The effect of plyometric training on 3-km running performance

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Introduction

Recently various authors have cited running economy (RE) as one of the best predictors for successful middle to long distance running, surpassing the previously well regarded VO_2max. (Conley, Krahenbuhl, Burkett, & Millar, 1984; Daniels, 1998; Noakes, 1991). In an attempt to describe why runners of the similar height, weight and VO_2max have significant differences in performance, Noakes (1991) speculated that a possible reason may lie in what Williams (1985) described as impact energy and its effect on RE. That is, with each stride taken during running, the muscles of the landing leg store the impact energy as they eccentrically absorb the force of the landing. Some of this stored energy may then be used during the concentric muscle contraction that propels the body forward. While Williams (1985), described such energy as impact energy, researchers today use the term stored energy to describe the available energy which is derived from the activation of the stretch-shorten cycle (SSC). A common method of improving SSC performance is plyometric training (Hennessy 1990). Plyometrics have been defined as exercises involving an immediate shortening after pre-stretching active muscles and have traditionally been used for sports dependant on speed and power (Hennessy 1990).

Traditionally a favored method of improving RE was to perform long slow distance training, known as LSD (Temple 1990), however, Noakes (1991) noted that whilst high weekly training distances may be a factor in increasing RE, the associated risks with such mileage were high. Currently, the optimal method for increasing RE remains to be determined, however recent research has focussed on the effects of utilising the SSC in training. Paavolainen, Hakkinen, Hamalainen, Nummela, & Rusko et al. (1999) conducted a well controlled study looking at the effects of explosive-strength (plyometric) training on 5km running time, RE and muscle power. They concluded that simultaneous explosive-strength training and endurance training produced a significant improvement in the 5-km running performance of well trained endurance athletes. The authors suggested that the improvements were due to improved neuromuscular characteristics that were transferred into improved muscle power and RE.

Whilst Paavolainen et al. (1999) cited the improved neuromuscular characteristics as the primary reason for the improvement in RE, and ultimately 5-km running performance, the authors did not stipulate between the neural enhancement or the improved mechanics of the musculature as to exactly where the improvement was attributed from. In a study by Wilson, Wood, & Elliott (1991) examining the neural contribution to the SSC, the authors concluded that maximal SSC activities are dominantly sustained through the mechanical factors such as musculotendinous stiffness (MTS) and the eccentric load, rather than the neural facilitation mechanisms which play a substantially lesser role.

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Statement of the Problem

In recent times RE has become an area of considerable attention in distance running performance. Extensive physiological research has led to RE becoming one of the most important performance predictors, particularly in middle to long distance running. However there is still relatively little known about what physiological factors determine RE, and how these factors are influenced by training.

It has previously been speculated that the utilisation of stored elastic energy could be a factor in improving RE (Williams 1985; Noakes 1991). One such method of improving the utilisation of stored elastic energy is plyometric training, whereby the SSC is activated. Such a training method has indeed proved to enhance RE and distance running performance, the reasons for improvements cited as neuromuscular adaptations derived from the SSC activities (Paavolainen et al.1999). Wilson et al.(1991) examined the contribution of both the neural and mechanical aspects involved in SSC activities and concluded that it is the mechanical factors, such as the MTS that are primarily responsible for such SSC activities, while the neural mechanisms play a much lesser role.

This study proposes that while a plyometric program may improve RE, and thus enhance running performance, the improvements will primarily be as a result of the changes in mechanical aspects, such as MTS of the lower leg.

Methods

Subjects: Seventeen male distance runners (age 26.2 ± 6.0 yr.) with an average training history of 10yrs were randomly assigned to an experimental (E) (n=8) and control group (C) (n=9).

Training: After the pre-testing was completed, the E group completed six weeks of plyometric training in addition to their usual running training regime. The plyometric program involved two sessions per week for the first three weeks and three sessions per week for the final three weeks. Exercises consisted of various jumps bounds and hops (squat jumps, split scissor jumps, double leg bounds, alternate leg bounds, single leg hops, depth jumps, double leg hurdle hops, and single leg hurdle hops). Prior to each session, the subjects underwent a dynamic warm up including leg swings, ankle bounces, skips, run throughs, as well as static stretching. Progressive overload principals were incorporated into the program, using foot contacts and complexity of the exercises as measures. During the six weeks of plyometric training the C group continued with their normal training.

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Measurements: Both groups were tested pre and post to the six-week training period for all measured variables. The variables tested included; aerobic power (VO_2max), RE, lactate threshold (LT), 3-km time, MTS (MTS) of the lower leg, maximum isometric force and rate of force development (RFD) of the lower leg, 5-bound test (5BT), and counter movement jump height (CMJ).

VO_2max, LT and RE were determined during an incremental treadmill aerobic power test. Commencing at a velocity of 10 km/hr and a 1∞ gradient, the subject ran for three minutes. After three minutes the treadmill was stopped for one minute in order to gather blood for the blood lactate analysis. After each one-minute recovery period, the treadmill was increased by increments of 2 km/hr. The subjects ran each of these increments for three minutes, before the one-minute recovery / blood collection period. Once the treadmill reached a velocity of 20 km/hr, an increase of 2∞ gradient was substituted for further increases in velocity. The test continued until volitional fatigue, whereby the subject could no longer maintain the treadmill velocity. Expired gases were collected using a Morgan Gas Analyser, with the values obtained over the last minute of each three-minute interval being averaged. Since RE is defined as the oxygen demand for a given pace (Conley et al. 1984), the RE in this study was determined by averaging the VO_2 values for the last minute at velocities of 12-km/hr, 14-km/hr, and 16-km/hr. A YSI Biochemistry Analyser was used to analyse the blood lactate levels after each of the three-minute intervals.

The 3-km time trial and the 5BT took place on an outdoor tartan athletic track. The 5BT involved the subjects attempting to cover the greatest distance possible by performing a series of five forward jumps with alternative left and right foot contacts (Paavolainen et al.1999). Such a test was used in order to indicate improvements in the utilisation of the SSC as a result of the plyometric training.

The assessments for maximal isometric force, RFD and MTS of the lower leg were performed on an instrumented seated calf raise machine. Maximal isometric force and RFD were assessed by performing a maximal isometric contraction. MTS was tested using the oscillation technique as previously used by Cavagna (1970); Wilson et al. (1991a, 1991b, 1992); Wilson, Murphy & Pryor (1994); McNair & Stanley (1994); Walshe, Wilson & Murphy (1996); and Walshe & Wilson (1997). MTS was assessed at the loads of 25%, 50%, and 75% of the maximal isometric force.

Results and Discussion

The 3-km run time for the E grouped improved by 2.7% when comparing the pre and post training data (see Fig.1.), whereas no significant changes were recorded for the C group. The CMJ height and the 5BT results for the E group improved by 12.5% and 7.9% respectively, proving the effectiveness of the plyometric training program. No significant changes for any variables were found in the C group. Whilst MTS was

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assessed at three different percentages of maximal isometric force (25%, 50%, and 75%), it was at the heaviest load in which the most significant changes occurred. An increase of 14.9% for the left leg and 10.9% for the right leg were recorded for the MTS test at the 75% load for the E group (see Fig.2.). No changes were recorded in the C group.

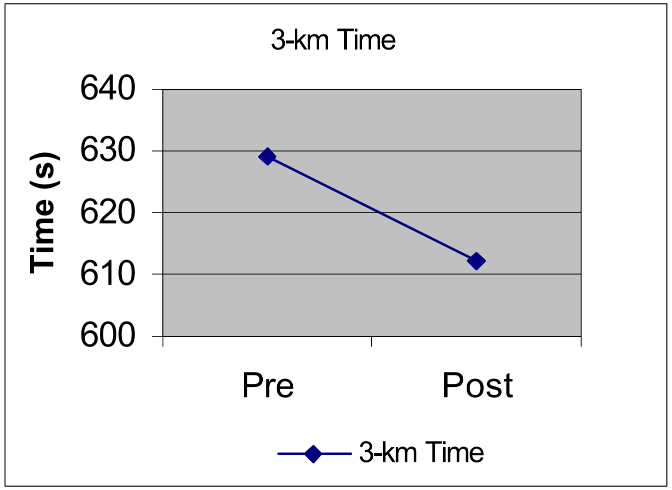

Fig.1. (E) Group Pre &Post 3-km Times.

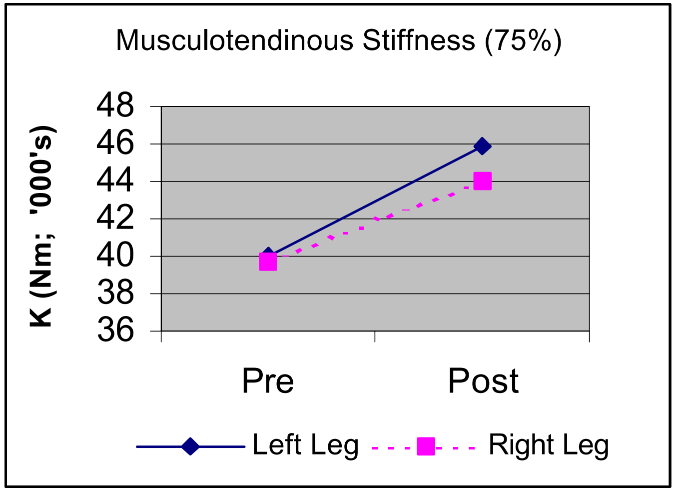

Fig.2. (E) Group Pre & Post MTS at 75% max. load.

The E group recorded improvements in the maximal isometric force test of 11.4% for the left leg and 13.6% for the right leg. No significant improvements were observed for the C group. RFD also improved in both legs for the E group, with increases of 14.1% and 15.0% for left and right legs respectively. The C group did not display any significant improvements. The lactate-velocity curve for the C group was near identical when comparing pre and post test data, while the post test curve was slightly shifted to the right when compared against the pre test curve for the E group. However, the changes in lactate accumulation and LT were not significant in either group. Following the six week training period RE improved in the E group for all tested velocities (12km/hr, 14km/hr, and 16km/hr), while no improvements were observed for the C group.

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The purpose of this study was to determine whether six weeks of plyometric training would improve 3-km running performance and if so examine the possible reasons for the recorded improvements. As mentioned above, 3-km performance did improve as a result of the plyometric training. The fact that both the 5BT and CMJ height significantly improved in the E group indicates that as a result of the plyometric training, improvements in the utilisation of the SEC occurred. The relationship between the increase in MTS and the increase in performance observed in this study is in agreement with the findings of Komi (1984), who showed that performance in SSC actions was enhanced in those athletes exhibiting a stiffer musculotendinous unit of the lower leg. It is not surprising that the increase in MTS at the 75% load is similar to the increases in the maximal isometric force production and the RFD. This is supported by Wilson et al. (1994), in which the authors noted that a stiffer musculotendinous unit will cause greater lengthening of the contractile component which, in turn, facilitates the production of force through improved length-tension conditions and force-velocity conditions. This improved strength and MTS, coupled with the improvement in RE among the E group is supported by Dalleau, Belli, Bourdin & Lacour (1998), who reported that the energy cost of running is significantly related to the stiffness of the propulsive leg. Further more, Johnston, Quinn, Kertzer & Vroman (1997) suggested that improved RE may be related to greater leg strength as a result of changes in motor unit recruitment patterns, supporting the results of the current study. Additionally, Johnston et al. (1997) suggested that improvements in RE may be attributed to increases in strength through changes in the mechanical aspects of the running style and technique. Unfortunately athletes in the current study were not filmed, thus no kinematic data was recorded. However it is suggested that further study into the effects of plyometrics on RE should incorporate such data. Whilst Paavolainen et al. (1999) recorded no changes in lactate levels, the current study saw a slight shift to the right for the post test lactate-velocity curve. It may be speculated that this shift was a result of the increased MTS. This may also be related to the greater propulsive properties of the leg resulting in lower lactate production.

Conclusions

The results of this study clearly show that a 6-week plyometric training program led to improvements in 3-km running performance. It is believed that such performance increases occurred as a result of the increase in MTS and consequently maximal force production and RFD. It is suggested that changes in such variables had a positive effect on running economy, which has been proven to be one of the best predictors for distance running performance. Based on these finding it is suggested that distance runners and coaches consider incorporating at least two plyometric sessions per week into their training regime.

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This study proposes that while a plyometric program may improve RE, and thus enhance running performance, the improvements will primarily be as a result of the changes in mechanical aspects, such as MTS of the lower leg.

METHODS: Subjects. Seventeen male distance runners (age 26.2 $\pm$ 6.0 yr.) with an average training history of 10yrs were randomly assigned to an experimental (E) (n=8) and control group (C) (n=9).

Training. After the pre-testing was completed, the E group completed six weeks of plyometric training in addition to their usual running training regime. The plyometric program involved two sessions per week for the first three weeks and three sessions per week for the final three weeks. Exercises consisted of various jumps bounds and hops (squat jumps, split scissor jumps, double leg bounds, alternate leg bounds, single leg hops, depth jumps, double leg hurdle hops, and single leg hurdle hops). Prior to each session, the subjects underwent a dynamic warm up including leg swings, ankle bounces, skips, run throughs, as well as static stretching. Progressive overload principals were incorporated into the program, using foot contacts and complexity of the exercises as measures. During the six weeks of plyometric training the C group continued with their normal training.

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(MTS) of the lower leg, maximum isometric force and rate of force development (RFD) of the lower leg, 5-bound test (5BT), and counter movement jump height (CMJ).

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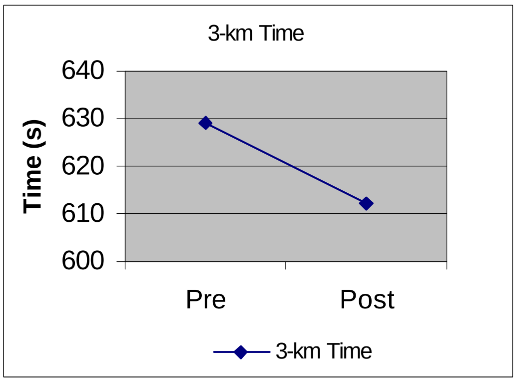
RESULTS AND DISCUSSION: The 3-km run time for the E grouped improved by 2.7% when comparing the pre and post training data (see Fig.1.), whereas no significant changes were recorded for the C group. The CMJ height and the 5BT results for the E group improved by 12.5% and 7.9% respectively, proving the effectiveness of the plyometric training program. No significant changes for any variables were found in the C group. Whilst MTS was assessed at three different percentages of maximal isometric force (25%, 50%, and 75%), it was at the heaviest load in which the most significant changes occurred. An increase of 14.9% for the left leg and 10.9% for the right leg were recorded for the MTS test at the 75% load for the E group (see Fig.2.). No changes were recorded in the C group.



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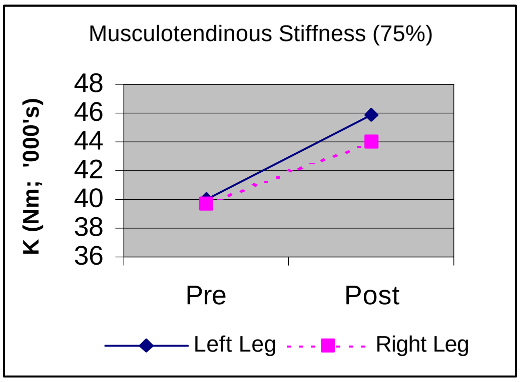

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