IAAF @-*Letter*

for CECS Level II Coaches

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SPECIFIC THEME: Strength training for endurance athletes

GENERAL THEME: Compatibility of strength and endurance training

Specific Theme

Strength training for endurance athletes

1 Introduction

Although research seems to be divided on whether concurrent training for strength and endurance has a negative effect on the development of either one (cf. HARRISON 2003, p. 5), it appears at least that endurance runners can engage in strength training without detrimental effects to aerobic power (cf. DOLEZAL & POTTEIGER 1996, p. 7).

Runners who avoid resistance training for fear it will compromise their performance fail to realize that resistance training leads to physiological adaptations that will actually improve performance. Some of these adaptations are:

- Usually strength training increases lean body mass and decreases fat weight and % fat. This improvement in body composition is likely to help maximize performance.
- Initial strength gains may be attributed to the recruitment of additional motor units and reduction of inhibitory impulses. These are changes that enhance motor skill performance.
- Strength training can lead to a significant increase in the intramuscular stores of energy, leading to increased performance and a delayed fatigue response.
- Enzyme activity of the energy sources increases due to strength training; this can lead to more energy production and more efficient energy use.
- Strength training can increase bone mineral content, thus guarding against stress fractures or providing a safety factor in the case of falls.
- Physiological adaptations in ligaments and tendons due to strength training may help prevent injuries.

Most important, research reveals that strength training does not affect a muscle's contraction time and therefore will not slow one down. In fact many athletes have shown increases in speed of movement. Moreover, results from research indicate that strength development may in fact enhance running economy (cf. JOHNSTON, QUINN, KERTZER & VROMAN 1995).

2 Strength training and running economy

JOHNSTON et al. (1995) found that low-volume resistance training of moderate to high intensity, when incorporated into an endurance training program, will significantly improve upper and lower body strength as well as running economy. The benefits from increased upper body strength help delay fatigue in the arms and postural muscles during a race. As the muscles become fatigued, they may compromise the efficiency of movement and increase the oxygen demand for running as additional motor units are recruited.

Moreover, greater leg strength also enhances mechanical efficiency and motor recruitment patterns. Oxygen cost at each running speed may be reduced if a more efficient pattern is induced through an increase in leg strength.

3 Strength training as a means of injury protection

Another benefit from resistance training is that it may protect against injury. Overuse injuries are often associated with the repetitive overload typical of running and jumping activities. The lower extremity must absorb a force of up to five times body weight at heel strike in running. For the endurance runner who runs many miles each week, the cumulative effects of impact can be traumatic.

Muscle weakness and imbalance is one factor that is related to this kind of overuse injury. It would seem that resistance training is imperative for ensuring that there be little or no damage to the muscles, bones, tendons, and ligaments from the high-intensity loads placed on the body during training or competition.

Muscle imbalance implies an incorrect strength ratio of the agonist and antagonist in an extremity, or asymmetry in agonists or antagonists between the extremities. A runner may be at a higher risk of sustaining an injury, for example, if his or her hamstrings-to-quadriceps strength ratio is 60% or less in one leg.

A resistance training program targeted to developing balanced strength between the extensors and flexors of the hips and legs will ensure safe execution of the powerful strides so essential for end-of-race sprints to the finish. Strengthening the muscles of the feet, legs, and trunk in order to relieve strain on the spinal column is also a good reason for the endurance runner to perform resistance training on a regular basis.

In particular, strengthening the feet has become an acute problem. Training shoes have become so sophisticated that the muscles of the feet do not have to develop strength for support. A certain amount of barefoot running on the grass during each microcycle should give the strength training necessary to develop this support.

4 Periodization of strength training for endurance runners

Just as with aerobic, anaerobic, and combined zone training, periodization for endurance running events must include an organized approach to whichever strength components are critical to the specific event and to the individual athlete (cf. CHRISTENSEN 2000, p. 4843).

Training for strength must be sequential and progressive in its development through the course of the macrocycle. Each endurance running event, middle distance and/or distance will demand different adaptations and strength capabilities. Middle distance has a much greater explosive component than the 10K.

The annual plan for strength training resembles that of the annual running plan. The basic model is that of the well documented Matveyev research, and is based on

- progressive loading,
- adaptation, and
- reversibility.

Absolute strength takes the longest to develop and may take several months to achieve a maximum training effect.

Elastic strength takes the least amount of time for adaptation at about 20 days. Much of the resistance work is actually just 'body weight' exercises, however absolute strength and strength endurance can only be achieved by workloads in excess of body weight.

According to CHRISTENSEN (2000, p. 4843), resistance work is composed of five general categories:

(1) Neuromuscular development drills (ND),

(2) Running form programming drills (RF),

(3) General strength drills (GS),

(4) Plyometrics (P), and

(5) Weights (W).

These categories are divided into

- Absolute strength (high tension – low velocity),
- Power strength (moderate tension – moderate velocity),
- Strength endurance (moderate tension – high velocity),
- Absolute strength (high tension – low velocity), and
- Speed strength (low tension – high velocity).

Only in the weights category do runners need to spend time in the weight room. The rest are done outside, inside, wherever work can be done.

A possible annual plan is based on championship competitions and is matched with corresponding developmental work that is part of the running plan. Phases and microcycles should be complimentary. When doing base work running, athletes are doing absolute strength work, and when emphasizing speed running, they are doing the same with the resistance work. The idea is to do some of the five categories each month, but not all five. The weights build from general to specific. A possible annual plan is shown on the next page.

Annual plan of strength training for endurance runners

September:	ND training, RF programming, GS drills, and W – absolute strength (85-95% of absolute max)
October:	ND, RF, GS, W – power strength (70-80% of absolute max)
November:	ND, RF, W – power strength
December:	ND, RF, W – strength endurance (50-65% of absolute max)
January:	ND, GS, W – strength endurance
February:	ND, GS, W – absolute strength
March:	ND, RF, GS, W – power strength
April:	ND, RF, P, W – speed strength (30-40% of absolute max)
May:	ND, RF, P, W – speed strength
June:	ND, W – absolute strength
July:	ND, W – absolute strength
August:	ND, GS, W – strength endurance

The goal of the strength training exercises and drills for distance runners presented on the following pages is not to build ‘big muscles’, but to make the neuromuscular system function as effectively as possible in order to meet the physiological needs of the runner. Therefore, strength training is undertaken to develop power or the ability of muscles to apply force at the proper rate.

Consequently, the role of this strength training is to create a physiological foundation in order to improve one’s overall ability to meet the needs of distance running and enhance performance.

Examples of exercises and drills as related to the five resistance training categories

ND training (to be done 20 different days on designated months):

- Skips (3 x 50m)
- Carioca (3 x 50m)
- Straight leg bounding (3 x 40m)
- Skipping for distance (3 x 60m)
- Butt kicks (3 x 50m)
- Backward thrusts (3 x 50m).

RF training (to be done 8 different days on designated months):

- Barefoot running (1 x 10-15 min)
- Running at seasonal goal pace (3 x 90 sec)
- Running at faster than seasonal goal pace (3 x 30 sec)
- End of practice strides (8 x 80m)
- Dorsal-flexion drills (3 x 50m)
- Arm-flexion drills (3 x 50m)
- Running with batons (4 x 400m).

GS drills (to be done 8 different days on designated months):

- Hill repeats (6 x 300m hill, jog recovery)
- *Speed Dynamics* assistance cords (3 x 50m)
- Bungee cords resistance (5 x 30m)
- Parachute runs (3 x 400m)
- Lunges (3 x 10 walking steps)
- Headwind running (run into the wind on windy days)
- Snow running (6 x 80m on snow-covered field)
- Stadium stairs (3 x 3 min on a stair-lateral running circuit)
- Jump roping (4 x 3 min).

P drills (to be done every 5 days on designated months):

- Vertical power bounding (4 x 6 reps)
- Horizontal power bounding (8 x 25m)
- Depth jumping (12'' box – 5 x 5 reps)
- Vertical double leg bounding (4 x 6 reps)
- Horizontal double leg bounding (8 x 25m)
- Medicine balls – one on one (4 x 3 min, 8lb ball).

W work (to be done 3 times weekly on designated months):

- **Absolute strength** (recovery time is 48 hours):
  - Power cleans, lats, bench press (4 reps, 3 sets at 90% max each)
  - Reverse curls (4 reps, 3 sets at 90% max each)
  - Preacher curls (4 reps, 3 sets at 90% max each)
  - Russian dead lift (3 reps, 3 sets at 90% max each)
  - Heel raises (50% of body weight on bar on shoulders, 6 reps, 3 sets)
  - Wrist curls (50% of body weight on bar, sitting, 6 reps, 3 sets)
  - Dips (max)
  - Pull-ups (max).

- **Power strength** (recovery time is 48 hours):
  - Power cleans, lats, bench press (10 reps, 3 sets at 70% max each)
  - Front curls (10 reps, 3 sets at 70% max each)
  - Incline press (8 reps, 3 sets at 70% max each)
  - Dips (80% of max number)
  - Push-ups (to exhaustion)
  - Pull-ups (50% of max number)
  - Arm-action running (15% of body weight [dumbbells], 50 reps)
  - Flys (15% of body weight [dumbbells], 50 reps)
  - Wrist curls (30% of body weight on bar, sitting, 6 reps, 3 sets).

- **Strength endurance** (recovery time is 72 hours):
    - Power cleans, lats, bench press (40 reps, 2 sets at 50% max each)
    - Russian dead lift (30 reps, 2 sets at 50% max each)
    - Incline press (20 reps, 2 sets at 50% max each)
    - Arm-action running (10% of body weight [dumbbells], to exhaustion)
    - Push-ups (40 reps, 2 sets)
    - Power lunges (3 reps, 10 steps each, 45lb bar on shoulder)
    - Heel raises (30% of body weight on bar, on shoulders, 10 reps, 3 sets)
    - Abdominal crunches (50 reps, 2 sets).

- **Speed strength** (recovery time is 36 hours):
    - Power cleans, lats, bench press (FAST – 10 reps, 5 sets at 30% max each)
    - Half squats (6 reps, 4 sets at 40% max each)
    - Arm-action running (FAST – with lightest dumbbells, to exhaustion)
    - Abdominal crunches (FAST – 35)
    - Dips (FAST – to exhaustion)
    - Stationary circuit (FAST – with 40lb bar; do not set it down until completely done; 10x overhead lift, 10x reverse curls, 10x front curls, 10x pull-up, hands together on bar, 2 sets).

General Theme

COMPATIBILITY OF STRENGTH AND ENDURANCE TRAINING

1 Introduction

Strength and endurance training represent, in their extremes, opposite forms of training. Typical strength training involves large muscle groups and consists of a relatively small number of contractions of maximal or near-maximal force. In contrast, endurance training consists of a large number of sub-maximal contractions, as for example in bicycling or running, to increase maximum O_2 uptake (VO_{2max}). Endurance training does not increase the force output ability of the muscles, and training for strength induces little or no increase in VO_{2max}. Obviously the nature of the adaptive response to training is specific to the training stimulus. Strength training causes muscle fiber hypertrophy associated with an increase in contractile protein, which contributes to an increase in maximal contraction force. Endurance training, on the other hand, usually causes little or no fiber hypertrophy, but it does cause an increase in the following adaptations expected to enhance endurance performance: capillary density, mitochondrial volume density, and oxidative enzyme activity.

Strength and endurance training are sometimes done concurrently by athletes. However, since the adaptive responses to strength and endurance training are different and some may even be opposite, it is conceivable that the skeletal muscles cannot adapt optimally to the two contradictory training stimuli when they are simultaneously imposed. For example, strength training may cause a decrease in capillary and mitochondrial volume density, which would undermine the increase in these measures induced by endurance training. Endurance training has been associated with a loss of strength and decreased muscle fiber size. These changes are obviously antagonistic to strength development.

On the other hand, concurrent strength and endurance training may interact to enhance rather than hinder strength and endurance development. It has, for example, been shown that some forms of endurance training can increase strength and muscle fiber size. It has also been confirmed that strength training can lead to increases in short- and long-term endurance, maximal aerobic power, and oxidative enzyme activity (SALE et al. 1990).

2 Results of early studies

Two studies conducted during the eighties addressed the issue of compatibility of strength and endurance training. DUDLEY and DJAMIL (1985) as well as HICKSON (1980) examined alterations of aerobic power and muscular strength after training for strength, for endurance, or for both concurrently.

The strength-trained subjects in HICKSON's study performed weight training 5 days per week for 10 weeks. Three days per week they performed parallel squats, 5 sets of 5 repetitions and knee flexions and knee extensions both for 3 sets of 5 repetitions. Two days per week leg presses, 3 sets of

5 repetitions and calf raises, 3 sets of 20 repetitions were performed. Throughout the training all exercises were performed with the maximal resistance possible for the required number of repetitions. The endurance group of subjects trained 6 days per week for 10 weeks. Three days per week interval training on a cycle ergometer consisting of six 5-minute work bouts at a rate which approached the subjects' VO_{2max} were performed. Work rate on the ergometer was increased throughout the study to approach the subjects' increased VO_{2max} during each interval. On alternate days a running program consisting of running as fast as possible for 30 minutes during the first week, 35 minutes during the second week and 40 minutes during weeks 3 to 10 was performed. The combination strength and endurance group performed the exact exercise regimens as the strength only and endurance only groups. Thus, they performed strength training 5 days per week and endurance training 6 days each week. Training sessions on the same day were normally separated by at least 2 hours of inactivity.

The results of HICKSON's study indicate that simultaneous training for strength and endurance induces increases in both muscular strength and aerobic power. The increase in aerobic power of the group training concurrently for strength and endurance, however, was no greater than that induced by endurance training only. Performance of endurance training only did not increase muscular strength. Likewise, conventional weight training improved muscular strength but not aerobic power. Performance of both modes of training compromised strength development. Strength development for the combination group declined in rate after 4 to 5 weeks of training relative to that of the strength-only group only; this response became significant after 7 weeks of training.

As it was possible that the compromise response evident in the group performing both types of training concurrently was caused by overtraining, DUDLEY and DJAMIL (1985) reduced the number of training sessions and the total training time per week by approximately 50 and 75%, respectively, relative to the measure of these values used by HICKSON (1980) in an effort to reduce the potential for overtraining. DUDLEY and DJAMIL (1985) also did not require performance of both modes of training on the same or consecutive days. Strength training of the knee extensors was performed on an isokinetic loading dynamometer 3 times per week (alternate days) at an angular velocity of 4.19 rads per second for 7 weeks. Two sets of 30 seconds (26 to 28 contractions) of voluntary maximal knee extensions were performed each training session. Endurance training was performed on a cycle ergometer 3 days per week (alternate days) for 7 weeks. Five 5-minute exercise bouts with a 5-minute rest between bouts were performed per training session. Power outputs were chosen to elicit VO_{2max} in the 4^{th} to 5^{th} minute of each work bout. The concurrent strength and endurance training group performed the same exercise regimens as the strength and endurance only groups. The concurrent group did 6 days per week alternating strength and endurance training on a daily basis.

The results of DUDLEY and DJAMIL (1985) are nevertheless similar in nature to those of HICKSON et al. (1980). Performance of both modes of training did not influence the increase in peak cycle ergometer VO_2 induced by endurance training only. Concurrent training did, however, compromise the magnitude of increase in angle-specific peak torque at fast, but not slow, speeds of contraction evident with strength training.

3 Conclusions from the studies

In summary, the following conclusions can be drawn from these studies: Concurrent strength and endurance training induce increases in muscular strength and aerobic power. This type of training, however, interferes with optimal development of muscular strength. This is especially true at fast velocities of contraction, suggesting altered adaptive responses mainly in skeletal muscle. Possible explanations for the lack of optimal development in strength with concurrent training include, besides overtraining, transformation of fast-twitch to slow-twitch type muscle fibers.

Thus, it may be advised that

- athletes involved in pure strength or power type activities should not perform large volumes of endurance type training.

Concurrent training, in contrast, does not affect the development of aerobic power.

- Endurance type athletes may therefore perform strength training with no decrement in maximal aerobic power (cf. DUDLEY & FLECK 1987, p. 84).

4 How much strength do endurance athletes need?

4.1 Components of the functional system required for endurance events and the importance of the ‘special foundation phase’

Record-breaking performances in the middle and long-distance events stem from a highly organized functional system. This system comes into being during long-term, multi-year training that includes an optimal level of training and racing activity. The system consists of three harmoniously developed links:

- the ‘executing’ link, i.e. the muscular system,
- the ‘supply’ link, i.e. oxygen transport, and
- the ‘regulating control’ link, i.e. the central nervous and endocrine system.

Runners usually reach their physical peak during the *special foundation phase* before achieving their season’s best performances (cf. SUSLOV 1997, p. 10). The special foundation phase develops the components required for specific endurance.

The parameters which characterize the concept of a ‘special foundation’ are:

- a high maximal oxygen uptake,

- a high anaerobic threshold speed and oxygen uptake (85 to 90% of the maximal oxygen uptake),
- an effective and economical running technique,
- a high level of specific muscular strength,
- a high utilization of muscular strength in the competition event,
- the 'regulating control' link, i.e. the central nervous and endocrine system.

4.2 Muscle strength as an important component of the 'special foundation phase'

The strength of the muscles involved directly in powering an athlete through a distance race is an important component to be taken into consideration in the 'special foundation' phase of training. Increasing the power output and sustaining it throughout the entire race is based on the following factors:

- increased stride length,
- formation of an effective movement structure,
- achievement of an optimal combination between stride length and stride rate,
- maintenance of the required running speed for a particular distance.

Strength development exercises improve the elastic and reactive properties of the muscles. These elastic and reactive properties are reflected in the ability of the muscles to restore mechanical running energy. Consequently, coaches should pay particular attention to the development of 'prime mover' muscle groups by loading them above the competition demands in training.

4.3 Which kind of strength exercises do endurance runners need?

Middle distance runners need exercises to develop general strength, explosive strength (speed strength) and, above all, strength endurance.

These categories of strength have different methodological features. The relative percentages of different exercises within the total volume of strength training, the intensity and the distribution of the exercises throughout the year's training cycle follow a definite pattern. The effectiveness of strength and endurance development hinges on the two properties of muscle fibers – contractile capacities and considerably increased oxidative capacity. These effects are the result of the growth of the mitochondria mass, capillarization of the muscles, and enzyme activity. The oxidative and contractile capacities can be improved in the same direction at a training intensity that does not exceed the anaerobic threshold (heart rate up to 170/min, lactate not exceeding 4 to 5 mmol/l). Excessive strength and speed-strength training, on the other hand, can be responsibe for a shift from oxidative-glycolytic fibers to fast glycolytic fibers, myofibrillar hypertrophy, and can lead to a decrease in the volume of mitochondria and thus lower the oxidative capacity of muscle fibers (cf. SUSLOV 1997, p. 11).

Optimizing these two processes calls for correlating aerobic work and strength development leading to a moderate hypertrophy of the myofibril cross-section. The balance depends on the nature of the athlete's main competition event. It is important therefore that the athlete's endurance level is constantly monitored during strength training. A considerable drop in the running speed at the anaerobic threshold level suggests that the level of strength training is too high.

Well balanced strength training, designed to develop the runner's main muscle groups, should be performed 2 to 4 times a week during the first stages of a year's training cycle (4 to 6 weeks). This development should take place against the backdrop of improving specific endurance and its components. Speed-strength training takes over after the base general strength development phase.

Strength-endurance training begins within the sixth to eighth week of the following macrocycle and is performed twice a week over about nine months. However, it would be wise to lay off from strength-endurance training 2 to 3 weeks prior to emphasizing of oxidative capacities.

In middle distance running the total volume of all three types of strength development exercises should not exceed 100 to 120 hours a year. However, it must not be forgotten that such a volume of strength training calls for an increased quantity of flexibility exercises to assure joint flexibility and mobility in the lower extremities and spinal column, responsible for muscle and ligament elasticity.

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