Maintaining Form

During Middle Distance Running

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Wilson Kipketer
800m 1:41.11

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Introduction

For many years I have watched Middle Distance races and I have noticed something special that exists in some of the Elite. It is particularly evident in athletes such as Wilson Kipketer, Hicham El Guerrouge and Sebastian Coe.
In assessing what makes them different, it can be identified that these athletes have apparent Special Abilities in two areas:
1. An incredible appearance of “Ease of Speed” at race paces. They seem to be able to run effortlessly in the middle stages of their races. All are not large athletes yet they have been able to cruise with apparent efficiency at race pace. This is also accompanied by a superior ability to accelerate and ‘change gears’ at paces near maximum.
2. They are able to maintain a very high level of their most effective running form for the entire duration of their races. They do not collapse into a poor running position in the final straight.

I believe these two special abilities can be developed using a range of methods in any athlete. The variety of ways that athletes can improve the special abilities listed above will be discussed in this paper with some practical suggestions.

Hicham El Guerrouj
1500m 3:26.00

The Quest for Special abilities

The "Training in" of bad habits

Every time an athlete runs they are practising a motor pattern. The motor pattern that they can run with at any time is dependent on many things. Things that can inhibit running with an ideal motor pattern are the athlete's current postural habit and any injuries, imbalances and/or deficiencies that are being compensated for. e.g. an athlete cannot run smoothly with a blister on one foot. However, if they continued to train with the pain of a blister they would end up with a different biomechanical habit of running.

Entering fatigue into the equation in training will always challenge running form and in most cases cause at least a slight loss of form. This introduces the reality that athletes may decrease efficiency and "ease of speed" by practising bad running habits. Some types of training in particular will produce higher levels of fatigue particularly of the stabilizer muscles:
- Interval training with short recoveries at high intensities. e.g. 2 x 5 x 200 at 800 pace with a 30s rest between reps. In a situation where the athlete looks good for the first two reps then fatigue causes the athlete to collapse into significant loss of form during a majority of the final three reps. It maybe better to do 3 x 3 x 200 at 800 pace with 30s rest and focus on maintaining good form, than to perform the first session as described.
-If an athlete completes a 2hr run in a situation where the stabilizer muscles have fatigued early then they are also doing a large amount of bad technical practise. Maybe it would be better to run 75min with good form than 2hrs in a 'lazy' position, unless the extra distance is absolutely necessary. The plan could be to improve maintenance of good running form and then extend the distances while moving with quality.

The flip-side is that if an athlete has done special activities to improve their maintenance of form when highly fatigued then they can do training that really challenges this ability and further improve their ability to run with good form even when under conditions of race-end fatigue. It has been reported that Wilson Kipketer does sessions like 20 x 200 in 26s rest 30s. However if an athlete with poor ability to maintain form was to regularly perform a similar session this would likely result in "trained in" bad habits. Eventually these bad habits may even be evident in these athletes before they fatigue and result in decreased efficiency and increased risk of injury.

The key to performing training in a way that slowly improves fatigued running form is to do minimal training with form loss. The aim should be to work using various methods to push the point where an athlete loses form toward higher and higher levels of fatigue. There is an argument from some coaches that athletes must train to the point of technical breakdown and a bit beyond. The theory exists that the slight variations in angles allow muscles to be recruited that are less fatigued. However, training to these extremes is most likely counterproductive and invites injury.

Accelerating and Gears

It is important for all athletes to practise regularly at a variety of speeds when they are not fatigued. They should also practise accelerating maximally from race speeds and then relaxing while maintaining the new pace and then accelerating again. This ability must be practised in low fatigue situations first before developing the ability to do it under high levels of fatigue.

Many athletes will find that there is a great difficulty in being able to maintain good pelvic position when they attempt to accelerate maximally. The first more powerful step will tend to create anterior rotation of the pelvis unless the athlete has very good mid-torso strength and control. Anterior rotation of the pelvis lowers knee lift range and therefore speed.

There is also value in finishing a significant number of training repetitions fast and with optimal form. This is a great opportunity for quality practise e.g. Instead of always doing 1000m repetitions in 2:35

why not do them in 2:40 with a faster last 100m. The metabolic effect will be very similar.

There is great value in doing as much pace changing as possible. Just the act of changing pace means the athlete is thinking more of technique and may stimulate further improvement of their motor patterns at different speeds. 'One pace' training will produce one-paced runners and there are plenty of them around. Former World Champ Medalist Rich Kenah (USA) a known strong finisher in 800m races conducted most of his track training at varied paces and the emphasis was most often to relax while running fast.

The nature of "loss of Form"

In every movement that occurs during landing while running, the quadriceps muscles are involved in eccentric contraction. The adductors, abductors as well as the inward and outward rotators of the thigh work together to providing stabilization in controlling this movement. It is important to note that the situation is very different in a double leg movement.

In take-off while running, the hamstrings and glutes work concentrically in hip extension and the quadriceps work in knee extension. At the bottom of the movement the gluteals and abductors act together to stabilize the hip. The hip abductors work in a stabilizing role by guiding and assisting with hip extension. If they are not strengthened in balance with the hamstrings, additional stress will be placed upon the hamstring muscles during these movements (Bourne).

Research into fatigue during events from 400m and longer has revealed a common trend. A variety of different studies have been performed at various running velocities. Most findings are very similar to the studies performed by Tupa et.al summarized below:
- Reduction of the movement velocity and cadence.
- Reduction of the driving force.
- Increased braking force of the lead leg.
- Increased vertical displacement of the hip joint. This creates increased mechanical work to displace the body's centre of gravity.
- Increased take off angle of the centre of gravity.

Stride frequency usually reduces more than the stride length shortens. A longer support phase, during which braking increased more than in the driving phase, reducing the stride frequency. The study was on the 400m event, which obviously creates a similar magnitude of loss of form in many athletes as the Middle Distance events.

Another study found that during a 3000m time trial as athletes fatigued their stride length decreased and stride rate increased to compensate so they could maintain a constant velocity. There was also a small shift to increase the period of support and a corresponding decrease in the period of non-support. What was very significant was that the lower leg was more angled at foot strike, the thigh was less extended at the end of the support phase, and the trunk was carried further forward during the running cycle (Elliott & Roberts).

Other comparisons of the characteristics of athletes in various states of fatigue showed a significant decrease in step length, an increased maximal knee flexion during swing, and an increased maximal thigh angle during hip flexion (Williams et.al).

Improving Foot Strike

It seems that part of the explanation for the type of the changes due to fatigue evident in many of the studies, is that athletes tend to overstride in the latter phase of the race. The first goal then should be to improve the efficiency of foot strike.

Many athletes are taught to sprint with their feet pointed down so they land on their toes. There are

numerous athletes at any race meet that can be observed losing dorsiflexion early before footstrike. They are most likely swinging out their leg in an attempt to get more stride length (especially when fatigued). The effect of this is that athletes will strike the ground too far forward resulting in greater than necessary braking forces. This is not only bad for movement efficiency and maximum speed but it is also the cause of a great number of injuries to the lower leg.

The solution can be summed up by the comments of Coach Bill Bowerman “Your foot should strike after it has reached the farthest point of advance and has actually started to swing back”. He also said, “when your foot strikes, the point of contact should be directly under your knee, not out in front of it, and as nearly as possible squarely beneath your centre of gravity” (Benson).

Optimizing knee lift

Athletes may lack knee lift because of lack of mobility, weak or fatigued hip flexors or in most cases because of the angle of the pelvis. When the pelvis is tilted, so that there is increased lumbar curvature, it is not possible in most people to lift the knee freely. It is restricted in its movement, limiting knee lift to a considerably smaller range. The key to optimizing this situation is to maintain a tall position with high hips and produce an optimum level of lumbar curve that is more constant.

Stabilizing the Pelvis

Some athletes may have permanently poor postures that display a readily observable excess of lumbar lordosis. These athletes may have already compensated for their postural deficiencies by developing a running action that has a high degree of rear-side mechanics i.e. most of their leg action is out the back. They are also likely to be toe strikers who lean forward to minimize the effects of overstriding from their early foot-strike. By leaning forward and having low hips they are ‘accidentally’ (unless it has been taught) in a position where, if they also lower their centre of gravity slightly, they can then use their quadriceps much more. The result is more of a pushing action that will exist even when they are at maximum speed. Athletes that move in this way can exhibit high levels of speed but their movement is very inefficient. Many endurance athletes only run this way when they switch techniques to sprint in the closing stages of an event. It should be recognized that sprinting like this is an attempt to run in a way that compensates for lack of pelvic stability and hip mobility. It does not have to be accepted as permanent or definitely not as their “natural style”.

Many athletes may suffer from some degree of pelvic joint dysfunction and this can produce a pattern of muscle inhibition in the gluteal muscles. Altered muscle recruitment decreases the ability to sustain a muscle contraction and this can decrease effective joint stabilization in a variety of postures. Decreased muscle strength and posture control inevitably transfers the stress to other structures and may produce compensatory myofascial tightness or instability at the sacro-iliac joints, the hip or the lumbar spine. At the sacroiliac joint the ipsilateral gluteus maximus activity is altered with joint dysfunction, which may decrease tension on the thoracolumbar fascia and sacrotuberous ligament. Decreased gluteal function, especially in sports involving hip extension motion, e.g. running, will produce a change in function of the hamstrings, as they now must increase activation to extend the hip. Resultant change in activity of the hamstrings may increase the chance of repetitive strains, knee extension dysfunction etc. Concurrent weakness of gluteus medius produces compensation at the hip with increased activity of the tensor fascia lata and adductors to maintain lateral stability (Hungerford).

Maintaining hips that are level vertically requires stabilization from the “lateral system” e.g. the pelvis is stabilized on the left support leg by the contraction of the left gluteus medius and the left adductors in concert with the right quadratus lumborum. The QL acts to lift the pelvis enough to create free space for the swinging right leg. If the lateral system fatigues the trunk will become unstable and this will compromise the body’s ability to generate the forces required to move the swing leg quickly (Chek). “Wobbling” athletes will have great difficulty maintaining short foot contact times and greatly increase the risk of injury. This is because they will likely be using joints outside of their optimum movement angles.

The nature of the way the hips move horizontally as the body moves forward has also been described. The ‘anterior oblique system’ describes the way the adductors of the stance leg work in concert with the internal oblique on the same side and the external oblique from the other side. They collectively function to both stabilize the body on top of the stance leg and also to rotate the pelvis forward in a good position for the next foot strike (Chek). The function of the anterior oblique system is challenged at a higher level when an athlete accelerates or changes direction.

The gluteus maximus works in concert with the opposite lattisumus dorsi. This has been labelled as the “posterior oblique system”. The contraction of both muscles at the same time creates tension in the thoracolumbar fascia, which will assist in stabilizing the sacroiliac joint of the stance leg and results in a reduced energy cost.

The important range of functions of various muscles in the above systems emphasizes the need to prepare in a functional way as much as possible so that running movement can be optimized. Thinking about training needs to expand beyond conditioning in two dimensions. The days of simply doing a combination of squats, hamstring stretches and sit-ups are clearly over.

Can we and should we change Technique?

Some people have suggested that it is not possible to change an athlete’s technique for the better. The argument being that athletes can optimize their running efficiency to suit their body’s characteristics by performing large volumes of continuous running. To an extent this is regrettably true because the unique technique they will develop is likely a result of compensating for lack of mobility, lack of core strength and lack of strength in prime movers. This natural compensation combined with poor or incorrect shaping of technique will gradually develop an athlete with form that is not biomechanically optimized and is therefore less efficient. The athlete will be less capable of acceleration and high speeds than their potential. Additionally, the athlete will also be less resilient and therefore have a shorter career.

Poor running form is especially evident in athletes who have done a lot of specific training starting at an early age. This is because the athletes with under developed postures etc. have been unable to move with good form. Consequently, they have trained with bad habits and made them almost permanent. Jack Pross (Coach of Alby Thomas) wrote that “incorrect posture in the developmental stages of adolescent growth is one of the foremost reasons why young athletes who show promise at an early age do not make the grade in senior Competition” (Pross). Multi-lateral training is very important because it creates a foundation for the long term development of sound technique in mature athletes.

Athletes that have comprehensively conditioned their stabilizing muscles and optimized their mobility will likely also improve their movement in others ways. The athlete may have a decreases tendency to run with their feet pointed outward or to run with bent legs, especially during fatigued conditions.

Conditioning to improve the Special Abilities

Focusing on improving function

It is recommended that coaches aim to develop strength and mobility in a way that enhances function and there are many ways to do it. It is important to avoid focusing training particular muscles (an approach common in many gymnasiums). Isolation exercises like hamstring curls involve using the muscles in ways that are unrelated to their function while running. This type of training may only be appropriate in remedial situations.

The focus is better to be on training movements as much as possible. This means avoiding the use of many machines (Gambetta 1997).

A good goal is to expose athletes, especially in foundation years, to a great variety of training modalities. It is also a good idea to change the emphasis and the actual routines regularly throughout each training year. Use of a great range of training methods will usually enhance the athletes enjoyment of training. This is because there will always be something different that can be introduced and developed. The variety also causes development to occur across a wider range of areas.

Physiotherapy Assessment

It is essential that the athlete & coach develop a relationship with a good athletics physiotherapist. The first step is to have the athlete carefully assessed for deficiencies in muscle flexibility, muscle strength and postural habit. A very valuable activity may also be for the physiotherapist to see the athletes running motion. This may provide even more useful information. After the initial visit all stretching can then be part of a targeted plan designed by the physiotherapist, guided by the coach and possibly monitored on a regular basis by a massage therapist. Strengthening programs can also be better prioritized and planned in a similar way. An extra benefit of this team approach is that many injuries may be avoided. This is because numerous injuries have preceding factors that can be identified, controlled and monitored by the physiotherapist.

Mid-Torso Conditioning

There are many exercises that can build the required strength and endurance. There has been plenty of research published on this topic. The importance of mid-torso conditioning in the development of speed is well known (Faccioni 1985; Brittenham & Brittenham).

My squad has been following some of the suggestions made by Paul Chek (Chek 1998). Once a week on different days we aim to develop a high level of strength by focusing on the Obliques, Back, Upper abs or Lower abs using sets of 8-10 reps. Exercise examples are resisted swiss ball crunches, lumbar stabilized leg lowering, across body cable pulls etc. They also do a large variety of other conditioning exercises throughout the week performing 2-3 sessions of 20min Swiss Ball workouts and 2-3 sessions of Pilate's floor exercises. They also perform a variety of Weight Training and Theraband exercises.

Swiss Ball

The swiss ball can be used as a multi-purpose bench, which has the training advantages of being an unstable environment. Any kind of training in an unstable environment is great for strengthening stabilizer muscles. The shape of the ball also allows for multi-angle training and allows greater range of motion on some exercises. These are important factors in properly training certain muscle groups e.g. the swiss ball crunch. It can be performed starting from a hyper-extended position over the ball. It is recommended that athletes learn the correct techniques. The best way to do this would be to attend Swiss Ball classes which are increasingly becoming a regular fixture at many fitness centres. Alternatively, there are a number of very good video workouts, which explain carefully the finer points of technique. I have found videos to be very effective and enjoyable for the athletes in my squad. It is important to recognize Swiss Ball training as a way of improving functional strength and not just a toy for improving balance etc. (Chek)

Pilates

The Pilates variety of exercises have been an integral part of ballet training for many years. The basic principles of Pilates conditioning are to make people more aware of their bodies as single integrated units, to improve alignment and breathing, and to increase efficiency of body movement. The method consists of a sequence of carefully performed movements with some carried out on specially designed equipment. Each exercise is designed to stretch and strengthen the muscles involved accompanied by a high level of focus on learning to relax. Athletes in my squad that have done a significant amount of pilates have exhibited improved body awareness and control e.g. they are able to learn to do drills much easier. I believe this area of training is exceptionally good for enhancing hip mobility and strength.

Pilates can be done at studios where it is common to have personal tuition or there is a variety of good video workouts of floor exercises. My squad uses a variety of Pilates video workouts, one good one combines Pilates with some yoga stretching (Austin).

Medicine Balls

There are new varieties of bouncy rubber medicine balls that are the size of a volleyball or basketball. These can be used to do a large variety of conditioning exercises. Athletes can perform some exercises very fast and develop power especially in the mid-torso and arms (Faccioni). In addition, the experience of being able to train at coping with impact forces is also beneficial. They will improve the ability of an athlete to cope with rough races and have a better chance of staying on their feet when bumped. Many exercises are great for overall co-ordination and balance.

Theraband exercises

Therabands are thick flat rubber bands that can be purchased in a roll. They exist in a number of resistance grades. Many stabilizer muscle groups can be specifically strengthened using them.

A few examples are:

1. Cut a 90cm length, and tie the ends. Get the athlete to step into the theraband circle (band around ankles) and get them to do a series of sumo type walks (squat position with wide legs). Get them to walk sideways, forwards and backwards lifting each leg up (like sumo wrestlers do) and not allowing the theraband to pull their legs together. It is recommended to do one set of 15-25 steps.
2. The athlete lays face down with the theraband around their ankles. They then get into a hyperextended position and abduct their legs. It is recommended to do 1-2 sets of 20.
3. Hip Rotators can be strengthened by having the athlete lay face down, knees together with the lower legs held vertically and placing the Theraband around their ankles. The athlete should then maintain the knees together and rotate their hips so that their ankles move outward. A similar exercise can be devised to strengthen rotation in the opposite direction.

Often there are big differences in the strength of outward movement and the inward movement. Strengthening and equalizing hip rotator strength should improve stability and improve running form especially when fatigued.

Weight Training

Gym training can contribute strongly to improving the special abilities by:

1. Effectively strengthening and improving power from the prime movers.
2. Improving Core Strength in a variety of ways. This can improve mid-torso stabilization and the ability to maintain good posture while running fatigued.

Exercises with free weights can target the prime movers in specific ways while at the same time the stabilizer muscles are being challenged e.g. standing alternate-arm vertical-presses load the mid section vertically and challenge the athlete's ability to hold themselves up straight. There many opportunities to develop core strength in the gym doing exercises that may seem unrelated to stabilization at first glance. Recent opinion is also tending toward athletes aiming to do one leg exercises instead of two legged wherever possible. Exercising on one leg is much more specific because it involves the use of the important stabilizing functions of muscles near the hips. (Gambetta 1997)

There is a distinctive way to perform Step-ups that is a good test of stabilization ability. They are performed on alternate legs with the lower leg kept close to vertical throughout the movement. Executed this way they target the glutes more than when the knee is allowed to move forward and are a good specific hip extension exercise. Often when Athletes start training with this exercise they have great difficulty in staying tall and maintaining level hips. There is a great tendency to 'wobble' or 'twist' on the way up. This indicates that they have weak stabilizers. Athlete progress is clearly limited by their ability to stabilize the weight. This is a good way to measure improvements in stabilization strength. Athletes usually display the gains from other training methods that impact upon stabilization by improving in the perfect execution of this exercise more rapidly.

Athletes could also perform a great range of other exercises e.g. splits lunges, cleans, snatches, squats etc.

There has been great debate over the years about the best way to perform weight training for Middle Distance Athletes. However, for many years athletes have been told of the need to be strong. Renowned coach Arthur Lydiard recommended that during the conditioning period the athlete needs 2-3 weight training sessions a week. Maybe surprising for some people is that he also suggested progressing to heavy lifting including the Clean & Jerk, Jump Squat, Parallel Squat, Military Press etc. (Lydiard).

The debate about what to do has been mostly related to the theoretical impact of heavy strength training on the endurance capacity of muscles. The effectiveness of strength endurance development for endurance athletes is dependent on the combination of two properties of muscle fibers. The goal is to improve both their contractile properties as well as their oxidative capacities. The oxidative properties develop as a result of increases in the mitochondrial mass, capillarization of muscles and enzyme activity. A potential clash could occur in the development of both contractile and oxidative properties if excessive strength training is performed that results in myofibrillar hypertrophy. This can lower the mitochondrial density and therefore the endurance of the muscles (Suslov).

The role of the coach is to plan a program that will optimize these two processes by the right balance of aerobic work and strength training. The way to do it is to monitor the athlete's endurance level throughout strength training periods. A drop in endurance capacity may suggest that the level of strength training is too high. Many endurance athletes and coaches are very focused on developing the oxidative properties of muscle through high volume training. Balancing and absorbing the running alone may create a feeling that strength training is an unnecessary distraction. However, strength training can have a very significant impact and should be planned carefully. It is better to be performed hand in hand with aerobic development over many years.

Circuit training

Many kinds of circuit and stage training can be performed to broaden the conditioning effects on an athlete. This area of training can specifically target muscular endurance and speed strength (Martin & Coe) (Coe). Sessions with a speed-ball are also brilliant for improving endurance especially of the upper body.

Ankle Conditioning

If a runner has weak ankle dorsiflexors they will make a lot of noise when they run where those with well conditioned and functional dorsiflexors will make much less noise. It has been suggested that Kenyan athletes build up tremendous dorsiflexor strength and functionality because they spend their initial years of life running and walking endless miles while barefooted, instead of being in shoes. Consequently, many Kenyans are able to conserve energy during the stance phase. This is because in addition to controlling plantar flexion, the dorsiflexors must also deal with the side-to-side motions of the foot and ankle during running, as well as the rotational motions which are a natural part of the gait cycle. Any tendency of the foot to pronate must be controlled by the shin muscles. Any tendency of the foot to supinate must also be minimized by the dorsiflexors. It is important to condition the dorsiflexors to be able to cope with stress in the full range of directions. As well as improving efficiency, strengthening the dorsiflexors minimizes the risk of developing Medial Tibial Stress Syndrome.

Recent research has shown that fatigued dorsiflexors produced a greatly increased vertical ground reaction force. The ideal situation is when a large degree of dorsiflexion exits because it creates a situation where greater lengthening of the tibialis anterior can occur during the eccentric phase. This allows greater absorption of energy, which lowers the vertical ground reaction force. The tibialis anterior when fatigued displays a loss of ability to act eccentrically and vertical ground reaction forces have been found to rise dramatically for every degree of loss of dorsiflexion (Christina et.al).

Exercise ideas for dorsiflexors

(Anderson & Reynolds)

Shin Raises – athletes simply use shins to lift toes up as high as possible when standing on their heels, perform 3 sets of 15. Progress can be made by varying both the range of motion and the speed. Athletes could also progress to doing them on one leg at a time.

Heel Step-Downs – Athletes step forward with one foot but by using eccentric contraction of the dorsiflexors they prevent the ball of their foot from descending any more than a few centimetres toward the floor. Maybe progress to 3 sets of 15 each leg. Athletes could increase the intensity of the exercise by taking longer steps and then to going down a high step.

Some ideas for shin conditioning during warm-ups are:

Walking on toes - Athletes walk high on their toes with their toes pointed straight ahead for 20 metres. Then 20m high up on their toes, but with the toes pointed outward with the rotation coming from their hips so that the whole leg rotates. Follow this with a high on toes 20m walk with toes pointed inward, once again by rotating from the hip.

Walking on heels – Athletes walk on their heels with their toes pointed straight ahead for about 20 metres and repeat like in the toe walks with toes out for 20m and toes in for 20m.

Jogging on toes or heels - Progress can be made with both exercises by jogging gently performing the above two variations. Further progress is made by skipping which would be of a much higher intensity.

Rhythm ankle bounding is performed by jogging along with very springy, short steps, landing on the mid-foot area with each contact and springing upward. In rhythm bounding the athletes ankles should act like coiled springs, compressing slightly as they land mid-foot and then recoiling quickly. This causes the athlete to bound upward and forward. Athletes progress toward performing a mixture of mini hops and rhythm bounding over 20m with around 100m of variations in total.

Dorsiflexion bounces are performed by jumping vertically and repetitively at close to maximal height, landing in the mid-foot area with both feet and then springing upward quickly after each contact with

the ground. Athletes should dorsiflex their ankles on each ascent and slightly plantar flex their ankles just before making contact with the ground. Maybe start with ten dorsiflexion bounces progress to thirty and then toward doing them on one leg at a time.
Rhythm bouncing is jumping around moderately fast, with medium height, and with maximal motion at the ankles, but minimal flexion and extension at the knees and hips. Combine these with some low fast bounces of less than a few cm. All Rhythm bouncing should be performed as if the landing surface is very hot. The athlete could start with ten bounces and progress to forty.
Advanced Rhythm bouncing involves jumping in various directions and then eventually developing the ability to do them on one leg. The challenge of doing them in different directions increases the ability of the shin muscles to handle the side-to-side and rotational stresses during running.

Foot conditioning

The muscles of the foot when well conditioned can contribute to running efficiency as well as prevent injury. Research by Unger & Wooden on the effects of an arch strengthening on athletes produced gains of 4cm in the vertical jump and 11cm on a horizontal jump. (Unger & Wooden).

There are many simple ways to develop and maintain good arch conditioning e.g. spending time barefoot, doing smart amounts of running barefoot etc. An exercise called 'Toe grasping' can be performed by having the athlete stand barefoot with feet hip-width apart. They should then curl the toes of their right foot and then their left foot down and under, as though they are grasping something with the toes of each foot. It is recommended to do 2 sets of 50 repetitions with each foot. The aim should be for the athlete to try to pull themselves across the floor. Initially I have had athletes perform this exercise by having the athletes flex their toes in a pulling action to "scrunch" a towel under their feet. (Anderson & Reynolds)

Plyometrics

An exciting development for Middle Distance running is that research performed in Sydney has revealed that Plyometric Training can have a strong positive effect on performance in endurance running events. Seventeen male distance runners with a training history of average 10 years were randomly assigned into an experimental (Plyometric training) group (E) and a control group (C). The experimental group then completed a 6 week plyometric program (first 3 weeks 2 sessions/week, second 3 weeks 3 sessions/week). Both groups continued training normally (60-80km/week). The Plyometric program progressed from 60 total contacts each session in the first week to 180 each session in the final week. The intensity also progressed from exercises such as squat jumps, double leg bounds in week 1 to alternate leg bounds, single leg hops, depth jumps, double leg hops and single leg hurdle hops in the final 2 weeks.
Both groups were tested prior to and after the 6-week training period for all variables. The testing resulted in the following:

Group E improved 13.2% in the Counter Movement Jump, Group C no significant change.
Group E improved 7.8% in the 5 bound test, Group C no significant change.
Group E improved Running Efficiency at 6.7% at 12kph, 6.4% at 14kph, 4.1% at 16kph , Group C no significant change at any velocity.
Group E improved Musculotendinous stiffness at heavy loads by 11-15%, Group C no significant change.
Group E improved Maximal Isometric Force by 11-13% , Group C no significant change.
Group E improved Rate of Force Development by 14-15%, Group C no significant change.
Group E improved 3km Time Trial by 2.7% which was in reality an average of 16.6s, Group C had no significant change.
Group E & C both showed no significant change in VO2max , Lactate accumulation or Lactic Threshold

The improvement in 3km running performance occurred without any change in VO2max and Lactate Threshold while body mass showed no change in pre and post testing. It was concluded that

improvement in Running Efficiency had lead to the the significant drop in 3km time. It was also suggested that the increased Musculotendinous stiffness and the resulting increase in maximal force production of the lower limb had transferred into improved Running Efficiency (Spurrs et al). Similar has been reported by other researchers (Paavolainen et al.).

Many International athletes have used Plyometrics as an important part of their program. It has been reported that Hicham El Guerrouj does 300 impacts using a variety of jumps on a weekly or fortnightly basis in the off-season. (Velediaz).Svetlana Masterkova regularly performed 10 reps of bounding over 100m (Storkina). I have also observed Wilson Kipketer doing a session of relaxed quick contact bounding over 80m while training in Sydney.

A great article on the preparation of Steeplechase athletes described a way of integrating weight training and plyometrics. It was interesting that the authors highly recommended that the athletes complete a moderate pace 6-8km run after all speed strength training sessions. (Belichko et al.) This was most likely an attempt to transfer neural gains from speed-strength training into the endurance running action.

I have seen athletes in my squad improve their finishing kick and mid-race acceleration by a large amount after we have seen gains in Plyometric ability. This has also been reported by others (de Swardt)

From a physiological basis, if a muscle is pre-stretched or made to build up high tension, it will concentrically contract with a much greater force. Plyometrics make use of this factor. The key in performing plyometrics is that the response from the ground must be immediate. Otherwise the exercise turns into a concentric contraction and does not involve the stretch reflex.

Any kind of Speed-strength training can have a temporary negative effect on an athlete's nervous system and therefore their current level of speed-strength performance. Vern Gambetta has commented that any activity of high nervous system demand (like Plyometrics) will take twice the recovery time as compared to a similar load of metabolic work (Gambetta 1996). However, rapid improvement occurs after the load volume has been reduced and changed to a maintenance regimen. Positive changes of a greater magnitude occur after a certain amount of time has passed following the reduced training load. It is very important to plan the situation so that the highest level of speed-strength capacity occurs during the peak competition period (Polunin et al.). Some international athletes that use Plyometrics for a big part of the training year stop doing it at least 4 weeks before the main competition period.

The physiological theory behind plyometric training is to develop efficiency in the stretch/shortening cycle of muscle action. During the stretch (eccentric lengthening phase) of muscle action, a greater amount of elastic energy is stored in the muscle. This elastic energy is then re-used in the shortening (concentric) muscle action that follows, to make it stronger. The key is to shorten the switching time i.e. the time it takes for the muscle to change from the eccentric lengthening phase to the shortening work phase. The fundamental principle of plyometric training is that it is the rate, not the magnitude, of the stretch that determines the utilization of elastic energy and the transfer of chemical energy into mechanical work (Gambetta 1996).

Introducing Plyometric Training

Balance & Stabilization Tests and development of Basic Strength especially eccentric strength should come before serious plyometric training. Without adequate levels of eccentric strength, rapid switching from eccentric to concentric work becomes very in-efficient. It is possible to evaluate eccentric strength through stabilization jump tests and observation of basic jumping exercises.

What to watch for during Plyometric exercises:
- If slow switching from eccentric to concentric work is observed, then eccentric strength levels are inadequate.

- The foot strike must be on the full foot in order for the foot to help absorb the shock. It is incorrect to land completely on the heel or on the ball of the foot.
- The shock of the landing should be absorbed by a combination of the ankle, knee and hip joints working together that will absorb the initial shock of landing and transfer that force throughout the body's muscles.

Athletes should progress carefully with Plyometric Training. The method below was recommended by Vern Gambetta (Gambetta 1996):

A/ Landing exercises

Standing long jump with two foot landing emphasis on "sticking" the landing. Athletes aim to land quietly on the full foot and absorb shock by bending at ankle, knee and hip. They could make progress to landing hops in similar way.

B/ Stabilization jumps

Similar to landing exercises but hold for 5 seconds before initiating another hop or jump.
When athletes can stick and hold 3 jumps progress to be able to stick and hold 3 hops on each leg.

C/ Jumping Up.

Jumping up onto a box (not down).

D/ Bouncing Movements in the one place

Ankle-bounces progressing to tuck jump with quick contacts. It is important to perform with an erect torso, good balance and by landing in the one place.

E/ Short Jumps

Start with 3 consecutive standing long jumps with two foot take off and landing.
Athletes could progress to 5 jumps, then to going up stairs jumping every second stair.
Eventually they should aim to perform single-leg hops and build up to 10 hops. Aim for a cyclic action of hopping (using an active foot-strike)

Moving past this stage of development should not be rushed. To avoid injuries and for the exercises to be most effective it is important to learn to perform all movements technically very well.

F/ Long Jumps

Aiming to add more horizontal velocity. Develop the technique of alternate leg bounding and of single leg hops. Carry out 10-20 contacts.

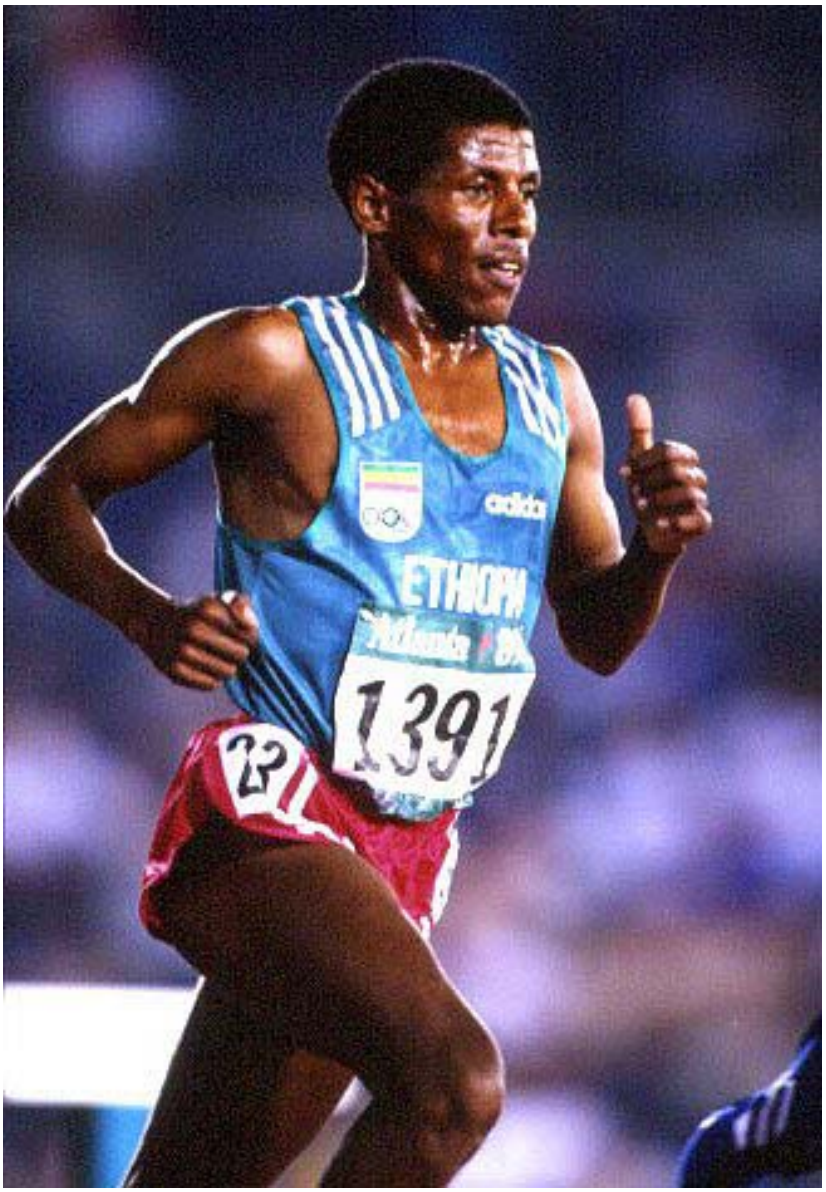
This is as far as most athletes may need to progress. A program should be designed that has a variety of jumps from all stages. They should be performed within a range of volume and intensity that is suitable for the athlete.

G/ Shock (Depth) Jumps

To raise power to the highest levels shock jumps can be used. This consists of jumps off boxes or rebound jumps over hurdles placed at mid-thigh height or higher. The training stress is high and this method should not be used with beginners.

The athletes in my squad have been training using a variety of Plyometric activities. They perform regular alternate leg bounding 3-5 sets of 6-10 contacts from a standing start throughout the off-season phases of the year. With most sets of bounds the athlete strives for maximum distance and the distance is measured noting improvement throughout the year. These are performed in racing flats on a Mondo surface and we have not had any problems with injuries from it. Other activities have included speed bounds with quicker contacts from a running start and bounding up hill. I have tried to focus on single leg exercises. We have also performed regular testing of standing triple jump, standing long jump and 4 hops. All athletes have seen large gains in performance of Plyometrics that has gradually developed. It is typical for an athlete with no plyometric background to improve their 10 bound distance by at least 2 metres over the course of a year.

It is important to start by doing Plyometrics as a way of increasing power. Athletes should work with Plyometrics in small volumes at an intensity that is effective. The athlete will improves in elastic power over a long period but they will eventually reach a plateau where it may not be appropriate for the athlete to aim for higher levels of power. Middle Distance runners do not need to exert the same levels of maximum force as sprinters or jumpers, so there should come a time when this area of training will be optimally developed. It may then be more appropriate to use Plyometrics for development of elastic strength endurance performed at an appropriate intensity for a Middle Distance athlete. This was the type of session I saw Wilson Kipketer doing. It was performed perfectly with plenty of feedback from his coach and was of a much lower intensity than a sprinter would use. The plan was likely to do enough volume to develop the “endurance of bounce” at the required force levels.



Haile Gebrselassie
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Transferring gains into Running

Good running form needs to be practised fresh before it can be transferred into fatigued states and have any chance of being maintained. This is because most bad habits of form will worsen under conditions of fatigue.

Drills

Drills aim to specifically strengthen the muscles in postures and actions that are similar to those that occur during the sprint action. They are posture drills, specific strength drills and functional flexibility drills all at the same time (Gambetta et al.). It is very important that correct execution of the drill be trained carefully with coach feedback essential. This is because drills performed incorrectly can ingrain bad habits that will result in the opposite of the intended effect. Bad drills are much worst than not doing drills at all. Athletes should never perform them as relaxed warm-up activities unless they are done perfectly. They are as serious a business as a concert pianist practising piano.

I have the athletes in my squad simply concentrate on two drills:
1. Ankling - circular movements of the lower leg maintaining dorsiflexion, striking with a backward moving (active) foot. They do 6-8 of these over 6-8s every time they warm-up.
2. Quick Recovery High Knee Running - they catch their leg early bring it rapidly up underneath stepping over the height of the other knee. They keep their pelvis stable lift their knees as high as they can without 'sitting'. They do these at varying speeds maintaining good form. This means maintaining constant lumbar curve, avoiding 'sitting' or losing dorsiflexion before impact. The positive cues are to stay high, step over opposite knee and land flatter footed. They do about 6-8 of these over 6-8s at varying speeds.

Once drills can be perfected over short durations, it is then appropriate to use them for the training of endurance of form e.g. reps of 100m of High Knees done properly. This may be one of the most powerful activities an athlete can do to help their race finishing form.

Hipflexor conditioning

When a knee is lifted the hipflexors have the ability to sway the spine forward because the muscles originate at the front of the lumbar region. This undesirable swaying action is counteracted by the lumbar stabilizing effect of the lower abdominal muscles. After building up good levels of strength in the lower abdominal muscles there will arrive a time when it is appropriate to focus on improving the strength and endurance of the hip flexors. It is important that hipflexor exercises are always done while maintaining a constant natural curve in the lower back. This means we can only really train the hipflexors within the capabilities of the lower abdominal region.

Improving hip flexor strength can improve the speed of leg recovery improving cadence. Improving hipflexor endurance can improve knee lift when fatigued. The chances of hipflexor strains may also be minimized.

Arm & shoulders

The motion of arms makes a small, but critical contribution to lift of the centre of gravity, which increases with running speed. The arms also decrease the horizontal excursions of the centre of mass, in both side-to-side and forward directions. This allows the athlete to maintain a more constant horizontal velocity. This results in improved efficiency. The arm action that is most important to running is not the obvious back and forth motion, but the acceleration of the arm, effecting lift and momentum. (Moreau)

Athletes need to practice relaxing their arms and swinging them in such a way that optimizes balance. Have the athletes run with arms folded to show them the wobbling nature that would occur without any arm action. Training for speed and endurance of the arm action is best to be practised always with relaxation as a focus. Tired arms in the late phases of a race can certainly decrease the power of an athletes kick. If an athlete is unable to swing arms big and fast enough at the end of a race, they will not be able to balance the extra forces being generated from the lower body. The result will be a very wobbly and therefore slower athlete.

The shoulders are an area that Jack Pross (Coach of former World Record holder Alby Thomas and others) emphasized was poorly executed (Pross). It is suggested that in the arm recovery phase, or drive preparation movement, the corresponding shoulder should lift slightly. It is a natural 'freeing up' motion that prepares the arm for speed and power generation in fast running, or rhythmical movement in endurance activity. Many athletes restrict shoulder movement by holding them down but if there is no shoulder lift, a restricted drive will be activated in the forearm and the power of the shoulder will be greatly reduced (Pross). By simply relaxing the shoulders it is possible to allow a bouncing like action that frees up the upper body for a much more powerful action.

Running on Uneven surfaces

It has been reported that most Kenyan athletes train almost exclusively on uneven surfaces and avoid road running in their preparation for Middle Distance competition. A manager of European athletes commented to me on returning to Australia, after watching mostly African athletes run, that our best athletes seem to run with floppy weak looking ankles. A possible explanation is that the years of running on roads and paths by many athletes is inferior to doing similar volumes on uneven surfaces. Athletes should aim to do the majority of continuous running on uneven surfaces but do their track sessions on the surface they use for racing.

Hill Training

When an athlete is running at speed on a flat surface they have momentum and the total force required to maintain speed is equal to the amount needed to balance the opposing forces of air resistance and friction. The athlete also needs to generate force to hold their body up against gravity. Running up a hill increases the levels of force required to lift the body against gravity and also the force needed to be overcome to maintain momentum. The technique of running up a hill requires a greater range of knee lift, quicker recovery and a more forceful arm action. It is recommended that athletes aim to stay tall, lift their knees up straight ahead and push straight down the hill. Hills can be great stride 'straighteners' when performed in this way.

There are many ways to perform hill training to enhance running power and endurance:
-Peter Coe had Sebastian performed up to 30 x 100m hills up a 9.6 degree slope with a short recovery regularly since the age of 16. They believed that these sessions mimicked the muscular activity that occurs when an athlete has to change pace suddenly (Martin & Coe).

-Long hills on slight slopes are also good for developing strength to maintain good body position. Athletes can with surprisingly low perceived effort reach very high heart rates due to the extra energy cost of running up a hill. This makes this type of training very good for improving VO2max. My squad has used an 800m gentle hill on a winding path on many occasions.

-New Zealand Coach John Davies (Tokyo Olympic 1500m Bronze Medalist) credits the idea of the following hill session to Lydiard and Cerruty. His squad performs the following hill circuit 5 – 12 times in a session. The circuit is about 600m that consists of a 50m steepish hill, 150m flat across top, 160m gentle downhill and finishing with 200m flat back to the bottom of the hill. The athletes bound up the hill concentrating carefully on form. They then jog slowly across the top and then run downhill again

concentrating on good form, long strides and good body carriage. The goal of the downhill is to be fast but controlled. They then recover by jogging across the bottom. He tried using a longer hill but found that form deteriorated with longer distances so settled with the 50m hill.

-Training on sand-hills has been popular in Australia following the tradition of Herb Elliott. They are a good overall conditioning exercise. However, it should be recognized that they are by far the least specific and have almost no plyometric component. Therefore, they should not be performed exclusively at the expense of other hill training methods.

One concern I have about the frequent use of any kind of hill training is that they increase contact times and are very different to running on the track at race pace. Too much hill running near the race season may negatively influence speed and efficiency due to increased contact times. There are two ways to get around this problem:

1. The Lydiard Method involves an intensive four-week phase of hills three times a week. This phase is performed just before more specific training starts.
2. They can be performed twice every three weeks for most of the year and stopped when training become more specific.

Resistance Sled Tempo Training

An area that I have introduced this year in the goal of developing more strength at race speed is the use of a synthetic track resistance sled. The kind I have is a round metal disk of weight 1.6Kg and 25cm across. The method we have used with the sled has involved doing sessions like 10 x 200m rest 3min at slightly above 800m race speed. The athlete has aimed to maintain quick contacts and a normal running action. They often do a few tempo runs afterward without the sled and comment that the race tempo now feels very easy and therefore more relaxed. The sled has been used with a range of athletes from junior 50kg females to Senior Men. The aim is to train strength endurance in a more specific way than using hills and develop greater levels of “ease of speed” at race pace.

We have also performed some tempo type sessions with athletes wearing a 2kg weighted belt. Loaded vertically the athlete then has to do increased work to hold their bodies up against gravity while maintaining momentum. We have used weighted belts on alternate reps for a contrast like effect. The goal of these sessions has also been to develop better maintenance of form and ease of speed.

Downhill Running

Running downhill loads the muscle eccentrically much more than running on the flat. Recent research has indicated that from the stress of running downhill sarcomeres are added to the leg-muscle cells, and those additional sarcomeres may allow the muscle to recover more quickly from very severe training sessions and competitions (Proske et. al). This means the athlete may be ready for subsequent quality work quicker. The first experience of downhill running will likely cause a surprising large amount of soreness. However, subsequent soreness resulting from downhill running is much less for up to six weeks after the first exposure. This “protection from soreness” factor is likely to apply to running fast on a synthetic track as well. This introduces the possibility that some regular downhill running may make it possible for athlete’s muscles to cope with harder training. Muscles that have larger numbers of sarcomeres are also thought to be able to contract quicker so there may be power benefits as well. (Anderson)

Downhill is also recommended because of the technical benefits of learning how to run so that the athlete is not overstriding. The effects during downhill running of overstriding are much more noticeable, this makes it obvious to the athlete when they are running with an active foot strike and it

occurs in the right place. These sessions require a very slight downhill slope and careful technical input from the coach.

Tempo Training

Practising running at race pace is very important. This was emphasized in the writings of Percy Cerruty about 40 years ago. I believe this is an undervalued area of Middle Distance training. Athletes need to regularly spend time running various distances near race pace to develop good relaxation and efficiency. The effects of this training may develop slowly (over years) and are therefore difficult to measure. Athletes often equate painful effort at training with performance improvements, so many may not automatically recognize the long-term value of relaxed tempo training. A manager of some Elite International African Athletes has shared with me that most of the training the athletes do while in Europe are various forms of relaxed tempo sessions, peak form is arrived at mostly from the specific training effects of quality racing. Most of the hard work has been done before the athletes travel to Europe.

I think for all the above methods to be successful the athlete need to set aside time to simply practice running. Ideally this needs to happen from the foundation stages of the athlete as a youngster. The ultimate goal being to develop a situation where they can “just run” without thinking about it and automatically be moving with good form and relaxation. A simple tempo session example is 6 x 200 rest 3min at 800m race pace.

Andre Bucher & Yuriy Borzakowskiy

Planning Ideas

Some thoughts on planning

I have implemented with my squad a mixture of all the above methods that varies throughout the year. It is very important to have a clearly defined off-season where basic training, implementation of new ideas and technical improvement are the priority. Our off-season training has followed variations of the structure below. (We follow 2 weeks hard 1 week easy and also use a Multi-pace training method similar to what Frank Horwill has advocated for decades.)

Monday
Morning – easy continuous run
Afternoon – Track Session
Evening – Lower Abs focus

Tuesday
Morning- easy continuous run
Mid – Theraband and Recovery activities
Afternoon- Continuous Run / Speed Ball
Evening – Swiss Ball session

Wednesday
Morning –easy continuous run
Afternoon – Track Session + Medicine Ball
Evening – Pilates

Thursday
Mid – harder continuous run
Afternoon – Main Gym + obliques/upper abs
Evening – Pilates

Friday (Recovery Day)
Morning – Swiss Ball
Afternoon – Pilates/ Recovery activities e.g. Massage/ Plunge pool etc.

Sat
Morning – easy continuous run then Swiss Ball
Mid- Track Session/Hill Session or Time Trial/Race
Afternoon- Pilates

Sun
Morning-easy continuous run
Mid – Minor Gym/Circuit Training + Theraband + Back
Afternoon- harder continuous run

Race preparation phase

The move toward being more specific involves changing the mix of training methods:
- Gym is put on maintenance mode and the focus is away from legs and onto specific arm conditioning.
- Less Plyometrics with a focus on quicker contacts and being more specific.
- Hills are phased out and replaced with use of the sled in Tempo sessions.
- Swiss Ball and Pilates less of a focus but maintained.

Foundation Training

It is exceptionally important to start at a young age with training that aims for multi-lateral development (Faccioni & Barnes; Gambetta). Having athletes simply compete in events without preparation is an opportunity to develop and practise bad habits. The other extreme is where a talented young distance runner does nothing but run volume. The goal needs to be exposing the athletes to as many different experiences in training as possible and on shaping their technique steadily as their bodies develop the qualities that are needed.

Some physiotherapists have told me that if a young athlete had done their homework and spent 3-6 years developing the muscles in the mid-torso in a variety of ways. They would then have such good function in the mid-torso that their programs would allow them to simply complete maintenance training for the rest of their career. This would allow them to focus more on developing the specifics of their event and they would have superior resilience to people who have taken short cuts.

Preparing athletes to be functioning as well as possible in partnership with a good athletics physiotherapist is likely to be critical to athlete longevity and an increased chance of the athlete getting much closer to their full potential.

800m Womens Final at Edmonton 2001

Letitia Vriesde of Surinam leads, followed by Stephanie Graf, Mutola ,Cummins obscured, Ivonne Teichmann, Holmes, Mayte Martinez and Faith Macharia.

References

Eccentric Training with Downhills
by Owen Anderson
http://www.pponline.co.uk/encyc/0009.htm

How to strengthen the lower parts of your legs, and prevent (or repair) shin-splint problems.
by O. Anderson and W. Reynolds
http://www.pponline.co.uk/encyc/0161.htm

Plantar Fasciitis Advice
by 0. Anderson & W. Reynolds
http://www.pponline.co.uk/encyc/0180.htm

Mat Workout Based on the Work of J.H. Pilates
by Denise Austin (Video)

The Preparation Phase in Steeplechase Training
by A. Belichko and V. Sirenko
Modern Athletes & Coach 35:1 p7 January 1997

Ground Contact in Distance Running
by Tony Benson
Modern Athletes & Coach 39:3 p35 July 2001

Specificity of Horizontal Jumps Performance
by Gary Bourne
Modern Athletes & Coach 33:3 p3 July 1995

Stronger Abs & Back
Dean Brittenham & Greg Brittenham (1997)

The Effects Of Dorsiflexor Fatigue On Kinetic Measures During Running
by K. Christina, S. White & J. McCrory
http://www.asb-biomech.org/NACOB98/204/index.html

The Outer Unit
by Paul Chek
New Studies in Athletics (2000) 15:2 , p52-62

Scientific Core Conditioning Course Notes
by Paul Chek (1998)

Swiss Ball Exercises for Athletes Vol 1 & 2
by Paul Chek (Video series)

Swiss Ball Exercises for Better Abs, Buns & Backs
by Paul Chek (Video series)

Speed through Strength
by Peter Coe
Athletics Today Series

Plyometrics in Middle Distances Training
by Abrie de Swardt
Modern Athletes & Coach 36:1 p31 Jan 1998

A Biomechanical Evaluation of the Role of Fatigue in Middle-Distance Running
by B.C Elliott & A.D. Roberts
Canadian Journal of Applied Sports Science 5:4 p203-207 , 1980

The Function of the Mid-torso in Sports Activities
by Adrian Faccioni
Track Coach Fall – 1995

The Use of Medicine Balls for Speed & Power Development
by Adrian Faccioni
http://www.faccioni.com/Reviews/medballtraining.htm

Young Athlete Conditioning
By Adrian Faccioni & Di Barnes
http://www.faccioni.com/lectures/juniorcondition.PDF

Electronic Roundtable The Use of the Mach Running Drills
by V.Gambetta, A. Faccioni, C. Mallett, E. Peltola, M. Ladbrook
Modern Athletes & Coach 40:1 Jan 2002 p9 -13

Fundamental Fun
By Vern Gambetta
Training & Conditioning

Leaps & Bounds
by Vern Gambetta
Sport Coach – Summer 1996

How Much Strength is Enough?
by Vern Gambetta (1997)
http://www.gambetta.com/articles/a97005.html

Leg Strength for Sport Performance
by Vern Gambetta (1997)
http://www.gambetta.com/articles/a97006.html

Anatomical and Biochemical considerations related to assessment of Pelvic Dysfunction
by Barbara Hungerford
http://www.amta.com.au/spinepain.html

Running to the Top
by Arthur Lydiard 1995

Training Distance Runners
By D. Martin & P. Coe (1991)

The Biomechanics of The arms During Running
by Megan Moreau
http://dragon.acadiau.ca/~pbaudin/meganppr.html

Explosive-strength training improves 5-km running time by improving running economy and muscle power.
by L Paavolainen, K Hakkinen, I Hamalainen, A Nummela, H Rusko
(1999) J. Appl. Physiol. 86: 1527-1533

Fundamentals of Running Movement – Clinic Notes
by Jack Pross & Toni Dickson , Oct 1994

Mechanical Properties of Muscle as Indicators of Damage and Repair from the Injury of Eccentric Exercise
by U. Proske, N. Whitehead, J. Rundell & D. Morgan
Department of Physiology, Monash University, Victoria, Australia
The Muscle symposium book of proceedings, 1999 at AIS

Development of Speed Strength in Middle Distance Running Training
by A. Polunin and G. Narskin - from Legkaya Atletika, Russia, No 1, Jan 1991
Modern Athletes & Coach 34:3 p32 Jan 1996

The Effect of Plyometric Training on Distance Running Performance
by Robert Spurrs, Aron Murphy & Mark Watsford (2002)
Human Movement Department
University of Technology , Sydney

How Olympic Champion Svetlana Masterkova Trained.
by Svetlana Storkina
Track Coach Winter 2001 p5060

Do Middle Distance Runners Need Strength
by Felix Suslov
Middle Distances Contemporary Theory. Edited by Jess Jarver p113-116

Fatigue Influenced Changes to Sprinting Technique
By V. Tupa, F. Gusenov and I. Mironenko
Modern Athletes & Coach 33:3 p7 July 1995

Effect of Foot Intrinsic Muscle Strength Training on Jump Performance
by C. Unger & M. Wooden
The Journal of Strength and Conditioning Research: Vol. 14, No. 4, pp. 373–378.

Hicham El Guerrouj's training for the 1997 season
by Marco Velediaz
http://run-down.com/guests/mv_el_guerrouj.php

Changes in Distance Running Kinematics with Fatigue
by K.R. Williams, R. Snow, C. Agruss
International Journal of Sport Biomechanics 1991:7 p138-162