the preferential recruitment of fast-twitch fibre seems more probable. If fast twitch fibre has been selectively recruited in the rapid dynamic exercise then this rapid dynamic exercise could be a method of isolating those fibres, enabling the strengthening of those fibres exclusively by subjecting them to increasing load.

Why is fast twitch fibre important for sprinting?

People having predominantly fast twitch fibres are able to achieve higher force and power output at relatively higher speed than those who have a predominance of slow twitch fibres (Tihanyi et al.1982). Researchers have found that a greater percentage of fast twitch fibre in the legs correlates with faster sprint performance (Mero 1985). Therefore finding a training method that develops these particular fibres is essential to improving sprint performance. One such method is sprint cycle training where Jansson et al. (1990) reported an increase in proportion of type IIa muscle fibre and a concomitant decrease in type I fibres. Looking at results of training by sprint running, Dawson et al. (1998) found that type II fibre percentage in the vastus lateralis increased relative to type I, and area of type II increased whilst area of type I decreased. This correlated with significant improvements to sprint performance. From this, it is reasonable to assume that training methods designed to develop type II muscle fibre will improve sprint performance.

The evidence shows that heavy resistance training methods which increase the proportion of fast twitch fibres do not benefit sprint performance to the same extent as explosive training methods that are more velocity specific and produce neuromuscular adaptations (Delecluse et al.1995, Kotzamanidis et al.2005, Harris et al.2000). Neither heavy resistance training nor explosive power training are significantly better than sprint training itself in terms of improving sprint performance, even though these methods have been found to produce an increase in type II fibres (Staron et al.1989, Hakkinen et al.1985, Hickson et al.1994, Dawson et al.1998, Pottieger et al.1999). According to Mero et al. (1992), a logical explanation for sprinters having greater type II than type I fibre areas in their leg extensor muscles, and therefore being faster, is that their training consists of fast repetitive movements similar to the rapid dynamic exercise in this experiment. If specific development of type II muscle fibre is required for improving sprint performance, then it is logical that in training, these fibres be recruited and relaxed quickly, as would be seen in fast repetitive movements. Therefore, the time of muscle activation in training would be specific to the task of sprinting.

Conclusion

The ability to develop a relatively high proportion of maximal strength is not a prerequisite to superior sprint performance at fast contractile velocities (Farrar & Thorland 1987). Instead, it is the ability to contract and relax muscles rapidly in a dynamic movement that is fundamental for the production of sufficient speed of the legs. Additionally, what is needed is greater average backswing acceleration of the thigh, as the backswing velocity of the leg relates directly to the velocity of the runner at full speed (Kunz & Kaufmann 1981, Wiemann & Tidow 1995). Furthermore, greater thigh acceleration results in shorter ground force production time thereby reducing time on the ground. The ability to accelerate the legs faster, or produce force quicker against the ground when sprinting requires the activating muscles to be recruited and relaxed in a shorter time, providing the force produced by the muscle remains the same or higher.

In this experiment, it was observed that the vastus lateralis muscle activated and relaxed in less time than that needed during maximal sprinting. The high frequency of movement and the short duration of muscle activation suggest a selective activation of fast twitch muscle fibre. Athletes are always in search of more speed for which they would benefit from the preferential development of their fast twitch fibres. Therefore, the rapid dynamic training exercise demonstrated in this experiment provides a facility through which those particular muscles can be isolated and subjected to progressive resistance. If the muscles that can be isolated are indeed fast twitch fibres then the rapid dynamic training method can also be applied to many more athletic activities.

References


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