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Beyond localized muscular endurance: Strength and Power Training as a means to improve the Aerobic Runner

Abstract

Objectives: The purpose of the paper is to highlight and demonstrate how to apply strength and power training to the endurance runner. This paper will discuss physiological adaptations beyond simply localized muscular endurance. Focused literature highlighting effects on oxygen consumption, lactate threshold, running economy and neuromuscular benefits will be further discussed.

Search methods: A search was conducted on the wide-body of research that exists in and around the skeletal muscle and sports performance and aligns the research in a clear manner, specifically describing the physiological response of various training to the endurance athlete. Literature gathered involved trails of comparative analysis with control groups in various exercise settings.

Main results: In an attempt to clarify the physiological adaptations specific to the endurance runner, the purpose of this paper is to demonstrate and describe how strength and power training can be used with aerobic athletes beyond just localized muscle endurance. The present paper identifies each adaptation specific to the training modality to clarify the scientific evidence for the sport practitioner.

Conclusions: Historically, runners have eliminated strength exercises form their training programs due to theorized decreases in VO_{2max} and Lactate Threshold. However, the majority of research analyzing those two variables has been conducted with stand-alone methodology. Concurrent strength and endurance training research has not displayed negative effects on in VO_{2max} and Lactate Threshold and furthermore has produced favorable adaptions to both running economy and neuromuscular coordination delaying fatigue. It is therefore suggested endurance based runners perform strength and or power training to maximize running economy and delay fatigue.

Keywords: muscle adaptations, strength and power training, cardiovascular training, running economy, lactate threshold, endurance

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Abbreviations: SPT, strength and power training; LT, lactate threshold; RE, running economy; ET, endurance training

Introduction

Strength and power training (SPT) has historically been absent from the training programs of endurance athletes in probable response of the adaptive outcomes of SPT in an independent environment. Historically, increased performance in endurance athletes was heavily related to improvements in the ability to utilize oxygen (VO_{2max}), a greater lactate threshold (LT) and improved mechanics (i.e. running economy). Adaptations in these three primary areas were traditionally attained through independent endurance modalities (i.e. the principal of training specificity). However, current literature has displayed that anaerobic conditioning elements and more importantly strength and power training, may provide added benefits to endurance athletes.[1] Additionally, SPT has been correlated to increased body mass, expand the recruitment of fast-twitch muscle fibers, and limit oxidative enzyme activity. All of which appear to interfere with endurance performance.[2-7]

Other factors contributing to the absence of SPT with endurance athletes may be the endocrine responses of SPT, as well as specific neuromuscular mechanisms of anaerobic SPT that don't appear to assist in increased endurance performance.[1,8,9]

Benefits of strength & power training

VO_{2max}

It is physiologically obvious that SPT will not produce advantageous results for an athlete's VO_{2max}. The methods of training the aerobic energy system resulting in greater oxygen consumption are generally not best achieved through SPT. More importantly, stand-alone SPT has been documented to increase body mass, increase the recruitment of fast-twitch muscle fibers and potentially limit the activity of oxidative enzymes.[5-7] All of which are physiologically theorized to decrease VO_{2max}. Similarly, SPT has also been associated with reducing mitochondrial density, which would inhibit the capacity to utilize and or transport oxygen; a negative hit against ones VO_{2max}.[6] The only documented literature that has associated increases in VO_{2max} resulting from isolated SPT has only occurred with sedentary untrained subjects when circuit training was implemented.[1] However, that documentation would not be applied to the trained endurance athletes.

Concurrent SPT and ET on the other hand, have produced interesting results in the discussion of SPT for the endurance athlete. Though SPT is not advantageous in improving VO_{2max}, several bodies of literature have reported no decreases in VO_{2max} when SPT was combined with ET.[1]Specifically, multiple studies on behalf of Hickson and colleagues have reported no negative effects on $VO_{2\,max}$when SPT was introduced [10,11] as well represented in Jung's 2003 review of concurrent E and SPT.[1] It should however, be noted that there may be some uncertainty when concurrently training the endurance athletes. In elite endurance population, some speculation exists when linking the factors in muscle power to endurance production.[12]Nonetheless, thorough documentation exists suggesting SPT alongside established endurance training should not diminish endurance.[13]

Lactate threshold

Lactate threshold (LT) describes the point during increased exercise intensity where blood lactate levels begin to rise above what would normally be present at resting levels. Historical theory has used LT as a predictive instrument to endurance performance.[14] Therefore, an endurance athlete with a high LT possesses the ability to perform at a high percentage of their VO_{2max} without producing blood lactate levels that exceed the removal.[1]

Similar to data collected analyzing SPT and increased VO_{2max}, results aiming to uncover the relationship SPT has on LT is also somewhat limited. The only study of knowledge that produced data recoding higher LT levels after stand-alone SPT was on behalf of Marciniket al.[15]However, results were produced again on untrained subjects in a circuit training protocol. Results do not seem applicable to the endurance athlete.[15]

Concurrent SPT and Endurance Training (ET) related to LT is similar the above discussion regarding VO_{2max}. The data appears to imply that though SPT won't likely produce LT improvements among endurance athletes, it is highly improbable that SPT would create a physiological adaptation to decrease LT. Therefore, to exclude SPT as a threat to LT does not seem to be supported by the literature.[1]

Running economy

Running economy (RE) refers to the relationship of VO_{2max} and the absolute running intensity. Greater RE has been documented to improve performance particularly among endurance athletes.[16]In theory, a runner who can cover the same distance in less time due to lower oxygen consumption levels would have an improved RE.[17]

SPT has been specifically documented to improve RE. Most likely resulting in neuromuscular adaptations, Paavolainen at al.[18] demonstrated that RE was increased significantly in runners who participated in 9 weeks of SPT. Five kilometer running time was reduced without improvements to the subjects VO_{2max}.[18] It is theorized that the major factor in RE is the potential to retain and regain elastic energy during the eccentric contraction.[19] An improvement to the stretch-shortening cycle resulting in less foot contact time has been associated with SPT.[18]

Several other avenues relating SPT to RE are present in literature as. SPT leading to added strength gains may heighten mechanical efficiency, muscle coordination and motor unit recruitment.[20] SPT may elicit co-activation of leg muscles around joints may that lead to speed improvements and even the influence on running style to improve running mechanics. The integration of improved mechanics and greater neuromuscular adaptations may be the cause to lower oxygen depletion and in turn enhancing RE.[1]

Neuromuscular adaptations

As alluded to above, SPT has obvious links to neuromuscular characteristics. It is likely that RE is most greatly affected by neuromuscular adaptations. These include increased muscle stiffness, muscle coordination, motor unit recruitment and coordination, as well as increased neural input. Two other areas related to neuromuscular improvements are also noteworthy. First, literature linked to time to exhaustion as a result of SPT has been improved by greater neuromuscular characteristics. Reports of increased time to fatigue were heavily correlated with increased muscle strength.[1] However, it is somewhat unclear if time to fatigue was directly linked to muscle strength or some other unknown factor. Nonetheless, there is enough consistent literature to suggest performance in fatigue test aresomehow linked to SPT.

Finally, stemming primarily from the neuromuscular adaptations, injury prevention is also a potential benefit to SPT and the endurance athlete. Greater neuromuscular characteristics, as mentioned above, not only provide the platform for greater performance, but also assist in reducing the likelihood of injury. A greater ability to stabilize joints and more efficient neuromuscular coordination not only aid in RE, but also provide added structure and improve the framework of the body. Improvements in strength and power resulting directly from SPT, also have the ability to decrease the probability of injury to muscle and connective tissue. Musculoskeletal injuries related to muscle imbalances or overuse can most often effectively be corrected through SPT. Similarly; SPT provides the means to increased collagen levels in connective tissues. Although, limited in documentation, evidence has been collected linking greater collagen content within connective tissue and sheaths in strength and power trained athletes. The benefits of SPT extend beyond performance and into the prevention arena particularly related to joints, muscle, and connective tissue. All are a benefit to the endurance athlete.[21-26]

Exercise programming

Exercises

There are a large number of various exercises that may be incorporated for a runner training for a full marathon. The exact movements, range of motion, speed of movement, and type of contraction are all contingent upon the specific athlete. As a result, the exercises for a beginning runner may be carried out far different than in an elite marathoner. And given the "elite" status of a runner doesn't always correlate with previous experience in SPT. However, regardless of the athlete, it may be suggested do perfrom two things prior to the integration of SPT in a runner's program: a biomechanical analysis to identify any joint actions that may be insufficient or those needing attention, and a prepared body to execute the movements with proper technique. Once the body is prepared for SPT, then incorporate a SPT program.

A few key exercises to include in a program

Lower body:

Squat (various execution)

Rationale: The squat and various formations of it, may be one of the most beneficial exercises a runner could perform. The purpose of the Squat and its many variations is to strengthen the quadriceps group as well as hip areas and the postural area.A key to a runner is balance and support. The squat contributes to a runner's ability to stay upright and supported during the support phase of the stride as well as maintain postural integrity.

- In an advanced setting, more variation can be incorporated. Plyometric squat jumps can be utilized and various ranges of motion. (i.e. Half Squat Jumpswith weight).

Heal and toe raises (Calf work)

Rationale: Strengthen muscles that mimic the push-off of the ankle joint (ankle extension). Toe raises, to stress the antagonist of the soleus and gastrocnemius. Also utilized as a combatant to shin splints.

- In an advanced/elite program the incorporation of bands as a manipulator of stress can be used. Similarly, Exploding Calf Extension where a more polymeric movement is used to represent more of an explosive ankle joint extension.

Lunge (various execution, and muti-directional)

Rationale: Actively engage and stretch hip flexor muscles. The downward position of the lunge often mimics the airborne phase of the runner's stride.

- In an advanced athlete, *Lunge Jumps/Split Squat Jumps* to develop eccentric strength in the landing phase of the exercise. The development of knee drive can also be coordinated with the push off. *Multi-directional Lunge* to develop adductor muscles and stabilizes the pelvis.

Hip Flexor Pulls (eccentric and concentric phases emphasized)

Rationale: To replicate and stress of the downward and knee drive phases of the running stride. Engage the gluts and hamstrings as well as the hip flexor to limit ground contact time.

- In advanced/elite programs bands can be a vital piece to manipulate the stress and accommodate the load.

Reverse Hyper/Ham Glut Curls/ Phys. ball Hamstring Curls

Rationale: Actively engage the hamstring muscles and their upper tendons. Engage the gluts. These movements also stimulate activation while keeping the back in its normal position.

- Multiple manipulations of these exercises can occur for the elite athlete. Weight can be added; physio-balls can be incorporated and well as single leg movements. All of which are based on the athletes previous training.

Upper Body:

Arm/Shoulder Raises

Rationale: To create strength in the muscles involved in driving the arms. Creating flexibility in the shoulder area is also important.

- In advanced/elite programs bands can be a vital piece to manipulate the stress and accommodate the load.

Lat Pulls (various execution)

Rationale: To stress the lats, lower pectorals and teres major all of which contribute arm pulls while running.

- Elite athletes can again manipulate this exercise using variations with bands and multiple grips and body positions.

Pull Over's

Rationale: To stress the lats, lower pectorals and teres major in a way that can expand the chest and the lower rib cage to improve breathing capabilities.

Bicep Curls (various execution)

Rationale: To stress the biceps and create stability for holding the arm at approximately 90 degrees during long runs.

- Elite athletes can again manipulate this exercise using variations with bands and multiple grips and body positions.

Tricep Extensions (various execution)

Rationale: To stress the antagonist of the bicep as well as the rear deltoids.

- Elite athletes can again manipulate this exercise using variations with bands and multiple grips and body positions.

Shrugs

Rationale: To strengthen muscle involved with shoulder stabilization for long runs.

Chest work (DB press, DB Fly, Push-Up at various positions and unstable surfaces)

Rationale: To strengthen the pectoris and create upper body stability

- Elite athletes can again manipulate this exercise using particularly using bands, changing up the position of the exercises as well as incorporating more plyometric type movements.

Abdominal & Lower Back

Leg Raises (multiple variations)

Rationale: To stress the rectus abdominis. Stabilize the pelvic girdle, which is important in knee drive. Variations of this exercise also stress the hip flexors.

Leg pendulums and rotational core

Rationale: To stress the internal and external oblique's to stabilize the upper body and limit rotation while running.

Back Extensions

Rationale: To stress the erector spinae. This contributes to maintaining posture during long runs.

The above exercises are considered the bulk prescribed to a runner. As mentioned more "elite" runner would receive variations of the above exercises. An elite runner would also be prescribed a different volume of SPT as well. More than likely elite runners (although not always) can handle higher volumes of stress. Therefore, not only to the exercises change, as mentioned above, but as do training loads.

Program considerations &periodization

From a macro-perspective, the periodization of the SPT program is important. It is important that the stress placed upon the body is often changing to elicit adaptation. This training principal is vital for both the beginning runner and the elite. Therefore, the same exercises with the same programming should never be administered. A sample-training plan may look as follows:

Competition during the summer months: May/June/July

- The goal of this phase is to maintain power, strength and muscle endurance.
- SPT exposure may only be one time per week with lower volumes.
- Ex) 1-2 sets x 10-12 reps based on the exercise and athlete.

Conversion/Peaking Phase: Mar/ Apr.

- Working backwards, this is the key phase in prepping the athlete.
- SPT volumes are moderate, with the mindset of building up to the *Competition.*
- 1-3 sets x 4-10, reps with an emphasis on more power and plyometiric exercises.

Max Strength Phase:Jan/Feb.

- The goal is to develop strength with and emphasis on neuromuscular adaptations.
- SPT volumes are moderate to high. SPT training exposures are 2-3 times per week.
- 2-4 sets x 3-8 reps working to maximize strength leading into the above *Conversion Phase.* Rest intervals are longer during this phase.

Adaptation Phase: Oct/Nov./Dec.

- The goal is to prepare the body for SPT. Biomechanical analysis is conducted. An emphasis on proper technique is key. Muscle firing sequences are also key. This is the first phase coming out of the *Competition Phase* and it is important the groundwork is laid.
- Higher intensity and lower volume. Exposure 1-3 times per week

1-3 sets x 8-10+ reps working on short rest intervals to prepare the body.

Conclusions

Many endurance-based athletes, particularly the running population, have abstained from strength and power training due to a disassociation in training adaptations. Moreover, runners often choose to remove strength training from their programs resulting in limited adaptions. The primary basis for this training regime is built on cited research that has been conducted in an independent environment of strength and power training alone. Current literature, in a concurrent setting (endurance and strength training simultaneously), has displayed no negative effects on primary aerobic adaptions and has been shown to improve both running economy and neuromuscular adaptations leading to delayed fatigue and injury prevention. It is recommended, based on concurrent strength and endurance training for the running population to incorporate strength and power training into their training periodization.

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Conflicts of interests

Authors declare no conflict of interest exists.

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