RUNNING BIOMECHANICS

increase efficiency, strength & speed

A SPECIAL REPORT FROM

PEAK PERFORMANCE

The research newsletter on stamina, strength and fitness

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Introduction to Biomechanics

Most athletes have heard of biomechanics, and the importance of wearing the correct footwear to prevent injury. But what is biomechanics? And how does it affect the rest of the body and your running performance? Is there anything you, as an athlete can do to improve your biomechanics and would that add efficiency and speed to your performance? If the closest you have come to experiencing biomechanics is asking your local running shop for the correct shoe then this report will give you a wealth of knowledge on the varying levels of biomechanics and a solid foundation of training tips to build on over time. In addition, the middle section of the report is equally fascinating for the clinician or technically hungry athlete/trainer. It offers both scientific and practical information that are sure to give you long term benefits.

The term biomechanics is used in a variety of ways. Most simply, biomechanics can be translated as 'The evaluation of movement technique' (*eg* walking, running, skiing, sporting biomechanics) and it's a term often used in clinical circles. It is important to realise that you can look at the biomechanics of the body as a whole or any one part of it; *ie* foot biomechanics, shoulder biomechanics and biomechanics of the body while executing a particular movement, *eg* running, jumping or throwing.

Viewing these movements and the interconnecting segments of body parts, we can see how one affects another via a chain reaction. This is called the kinetic chain and will also be examined in the following pages. Therefore it is becoming increasingly obvious that correct biomechanics and the examination of the kinetic chain plays a *key role in both performance and in injury prevention*.

Two important methods of correction of lower limb biomechanics (which will be most relevant to runners) are the use of appropriate footwear and/or orthoses (prescriptive insoles), and the correction of poor pelvic biomechanics. Any deficiency in the pelvis or other area of the body can influence the balance of the way your body moves and will affect your sporting performance dramatically.

This key factor is emphasised in the second section of the report when ***Sean Fyfe*** in his article Beyond Three Sets of Ten. Sean encourages athletes, coaches and clinicians to think outside the box when prescribing exercises for dysfunction in any part of the kinetic chain. ***Matt Lancaster*** also contributes with some insightful strength and conditioning tips to aid biomechanical efficiency and robustness. The final word of this section is from ***Andrew van Ransburg***, who gives some useful technical and practical tips on core training to re-address the pelvic deficiency, improve your running biomechanics and style.

The POSE method of running examines the optimal biomechanical position for the body to be in when running. ***Scott Smith*** gives clear advice to help you implement as much or as little of this method into your next training sesson. Least of all it will give you an insightful resource into the optimal running position, which vertically aligns shoulders, hips and ankles with the support leg, while standing on the ball of the foot.

By touching on a handful of the excerpts from this insightful report, I am sure you can see that the biomechanical function has a profound effect on how movement patterns are controlled and compensated for during performance. With this in mind I'm sure you can utilise the knowledge and wisdom of both the scientific and practical theory from our panel of experts. We hope it becomes a vital reference tool that will keep you injury free and give you the edge over competitors to reach new limits in your running performance.

Lotty Skinner
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Distance running

From faulty movement patterns come injuries.* Raphael Brandon *goes back to first principles

Running is both a very popular com-petitive sport in its own right and a fitness activity used at all levels, from recreational gym routines to elite sports training programmes. But running requires the body to absorb continuous repeated impact forces, and running-related injuries are a common presentation in any physio-therapy or sports medicine clinic. At the extreme, elite endurance runners will probably require a weekly physio-therapy treatment, all year round, to keep their bodies healthy.

There is a complicated and highly individual interaction between intrinsic (personal) and extrinsic (environmental) factors that may contribute to a running injury. Specifically the research suggests that the biggest predictors of injury are the following two extrinsic factors:

- total volume of running undertaken;
- sudden changes in volume or intensity of running.

By contrast, research is equivocal when it comes to pinpointing specific biomechanical patterns (intrinsic factors) that cause injury. That said, it is probably safe to assume that, for a given amount of weekly running, an individual with an abnormal or inefficient running action is more likely to suffer injury than someone with good mechanics.

It is impossible to say, for instance, that all runners who over-pronate (tilt heavily inwards) at the foot will definitely suffer injury. Every runner will have a their own threshold of tolerance to the stresses of running, and it will take a unique combination of factors to tip that runner's body over the threshold and in to injury.

This article describes the bio-mechanics of running, focusing for each body part on what is considered 'normal' mechanics and then dis-cussing how deviations from that norm may increase stress on the body, and lead to injury. We are confining our scope to distance running, and therefore research from the analysis of running speeds between 12 and 16 kph (about 8 to 6 minutes per mile). The sprint action (9-10 metres per second or faster) is distinct from running at these more moderate speeds.

The running cycle

Running can be seen as a series of alternating hops from left to right leg. The ankle, knee and hip provide almost all the propulsive forces during running (apart from some upward lift from the arms). The running cycle comprises a stance phase, where one foot is in contact with the ground while the other leg is swinging, followed by a float phase where both legs are off the ground.

The other leg then makes contact with the ground while the first leg continues to swing, followed by a second float phase. At running speeds of about 6 min/mile, a single running cycle will take approx 0.7 sec, out of which each leg is only in contact with the ground for 0.22 sec. It is, not surprisingly, during the stance phase that the greatest risk of injury arises, as forces are acting on the body, muscles are active to control these forces, and joints are being loaded.

Two sub-phases of stance

The first sub-phase is between 'initial contact' (IC) and 'midstance' (MS). IC is when the foot makes the first touch with the ground. MS is when the ankle and knee are at their maximum flexion angle. This sub-phase is called the 'absorption' or sometimes the 'braking' phase. The body is going through a controlled landing; the knee and ankle flex and the foot rolls in to absorb impact forces. At this point the leg is storing elastic energy in the tendons and connective tissue within the muscles.

The second sub-phase is between MS and 'toe-off' (TO). TO is the point where the foot leaves the ground. The period between MS and TO is known as the 'propulsion' phase. The ankle, knee and hip all extend to push the body up and forward, using the recoiled elastic energy stored during the absorption phase.

This is an efficient way for the body to work. The more 'free' recoil energy it can get from the bounce of the tendons the less it has to make or to draw on from its muscle stores. Research shows that at least half of the elastic energy comes from the Achilles and foot tendons – a reminder of how important the lower leg is to running efficiency.

Ankle, knee, hip mechanics

The ankle, knee and hip motion are described in the side view (sagittal plane). At IC the ankle will be slightly dorsiflexed, around 10 degrees; the knee will be flexed at 30-40 degrees and the hip flexed at about 50 degrees relative to the trunk (a fully extended hip is at 0 degrees when the midline of the thigh and the midline of the body form a straight line through the centre of the pelvis). The further forward the trunk leans, the greater the hip flexion. Prior to IC the hip is already extending (the leg is moving backwards) and so the foot at IC is moving back towards the hips. If the gluteal-hamstrings are not actively pulling the foot backwards prior to IC, then the foot contact will be too far ahead of the hips and the braking forces on the leg are increased.

During the absorption phase the angles change. By MS the ankle dorsiflexion angle has increased to around 20 degrees and the knee has also flexed to 50-60 degrees. This ankle and knee flexion is coordinated to absorb the vertical landing forces on the body, which at distance running speeds are in the order of two to three times bodyweight.

This is where eccentric strength in the calf and quadriceps muscles is required to control the knee and ankle joints, otherwise the knee and ankle would collapse or rotate inwards. In fact the quadriceps and calf muscles are active prior to IC, and at their most active between IC and MS to help control the braking forces. The hip continues to extend through the

‘The role of the muscles therefore is to control the joint positions, creating stiffness in the leg system that allows the tendons to lengthen and then recoil.’

absorption phase of stance, reaching around 20 degrees of flexion by MS.

During the propulsion phase the ankle and knee motion is reversed. By TO the ankle is plantarflexed to around 25 degrees and the knee has re-extended to 30-40 degrees. The hip continues to move to 10 degrees of extension by TO.

Thus during the second half of the stance phase the ankle, knee and hip combine in a triple extension movement to provide propulsion upwards and forwards. The calf, quadriceps, hamstring and gluteal activity during the propulsion phase is less than during the absorption phase, because the propulsion energy comes mainly from the recoil of elastic energy stored during the first half of stance. The role of the muscles therefore is to control the joint positions, creating stiffness in the leg system that allows the tendons to lengthen and then recoil.

During the swing phase between TO and IC the knee and hip flex to maximum flexion angles of 130 degrees and 60 degrees respectively and then re-extend prior to IC, with the ankle dorsiflexing throughout swing to 10 degrees at IC. Good runners will follow these movement patterns. It is essential that the ankle and knee can quickly control the braking forces and create a stable leg system to allow the tendons to maximise their recoil power. This is where good technique is vital. Too much upward bounce will increase the landing forces, putting greater stress on the joints and requiring more muscle force to control. Runners need to learn to bounce along and not up, by taking quick, light steps.

It is also important to bring the foot back prior to IC using active hip extension as this reduces braking forces and time needed for the absorption phase. The benefits of a ‘quick contact’ and a ‘horizontal’ running style were discussed in SIB 47 (‘Beginner’s guide to pose’). Good strength in the gluteals, hamstrings, quadriceps and calf muscles will help runners achieve this.

In summary, excessive braking forces can contribute to injury. The correct movement patterns of the hip, knee and ankle combined with correct activation and strength of the major leg muscles will help control braking forces during running and result in a more efficient action using tendon elastic energy and minimising landing forces.

Pelvis and trunk mechanics

The motion of the pelvis and trunk are described in side and rear views (sagittal and frontal planes). The angle of the pelvis from the side view is called the anterior-posterior tilt (A-P tilt), with a positive angle describing a tilt down towards

the front. The trunk angle from the side is described relative to the horizontal.

At IC the trunk will be flexed forward between 5 and 10 degrees and the A-P tilt will be 15-20 degrees. During the absorption phase from IC to MS, trunk flexion increases by 2-5 degrees while the A-P tilt remains stable. This slight forward flexing of the trunk during the braking phase helps to maintain the body's forward-horizontal momentum. Gluteal-hamstrings, abdominals and erector spinae are all active to control the trunk and pelvis during the absorption phase.

During the propulsion phase the trunk re-extends to the initial position, so the trunk angle at TO will be similar to that at IC. The A-P tilt however will increase by 5-7 degrees in concert with the extension. This slight shift in the anterior tilt of the pelvis helps to direct the propulsion forces of the leg horizontally. If the pelvis were in neutral then the triple extension of ankle, knee and hip would be directed more vertically. In summary, a slight forward lean and anterior pelvic tilt is thought efficient for running. Too much forward lean may suggest that the posterior chain muscles (hamstrings-gluteal-erector spinae) are not strong enough and this may increase the strain on the hamstrings and back during the running action.

Too upright a posture may encourage vertical movement which will increase landing forces. Too much A-P tilt between IC and MS suggests that the gluteals and abdominals do not have the strength to control the pelvis adequately during landing and/or may indicate incorrect quadriceps activation and reduced hip flexibility. Excessive Anterior Posterior (A-P) tilt

‘In summary, a slight forward lean and anterior pelvic tilt is thought efficient for running. Too much forward lean may suggest that the posterior chain muscles (hamstrings-gluteal-erector spinae) are not strong enough and this may increase the strain on the hamstrings and back during the running action.’

Table 1: Stance phase in running

Sub-phase	from… to…	action
Absorption (braking)	IC (initial contact)	Foot makes first ground contact
	MS (midstance)	Ankle and heel at greatest flexion
Propulsion	MS (midstance)	Ankle and heel at greatest flexion
	TO (toe-off)	Foot leaves the ground

during the pro-pulsion phases is normally associated with tight hip flexors and inadequate range of motion during hip extension. This will reduce the power of the drive from the hip and encourage a compensatory reliance on lumbar extension.

In general, a poor trunk position or lack of pelvic stability is likely to reduce the efficiency of the running action, creating extra load on the leg muscles or increasing stress through the lumbar spine and pelvis. Any of these negative factors can increase the likelihood of injury.

From the rear view the pelvic angle is described as a lateral tilting, with a negative angle meaning the pelvis is tilted down towards the swing leg side. The trunk is described as lateral flexion with a positive angle meaning the trunk is leaning down towards the stance leg side. At IC the lateral pelvic tilt is around –5 degrees (*ie*, a small tilt downwards on the contact side). This position may increase slightly (up to 5 degrees) during the absorption phase, although ideally very little movement will occur. At faster running speeds, the lateral tilt will be bigger. Trunk lateral flexion is about 2 degrees at IC, which increases to 5 degrees at MS. This lateral flexion counterbalances the pelvic tilting.

Between MS and TO the pelvic lateral tilt should revert to +5 degrees by TO and trunk flexion should return to 0 degrees (ie vertical spine alignment). This balanced spine position allows the propulsion forces to be directed forwards at TO and the positive lateral hip angle supports the knee lift of the swing leg.

The aim of the pelvis and trunk in the frontal plane during stance phase is to be stable and provide balance. The gluteus medius muscles (abductors) are of primary importance in providing lateral stability: their contraction prior to and during the absorption phase prevents the hip from dropping down too far to the swing leg side. The muscles will be acting eccentrically (the lengthening part of a muscle contraction while performing a movement), or even iso-metrically (muscle contractions without shortening or lengthening), to prevent this movement.

An excessive or uncontrolled pelvic tilt increases the forces through the lumbar and sacroiliac joints, and forces the knee of the stance leg to internally rotate, which in turn may increase the pronation forces on the ankle. It is possible to observe a correlation between excessive pronation and excessive pelvic tilting in runners, and it is a good illustration of how one unstable link in the biomechanical chain can have an adverse knock-on effect and increase the risk of injury.

‘This rolling action (of pro-nation and supination) is normal and healthy. It is only excessive pro-nation or supination that leads to injury.’

Foot mechanics

The outwards and inwards roll of the foot during running, as seen from the rear view, are called supination and pronation. This rolling action (of pro-nation and supination) is normal and healthy. It is only excessive pro-nation or supination that leads to injury. At IC the foot is in a supinated position, with the rear foot inverted. During the absorption phase between IC and MS, the ankle is dorsiflexing which – because of the way the subtalar joint works – also causes the foot to pronate. Pronation combines rear foot eversion (when sole of the foot turns away from the medial plane) with tibial internal rotation, and allows the foot to be flexible and absorb the impact forces of landing.

At around midstance the foot begins to re-supinate. This moves the foot into a more rigid position to allow for a stronger push-off and more efficient recoil through the foot and Achilles tendon. You can feel the difference for yourself: roll your heel and ankle inwards and your foot will feel soft and flat. Then roll your heel and ankle out, and your foot should feel strong with an arch.

Pronation and supination both involve three-dimensional movements (heel eversion/inversion, ankle dorsi/plantar flexion and tibial internal/external rotation), which makes them very difficult to measure. The most commonly used approach is to measure the inversion and eversion range of motion of the rear foot during the stance phase, representing the pronation and supination movement patterns.

Inversion and eversion angles are calculated by the angle made between the midline of the calcaneus and the midline of the tibia, viewed from the rear. In normal movement, at IC the rear foot is inverted by 5-10 degrees. The maximum pronation angle will occur around MS and will be an everted position of around 10 degrees.

However, foot mechanics are highly complex and these values must be read as simply one part of the picture. Similarly, you should interpret with caution any qualitative video analysis you make of a runner's rear foot motion. Don't rush to judgement about the need for orthotics based solely on a visual reading of rear foot movement.

An excessive supinator will typically land in the inverted position and then remain inverted during the stance phase. This means that they will lose out on the shock-absorbing benefits of the normal pronation movements. Excessive supinators tend to suffer from injuries to the lateral knee and hip, and can also be prone to stress fractures, because of the higher repetitive impact forces they incur.

Excessive pronators come in three types:

- those who land inverted as normal but rotate across into an excessively everted position (such as 20 degrees);
- those who may pronate normally on landing but then stay everted throughout the stance phase;
- those who seem to pronate through a normal range but do it very rapidly.

We do not know which of these three faulty movement patterns is most likely to lead to injury, but logically all three can be problematic. If a runner spends too long in pronation, the foot will not be in a strong position to assist push-off during the propulsion phase, so the lower leg muscles will have to work harder. If the runner pronates too far or too quickly, the rotation forces acting on the tibia and knee joints may lead to problems. Excessive pronators tend to suffer from anterior knee pain, medial tibial stress syndrome, Achilles and foot soft-tissue injuries.

Upper body and arm mechanics

The main function of the upper body and arm action is to provide balance and promote efficient movement. In the forward horizontal plane the arms and trunk move to oppose the forward drive of the legs. During the braking phase (from IC to MS), the arms and trunk produce a propulsive force and during the propulsion phase (MS to TO) the arms and trunk combine to produce a braking force. This may seem a little weird, but in fact it is an advantage: the out-of-phase actions of the arms and trunk reduce the braking effect on the body and so conserve forward momentum.

In the vertical plane around the centre, the arms and upper trunk also oppose the motion of the pelvis and legs. For example, as the right knee drives up and through in front of the body – producing an anti-clockwise angular momentum – the left arm and shoulder move for-wards – creating a clockwise angular momentum and counteracting the knee motion, thereby helping to reduce rotation forces through the body during the whole gait cycle. Although the legs are much heavier than the arms, the shoulders are wider than the hips, so the arms are well positioned for their job of counterbalancing the leg rotation. This may explain why female runners use a slightly wider or rotating arm action to compensate for their narrower shoulders and lighter upper body.

The normal arm action during distance running involves shoulder extension to pull the elbow straight back; then, as the arm comes forward, the hand will move slightly across the body. The arm action has more to do with running efficiency than with injury prevention directly. A good arm action needs to be encouraged to counterbalance lower-limb forces and angular momentum, which may in turn help reduce injury. The arm action also contributes a little to the vertical lift during the propulsion phase which may help the runner to be more efficient, reducing the work done by the legs.

The relationship between biomechanics and injury is specific to each body part. Overall though, poor mechanics of any body part will either increase the landing forces acting on the body or increase the work to be done by

the muscles. Both increase the stress, which – depending on the individual and the amount of running – can become excessive and cause injury.

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Running shoe choice and foot loading during running

During running and walking, the foot and (to a lesser degree) the ankle roll inwards after foot-strike to accommodate movement, which in turn helps to reduce impact shock. This movement is a natural biomechanical process known as 'pronation'. However, excessive pronation is detrimental, causing increased loading on the foot, ankle and knee joints and increasing injury risk.

Motion control running shoes are often recommended for runners who suffer from excess pronation, but how effective are they compared to 'neutral' running shoes? In particular, how do they change the foot motion and loading forces during running? To answer this question, scientists from Hong Kong measured the changes in plantar force at the beginning and end of a 1.5km running session in 25 recreational runners wearing motion control shoes. The runners were selected so that they displayed 6 degrees or more of pronation during their normal running action. The measurements were achieved using special insole sensors to register the plantar forces during each foot-strike. They then compared the results to those obtained when the runners wore neutral running shoes.

The results showed that compared to the forces measured at the start of the run, there was no change in the magnitude and distribution pattern of plantar force with the motion control shoes at the end of the 1.5km run. However, when the runners wore the neutral shoes, there was a 15% increase in mean peak force under the medial midfoot and an 8% increase under the first metatarsal head towards the end of the running bout.

The researchers concluded that when wearing neutral running shoes, plantar forces on the medial foot structures increased with running mileage. However, this trend was not observed with the motion control shoes. They also concluded that their findings have implications for injury prevention with footwear selection for recreational runners who have more than 6 degrees of foot pronation.

Phys Ther. 2008 Feb 14 [Epub ahead of print]

Masai barefoot trainers

Paul Brice ***weighs up the evidence for a trainer that would have us walk like warriors***

Hail the latest revolution in shoe design. Celebrate the end to the mindless time consuming task of exercising and strengthening the muscles of the foot and ankle. Let Masai Barefoot Technology transform your life.

The MBT trainer has been around for 10 years, squeezing its way in alongside the vast array of training shoes in this hugely competitive and dynamic sportswear niche. Its makers claim that the shoe:

- activates neglected foot muscles
- improves posture
- tones and shapes the body
- improves performance
- helps with back, hip, leg and foot problems
- helps with joint, muscle, ligament and tendon injuries
- reduces stress on the knee and hip joints.

The international media hype around MBTs has even gone so far as to suggest that the shoes can help banish cellulite and promote weight loss – claims not far short of alchemy.

MBT is based on a simple concept: that the human foot is designed for barefoot walking on soft natural ground, yet most of us in developed countries spend our lives entrapped in supportive and restrictive footwear and walk on hard, flat surfaces. The shoe design is the brainchild of Karl Muller, a Swiss engineer, who derived his inspiration from the low injury rates of the African continent.

'Strong intrinsic foot musculature is what allows the tissues of the foot and ankle to tolerate the stresses and strains of instability effectively and without damage or injury. It is therefore not unreasonable to suggest that areas of weakness can also be prime sites of potential injury.'

Leaving aside the obvious differences between the functional requirements of the average Masai tribal member and the average office worker/amateur athlete, does this shoe design add up to anything more than a gimmick in terms of injury prevention?

There is no denying the fact that ordinary shoes do little to correct poor gait. Most of us prioritise comfort or fashion in a shoe or trainer over our specific functional or anatomical requirements, with the result that we adopt a passive gait, in which the foot, ankle and leg muscles become under-worked and develop weaknesses. Strong intrinsic foot musculature is what allows the tissues of the foot and ankle to tolerate the stresses and strains of instability effectively and without damage or injury. It is therefore not unreasonable to suggest that areas of weakness can also be prime sites of potential injury.

There is as yet no solid independent evidence that proves it is possible to strengthen specific musculature by wearing a particular type of shoe.

We can say with some confidence that where an individual has a particular foot type (pronator, supinator) involving excessive movement, the wearing of shoes/trainers that limit or restrict these movements is likely to be beneficial in limiting or reducing the risk of injury. On the other hand, shoe support can simply mask the underlying problem without tackling the weakness that may result in injury.

The MBT was originally designed as a medical shoe. It is a slightly unsightly, bulky shoe, with a substantial thick curved sole, running from anterior to posterior, which forces a pronounced heel to toe walking action. The unstable rocking action is thought to promote and stimulate the natural instability of walking over undulating ground (similar to the daily activities of the Masai tribes) and thereby encourage beneficial muscle strengthening.

To date there appear to have been three main scientific studies on the MBT trainer and its effect on gait characteristics.

The first piece of research came from the Human Performance Laboratory in Calgary, Canada. The research group studied the mechanical effects of the MBT on eight subjects, looking at their kinematic (motion), kinetic and muscular activity patterns, soft tissue vibrations and oxygen consumption during stance and walking. Most of the group's findings apply to walking only.

The MBT was shown to:

- increase rotational ankle movement, notably plantar flexion and foot inversion (particularly in the first half of ground contact)
- decrease ankle joint impulses for the knee joint, which means that the knee has to withstand fewer repetitive rotational stresses (27% reduction)
- increase the user's oxygen consumption by 2.5%
- increase movement of the 'centre of pressure' (COP) during standing, which allows force to be dissipated across a greater area of the foot. High forces going through small cross-sectional areas of the foot are strongly linked to an increase in injury incidence with repetitive foot strikes over prolonged periods.

Based on these findings, the researchers report that the MBT strengthens the intrinsic muscles of the foot and ankle complex, while reducing loading through the ankle joint. But this study had small subject numbers and conducted its analysis at relatively low walking speeds (less than 5km/hr), which limits the usefulness of its findings. We would certainly want to see more research, including a look at the impact of the MBT on a variety of foot types.

The second relevant piece of research was a gait evaluation study by a research group from Sheffield Hallam University, England. The team observed footfalls over a force platform, noting the differences in kinematic and muscular activity between normal trainers and MBT design. They found, in summary:

Kinematics

- Less forward lean: MBT promotes a more upright posture, which may affect the position of the centre of mass at foot

strike. The further the distance of the foot when making contact with the ground the greater the braking forces that occur on the body. The authors imply that the MBT reduces braking forces, which does make mechanical sense, as anything that promotes a more upright posture tends to lead to a more efficient system and reduced load through the body
- Higher dorsiflexion ankle angle: the rocker system of the shoe, based on a ridge placed across the midfoot, forces the foot into a greater dorsiflexed position throughout the gait cycle. This would promote a rolling of the foot, which would distribute forces evenly through the feet, allowing the body to absorb force quickly, without injury.

Kinetics

- Reduced 'transient peaks' with MBTs: transient forces transmitted through the skeleton as a result of impacts during normal walking and running are a primary factor in the development of many musculoskeletal disorders, such as osteoarthritis, stress fractures and plantar fasciitis (*Whittle, 1999*)

EMG

- Muscular recruitment using MBTs allowed increased activity in gastrocnemius, biceps femoris and gluteus maximus but a decrease in multifidus, perhaps because of the more upright posture and production of greater propulsive forces.

A third research group, from Edinburgh, Scotland, compared the plantar pressures during gait among 22 subjects wearing MBTs and normal trainers. For the MBTs, It found:
- reduced plantar pressure in the heel (probably the result of the MBT design in which there is no cut-away on the heel section)
- reduced peak pressure in the mid foot (21% lower) and heel (11% lower)

- average pressure was greater in the toes and forefoot and less in the mid foot and heel.
- a shift in the pattern of the centre of pressure, allowing force to be dissipated over a greater area of the foot.

People suffering with conditions such as osteoarthritis or other degenerative diseases of the bones or joints may benefit from the reduction offered by MBTs in joint loading and the heel to toe rocker.

It would not, however, be suitable for anyone involved in multi directional sports such as squash, tennis or other team sports. Because the sole design (rocker system) works only in the anterior to posterior direction, the shoe is primarily designed for 'single plane' activities such as walking or linear jogging. Moreover, the large and bulky sole unit may not be suitable for multi-directional sports where shoe feel, lightness, durability, etc are important considerations.

'Because the sole design (rocker system) works only in the anterior to posterior direction, the shoe is primarily designed for 'single plane' activities such as walking or linear jogging'

We don't yet have any research into any possible longer term benefits of MBT-type footwear. We would also need research on how the shoe design performs during faster locomotion, when the foot strike may occur further along the foot. While there are manufacturer's claims for the MBT's efficacy in relation to jogging, there is no evidence to support them. Athletes using a more pronounced mid foot or even forefoot strike with the ground will find this kind of sole design irrelevant.

The bottom line? As things stand, it would be playing safe to advise your clients never to wear their MBTs in isolation. No single piece of technology, however great the claims are, should substitute for a well structured and balanced conditioning programme that incorporates the essential components of strengthening the intrinsic foot musculature. There remain no short cuts that allow us to omit those boring foot exercises.

Beyond three sets of ten

Therapists can devise tailored progressive exercise regimes only when they understand movement principles,* Sean Fyfe *argues

Sports therapists, in my experience, tend to stick to a very limited range of rehabilitation exercises, which means that they are sometimes unable to prescribe with the kind of specificity that our clients need in order to make a full recovery that will return them to their sport and prevent a repeat of the injury. As I explain below, with an improved appreciation of mechanics, you should be able to design a far more comprehensive range of exercises, customised to the particular needs of individual clients.

At the beginning of the rehabilitation process, exercises should be simple, aimed at correct muscle activation and building up basic strength. But as athletes get further along the rehab path, they need more specific and more challenging exercises. If the athlete fails to achieve (or regain) high level training of their muscles in terms of strength, speed and type of activation, degree of muscle stretch and joint position, then they will remain susceptible to injury once they return to sport.

My own preferred approach is to start at the end. Determine an end point exercise that will convince you and your client that they are fully fit and safe to return to participation in their sport. Take into consideration not just the movement patterns involved, but also the sets and repetitions to be performed, based on the sport-specific requirement for that athlete (power, endurance, sustained speed, *etc*).

The kinetic chain is the key

Whatever your choice of exercise goal, it will involve a ‘kinetic chain’. The kinetic chain, in one useful definition, is:

'a coordinated sequencing of activation, mobilisation, and stabilisation of body segments to produce an athletic activity'[1]

All kinetic chain movements will be either 'open' or 'closed'. We call them open chain when there is free movement at the end of the performed movement/exercise; and closed when there is minimal movement at the end of the chain of movement or exercise performed. Many athletic activities, such as a javelin throw, involve both closed- and open-chain movements: the legs push against the ground (closed chain) and the arm throws into free space (open chain). Kinetic chain sequencing achieves three objectives, all of which need to be kept in mind when the therapist is designing a rehab regime:

Focused power: Efficient generation and transfer of energy and force to the end section in the chain to move an object.[1]

Joint control against damaging forces: Stabilisation and positioning of the body segments and joints (in the chain) to help absorb the forces at the joints.[2]

A stable base for action: 'Stabilisation of body posture to counteract the loads and destabilising effects of the athletic movements.'[3]

From here you can work backwards. For your selected end-point exercise, break the kinetic chain into its components and assess which element(s) you believe are breaking down. Isolate the individual component(s): this is your starting point, getting the client to retrain their muscular activation and control. As you progress the exercise programme, you will gradually add back in the components of the kinetic chain, and then train them under increasing load. As an example I have included a spinters case study.

The sprinter

A young female sprinter is suffering from left-sided low back and upper gluteal pain. Briefly, assessment reveals left side hip/pelvis rotation and poor movement, as well as stiffness in her lower spine. Functionally, discomfort is reproduced in repetitive single-leg jumping in a straight line. So this can be the exercise we select as our end-point goal: five sets of eight maximal single-leg jumps in a straight line.

After considering what occurs in this kinetic chain and testing the components of the chain, I identify the main problem as poor activation and strength in gluteus maximus. The hamstring and erector spinae muscles are over-activating and the lack of glute activation is causing poor stability through the sacroiliac joint (SIJ).

The first step of the exercise rehabilitation programme is to isolate and retrain the failing component. A great way to achieve this is prone (lying on your front) hip extension, beginning with glute activation and then extending the hip with neutral spine stabilisation. The sprinter can progress to single-leg squatting while concentrating on squeezing the glute and maintaining a neutral spine. This in turn can be progressed by deepening the squat and adding resistance (weights).

The eccentric component of the jumping can be trained by jumping down from a step and absorbing the shock by bending through the hip and knee, keeping a neutral spine. The glute should be squeezed just prior to landing. After that, we can begin single-leg jumping exercises on the spot, concentrating on neutral spine, glute activation and lower limb alignment. At first, jump height should be kept to a minimum, increasing gradually. The athlete should land and balance before jumping again, until they have achieved maximum jump height with good control and posture. Jumps should then be done continuously, followed by forward, backward and sideways movement. I find it very helpful for clients to perform these types of exercises in front of a mirror. Gradually our aim of five sets of eight maximal single leg jumps in a straight line is achieved.

Conclusion

What matters is the therapist's and ideally the athletes understanding of the elements of the kinetic chain you are trying to fix, and how to approach the rehab programme. Once you have clarified that, you can be as creative as you like with your rehab equipment and exercise. Indeed you have to be, especially if you are working to return high level athletes to performance fitness.

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Injury prevention – taking a robust approach to running

There's more to reducing the risk of sustaining a running injury than incorporating a couple of stretches and the odd weights session into your training routine. As* Matt Lancaster *explains, a structured approach to build 'running robustness' is a much better approach…

Oscar Pistorius is able to run 400 metres in less than 47 seconds. While this does not mark him as a serious medal contender, his determination to compete in the Beijing Olympics has become a big story in athletics. However a recent announcement by the IAAF ruled that he would not be allowed to do so. Pistorius was born without fibulas (the smaller of the two bones which form the lower part of the leg) and he has never walked without the aid of prosthetic limbs. He began running competitively in 2003 and after winning the 200 metres at the Athens Paralympic Games, turned his attention to competing against able bodied athletes.

The IAAF ruling was based on an investigation by Professor Gert-Peter Brueggemann, and concluded that an athlete using the carbon fibre prosthetic blades has a more than 30 percent mechanical advantage over an athlete not using the blades. Once Pistorius reached a certain stride the blades, known as Cheetahs, behaved like stiff springs and he was able to run at the same speed as able-bodied runners using about 25% less energy. However, Pistorius' prosthetist Trevor Brauckmann has argued that the athlete still has to produce the energy to propel the blades and Pistorius has appealed against the ruling.

The IAAF decision and Braukmann's defence of the Cheetahs tell us a great deal about both the fundamentals of running mechanics and the stresses which running places on the human body. This article draws together key aspects of running mechanics and the principles of biological robustness to explore practical ways in which you can adapt your own training to minimise the stresses and strains on your body.

Running mechanics

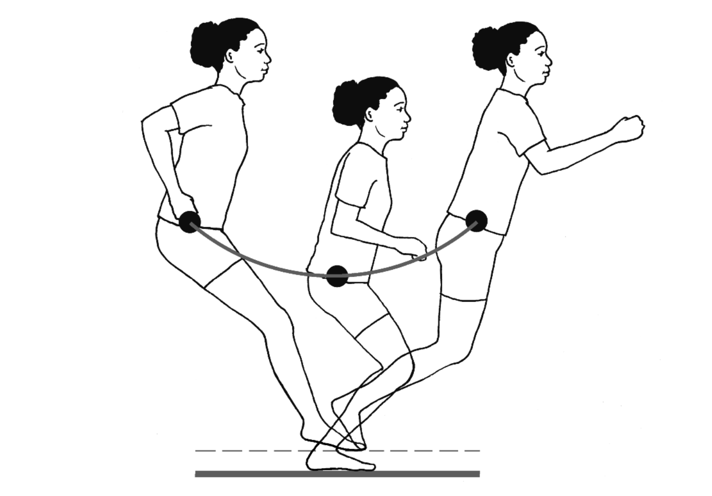
Locomotion requires us to propel ourselves forwards, while at the same time counteracting the force of gravity, which is constantly pushing us down[1]. In order to overcome this gravitational force, we have to push down into the ground with each foot strike, and (as anyone who recalls high school physics will know), if we are transmitting a force into the ground, an equal and opposite force is returning through our feet and ankles. This force is called a *ground reaction force* (GrF).

When you run, vertical GrFs can exceed three times your body weight, depending on your mass and the speed you run at[2,3]. In order to move forward, we simultaneously pull our leg backwards beneath our torso, creating a horizontal GrF. The amount of muscle activity and force production required to do this increases as we run faster[4]. This muscular action, along with the impact of GrFs, produces a considerable amount of stress and strain, which our tissues have to absorb if we are to avoid injury.

So, how do we accommodate these stresses while at the same time propelling ourselves upwards and forwards? Well, like Oscar Pistorius, we have springs too, only instead of being made of carbon-fibre they are composed of a complex system of muscles, tendons, ligaments and other connective tissues[5].

In simple terms, when your foot strikes the ground you absorb and dissipate energy by lowering your centre of mass (*compression*) before generating energy to extend the leg and propel us up and forward (*recoil*)[5]. In this way, energy is constantly stored (largely within the tendons) and recycled using a mechanism known in biomechanics as the spring-mass model (*see figure 1*)[3].

Figure 1: Compression and recoil of the 'spring-mass model'



However, running is not quite as straightforward as this. In addition to moving forward, up and down we also shift from side to side while our limbs and torso rotate. There are three reasons for this. Firstly, our joints are shaped irregularly and are neither perfect hinges nor spheres, meaning our movement has to occur in multiple planes. Secondly, these sideways and twisting movements help absorb GrF (Braukmann makes the case that as Pistorius does not have feet or ankle joints there is increased shock through his stumps into his knees, hips and back). And finally, if we tried to run without shifting our centre of mass from side to side, we'd almost certainly fall over! The primary purpose of running is to move forwards, but our body is subjected to stresses and strains acting in every possible direction.

Biological robustness

Biological robustness describes the ability of a biological system to maintain its core function in the face of stresses and uncertainty occurring within the system or its environment[6,7]. Another way to consider this may be to think of an organism continuing to perform despite ongoing changes and adaptations in either its components or surroundings[8]. If the organism can't adapt successfully, then disease or injury may follow[9].

Thinking about biological systems in this way draws on the principles underpinning a branch of science called *complexity*. Complex systems, such as our nervous system, circulatory system or indeed the entire human body, consist of a large number of components interacting together. Crucially, the overall function cannot be explained by examining the components alone[6,8,9]. Put simply, the performance of a complex system is greater than its parts. For instance, a function as basic as running cannot be described simply by studying anatomy.

Developing running robustness

There is no simple or sure-fire way to avoid injury, but if we combine our basic understanding of running mechanics with the principles of biological robustness, it may give us an insight into how we can structure our training to help reduce the risk of injury. The remainder of this article considers different forms of training in relation to both a specific training goal and a robustness goal. Training types and goals are summarised in table 1 below:

Table 1: Training and robustness goals

Training type	Training goal	Robustness goal
Strength	Specific tissue capacity	Enhanced modularity
Conditioning	Non-specific tissue capacity	Diminished fragility
Coordination	Skill	Enhanced system control
Running	Specific performance adaptation	Environmental buffering

Strength and modularity

Far from a single sprung structure, the human leg has three segments acting around joints – the ankle, knee and hip – which combine to produce the overall biomechanics required for running[10]. We can consider each of these segments a separate *module* able to absorb energy, primarily around the knee and ankle, and then produce a rapid propulsive force, which is supplemented by the recoil of the springs. Within this modular architecture, the calf, thigh (quadriceps and rectus femoris) and hip extensors (gluteal and hamstring muscles) are the key running muscles[1, 10].

In biological systems, each individual module must meet the stress demands placed upon it to ensure robustness[6]. Modules need to have a recovery capacity to repeat their function, which probably means that even for power-based athletes, developing local endurance properties over a period of time is important.

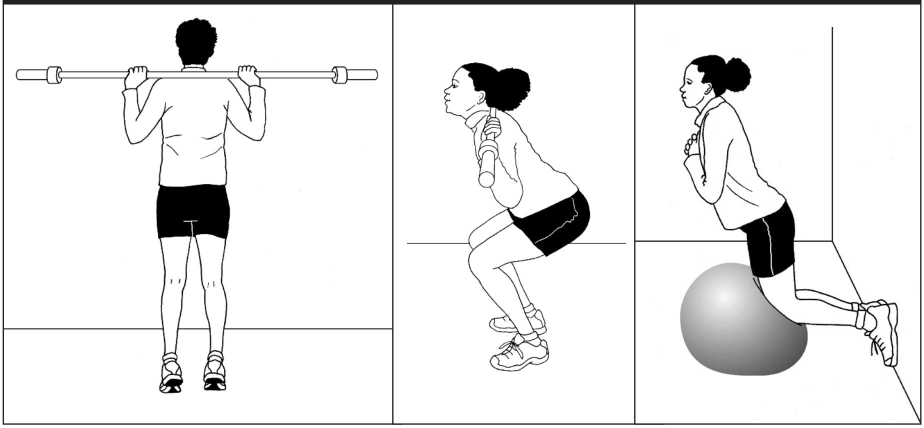
Interaction between modules, including their relative stiffness, also determines the distribution of stresses between the hip, knee and ankle joints[10]. A module with poor capacity may increase the stress demands placed on a neighbouring module. Finally, a strong modular structure can help contain excessive stress or local damage, minimising the effects of injury on the whole system[6].

Strength training is ideally suited to increasing the specific capacity of these modules to meet the demands of running. Working against resistance, whether gravity or weight training, can be an effective method for improving the capacity of muscle-tendon units to absorb and produce force. Progression of strength exercises is usually aimed at developing more of a specific capacity, while training phases often follow a similar series progression: first endurance, then strength and then power. Examples of strength exercises for key running muscle groups are shown in figure 2.

Conditioning and fragility

There is a price to be paid for developing specific robustness, and it goes some way to explaining how highly trained athletes can still be susceptible to injury. As training and strength progress we become increasingly adapted to the stimulus our body expects. However, high levels of adaptation to a familiar stress may conversely leave you potentially fragile to an unexpected stress. And as the highly adaptable and complex being that you are, it is often tiny unexpected stresses that may prove catastrophic. This is referred to as the *robustness-fragility trade off*[6,7,8].

Figure 2: Strength exercises for key running muscles: calf raise, squat and Nordic hamstring curl



A simple way to counteract this fragility is to increase the variety of stresses your tissues are conditioned to. Conditioning training is less concerned with the specific mechanics of running than strength training. Of course, if your primary sport is running, there is little to be gained from conditioning your body to stresses as divergent as those encountered in judo or rugby. However, conditioning your body to a range of stresses that are somewhat broader than the very specific adaptations gained from running and strength training may be advantageous.

Rather than progressing repetitions or resistance of a small selection of strength exercises, the key progression here is adaptation to a wider variety of moderate stresses. This means choosing exercises that stress trunk and leg tissues in particular (*see figure 3*), utilising a spectrum of resistance levels and joint ranges, as well as providing multidirectional tissue challenges.

And don't get stuck in the rut of repeating the same exercises for months at a time; adapt and then change. Remember, the goal is not necessarily to make each exercise progressively harder, but to expose tissues to a broader range of stresses than they are subject to when running. Building your condition and minimising your fragility may take time. This sort of conditioning is ideally suited to circuit training.

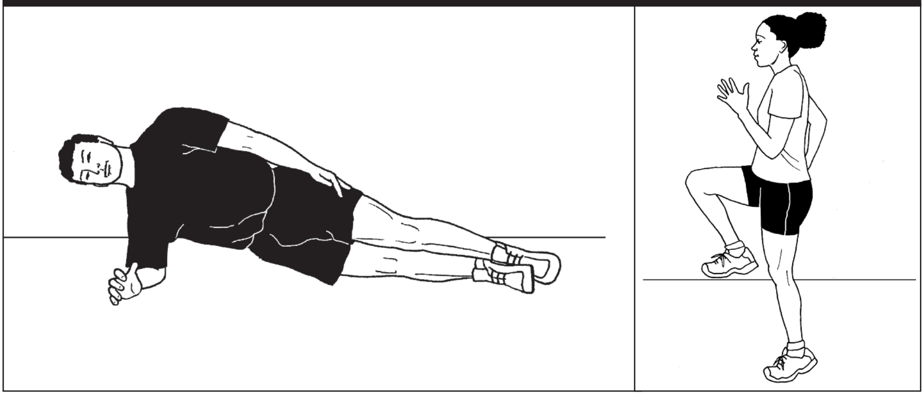
Coordination and system control

Within all biological systems, some form of control is essential to achieve a robust response to a particular stress (6). In humans, this control is provided by our nervous system and manifests itself as coordination. Within a complex biological system, coordination requires the mastering of all the possible movements available to us into a controllable movement pattern, such as running or jumping.

Skill involves ensuring this temporary movement pattern is resistant to any environmental stresses that may challenge its stability, and is therefore probably vital for us in developing robustness[11]. Regulating modules or utilising slightly different strategies to overcome unexpected stresses requires sophisticated orchestration[6]. Traditionally, theories concerning movement control have considered particular movement characteristics to be stored within our central nervous system, ultimately leading to control and limited variation when we perform a particular skill.

However, consider what happens when we run on different surfaces. If our leg stiffness were always the same then our vertical rise and fall would be greater when we ran on a soft, compliant surface. But biomechanical experiments suggest that we actually adjust our leg stiffness quite quickly (possibly within a single step!) depending on the compliance of the surface.

Figure 3: Examples of basic conditioning and coordination exercises: side plank and high knee running drill



In other words, our legs become stiffer and compress less when we run on a soft surface to allow us to maintain a steady running pattern[3].

Likewise, wearing footwear may influence our stiffness and it appears that our muscle activity is tuned to control tissue stress depending on GrFs[5,12]. Far from a single movement pattern, there is constant variability in even a seemingly repetitive skill such as running. This requires coordination and it is possible that the challenge is greater still for an amputee athlete like Pistorius who does not have feedback from the feet and ankles to assist.

So how should we incorporate coordination challenges into training? Firstly, aim to perform all training components (strength, conditioning and running) with skill. The central nervous system coordinates the activity of many muscles, tendons and ligaments to set the overall 'spring' characteristic of running, while strength training is redundant without highly developed motor control, involving appropriate timing of movements for effective force production[3,4].

Secondly, while making a conscious effort to move well, we also need to address fragility by introducing a 'bandwidth of variability' in the way we run or exercise and challenge our coordination to accommodate this variability – ie taking ourselves outside our coordination comfort zone. Running drills can be an effective way of achieving this. There are too many drills to attempt to describe here, but rehearsing components of the running action and then adding variety – speed, direction, range, rhythm – is a good place to start.

Thirdly, general coordination activities that relate to running mechanics are also helpful. Skipping with a rope or simple hopping activities, such as playing hopscotch, are examples. Base the progression on the quality and breadth of your skill. Coordination will be involved in all aspects of your training but take time to challenge and develop it further.

Environmental buffering

If you want to guarantee you don't get hurt as a result of running, don't run. But if you do want to run while minimising the risk of injury, run smart. The volume, intensity, gradient and terrain of any training should be consistent with your capacity to cope with the stress. And here lies the inherent risk of running; in order to adapt and improve our performance, we have to expose ourselves to progressive new stresses.

Nothing enhances running robustness like running. Indeed tissues such as tendons undergo greater adaptation in response to running than other forms of exercise[13]. This underpins both environmental buffering and the basis of successful coaching; it's not the overall volume or intensity of a running program that necessarily provides the risk, but the rate of progression and the time allowed for adaptation to significant new stresses. Don't be afraid to take things slowly in order to run faster.

Even a sensible training progression will not guarantee your protection from the small variations you may face however. By now you should be able to draw your own conclusions about how you may achieve this. Subtle variation and exposure to a slightly wider range of stresses will allow broader adaptation.

For example, based on changes in GrF and required leg stiffness, making an absolute transition from purely grass running to running only on the road is probably unwise.

However, a well-balanced programme incorporating components of each may provide safe but challenging exposure to a range of stresses.

On the same basis, manipulating your running form for short periods in a controlled and skilful way could subtly broaden tissue exposure and coordination challenges. For instance, in addition to running drills, practice over or under striding, exaggerating your pelvis and hip rotation or running without any arm swing. Make measured, sensible adaptations to your training plan but within that plan train with a degree of variability.

A final word

Developing robustness requires resources, including energy and time. Going to the gym, developing a broad conditioning base and performing coordination drills may leave you less fragile, but it may also detract from the time and energy you have for running. Sacrificing too much of your running time at the expense of less specific training may leave you less adapted to the demands of running itself. And in terms of performance, it is probably your specific robustness that is most relevant. You can never remove the risk of injury completely (genetics probably has a say in this(14)), but planning and performing your training well may reduce the risk.

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Why core training works

Andrew van Rensburg ***reviews the evidence for improving stability control***

It is almost impossible to work in a sports-therapy role these days without being involved with some aspect of core conditioning and core strength work. But how sure can we be that there is benefit to be gained from targeted retraining to strengthen stability muscles? Are we all in the grip of a long-running fitness fad, or does the evidence support the notion of specific retraining to optimise performance and wellbeing, whether that be for elite athletes, happy amateurs or desk workers keen to keep fit?

Anatomy revisited

Let us recap some basic core anatomy and what the research can tell us about the way core muscles work. The human spine, devoid of its musculature, is inherently unstable: a fresh cadaveric spine (of a corpse) without muscle can sustain a load of 1kg to 2kg before it buckles. So musculature plays an important role in stabilising the spine; it is no coincidence that clients with lower back pain often also have poor posture and weak lumbar spine stability mechanisms.

Divided according to anatomical, biomechanical and physiological features, we can classify muscles into two groups:

- *stabilisers*
- *mobilisers*

The stabilisers are structurally and functionally better equipped for postural holding, with an 'anti-gravity' function (they are intended to be activated while the body is upright). The mobilisers, often called 'task-oriented' muscles, are better set up for rapid dynamic movements.

We can sub-divide the stability muscles into primary and secondary. Primary stabilisers cannot create significant joint movement, so act only to stabilise. The secondary stabilisers have excellent holding capacity, but can also move joints; this group includes the internal oblique, pelvic floor and deep psoas muscles.

Even the mobiliser muscles can play a stabilising role in times of extreme need. In the presence of pain, for instance, the response of the postural muscles is to tighten and become inhibited, phasic muscles weaken, and the mobilisers go into spasm as a way of protecting the joint. The pain and spasm cycle must be broken before any strength-based rehabilitation can take place.

Stability and movement

Research has shown that when we move, the abdominal muscles contract before the agonist limb muscles. Some researchers have suggested the abdominals are preparing the body for unexpected disturbance by reactive forces that may result from limb movement.

TVA (transverse abdominis) does not only contract in anticipation of limb movement[1], it is also the first muscle to contract during trunk movement, supporting the idea of its role as a *primary stabiliser of the spine*. It contracts continuously during lumbar extension and flexion.

So, if the TVA is designed to work so much, why would this muscle be weak in so many people?

Research has found that people with chronic lower back pain seem to suffer a timing delay in which the TVA fails to contract prior to the initiation of arm or leg movement[2]. There is a compensation which overrides the normal timing of TVA activation, and allows large, strong mobiliser muscles to dominate movement patterns. The subtlety of these timing delays means that most people will not necessarily realise there is anything going wrong.

The major culprits of compensation are rectus abdominis, quadratus lumborum and erector spinae. These three muscles together dominate flexion, lateral flexion and extension of the trunk.

From our understanding of these key stability functions, it follows that a comprehensive stability programme will need to focus on TVA and multifidus, as both are needed to have a strong, well-balanced core and biomechanically correct postural alignment.

Body control and awareness

Concentrated strength of the trunk and spinal stabilisers is not functional if it does not fit in with the relevant movement pattern it has been designed to improve. In the real world, clients can be 'strengthening' TVA in their weekly hour-long stability sessions, be it Pilates or dynamic swiss ball exercises, and then throw it all away when they return to work, to sit in a crouched position for hours on end. Their efforts in the core strengthening session will have been quite literally worthless, as there is no functional use of the core strength they have been working to achieve.

The sports therapist therefore plays an important role in raising their client's body awareness during rehab, so the client or athlete can learn to identify poor positioning and movement and correct themselves when postural irregularities occur. There is absolutely no guarantee that a client or athlete will readily understand and accept the need for improved body control through core strength. Once the client or athlete has achieved predominantly pain free range of movement, the thought process goes out the window and old patterns of movement dominate again, allowing global muscles to regain power. Should this happen, statistics show that these clients will be knocking on the therapist's door with a similar or more severe pain within 18 months[3]. We should never underestimate the power of habits that people have lived in for years and which feel completely normal; unless they are given a new heightened body awareness, they will fall back into the old familiar patterns.

‘therapists should focus on strengthening specific movement patterns that promote optimal use of stabiliser muscle groups, rather than attempting to train individual muscles’

Athletes are no less likely than anyone else to backslide. But their need for good biomechanical alignment and core strength is far greater than average. As their sporting focus will predominantly be on the activity at hand, and not on posture, there is an even bigger responsibility on the support team to ensure their preparation is sound.

How does one go about increasing body awareness? There are many different views and techniques. My personal opinion is that therapists should focus on strengthening specific movement patterns that promote optimal use of stabiliser muscle groups, rather than attempting to train individual muscles. These movement patterns should be strengthened using a variety of exercises that lead towards a functional outcome.

An example is the use of ‘table-top’, a Pilates position in which the hips and knees are flexed to 90 degrees while the client lies supine. This position mimics the body sitting in a chair, but without the gravitational pull on the upper body and with a negative feedback system which can help them correct their posture. The negative feedback system is the position of the torso on the floor: if the shoulders are protruding or lifting away from the floor, the client lying in supine can learn to feel the postural fault and correct their positioning. This continuous re-evaluation of body position will over time allow the client to correct themselves in everyday situations or sport-specific movements.The key to a successful outcome lies in a mental focus on body awareness and a physical focus on stabilisation and muscle strength. The client who understands their own body movements will strengthen quickly and rehabilitate well.

Stability programming

A four-stage stability programme would include:

Stage 1:

Isolate and understand the muscles of the inner unit.

Train the muscles of the inner unit.

Stage 2:

Isolate the muscles of the outer unit, while maintaining control of the inner unit.

Isolate specific muscles of the outer unit (correct poor movement patterns).
Decrease the base of support and increase load.

Stage 3:
Control movement through the lumbar spine and pelvic girdle while maintaining inner unit control.

Stage 4:
Maintain stability with high-speed motion and functional activities.

'The key to a successful outcome lies in a mental focus on body awareness and a physical focus on stabilisation and muscle strength. The client who understands their own body movements will strengthen quickly and rehabilitate well'.

Core strength, athletes and performance

Core training is not a quick fix, nor the answer to all performance questions. It is an effective training and development tool which, when used intelligently in a well designed and managed programme, can provide the athlete with a performance edge.

John Carew, coach to Australia's distance swimming legend Kieren Perkins has put it this way: 'Create a platform, then perform off the platform.' I like to think of it thus: 'Power is nothing without control.'

By strengthening the core trunk muscles, we are, in effect, improving the efficiency with which sporting movements are carried out. Up to a 10% increase in efficiency has been noted in top swimmers[4]. A 10% improvement in an elite athlete is a massive achievement – one that could take years of strength training and technique modification to achieve. And all this can be achieved by a process as simple as allowing the correct muscles to carry out the correct tasks, without compensation.

‘The key to a successful outcome lies in a mental focus on body awareness and a physical focus on stabilisation and muscle strength. The client who understands their own body movements will strengthen quickly and rehabilitate well’

Train stability for specificity

Core exercises must train the core to be strong and stable in the positions and movements required for each sport.

'Running is the most unsupported of all sports. Any collapse of form causes energy loss, increased fatigue, reduced economy and impaired performance'

Swimmers, for example, are able to benefit from strong core stabilisers, as the competition position is either in prone (on their front) or supine (on their back) with spine straight and body extended. A swimmer's greatest nemesis is the drag force of the water. Top swimmers use 90% of their total energy expenditure to maintain body position and overcome the resistance of the water, leaving them approximately 10% to devote to the all-important task of forward propulsion. Less accomplished swimmers can need as much as 98% of their energy to maintain body position, leaving just 2% for forward propulsion. To be able to control your position in space using stabilisers while your global muscles power you to the other end of the pool is clearly an exceptionally advantageous arrangement.

Running is the most unsupported of all sports. Only one foot is ever briefly in a position of support without any other points of contact. The forces being applied to the surface are at least body weight and often as much as eight times that amount(5). In order for power to be harnessed, stored and returned in the form of elastic energy, the body needs to retain form and balance throughout that moment of foot strike. Any collapse of form causes energy loss, increased fatigue, reduced economy and impaired performance.

Runners need to maintain their form and balance as they stride, and using core stability they become more efficient in their movement pattern: the strong local stabilisers enable the global muscles to be recruited for the sole purpose of movement and not for stabilising the trunk and hips.

Raising the game

A six-phase performance facilitation protocol was devised by Richard Sutton, a kinesiologist (a scienctist of human movement) who works with tennis players on the ATP tour(6). Notice the emphasis on static and dynamic stability creating a platform from which the athlete can work. This protocol can be used both in building athletes and for post-injury rehabilitation.

The six interwoven phases of performance facilitation:

Core benefits for athletes

Consequences of core weakness:

- More chance of injury due to poor technique and lack of stabilisation.
- Less efficient movement, therefore an inability to perform skills correctly.
- Less endurance.
- Lower power output.

Potential benefits of core strength:

- Improved efficiency of movement.
- Improved power.
- Injury prevention.
- Improved endurance (postural muscles are primarily aerobic).
- Improved technique and performance.

1. Proper evaluation, flexibility, optimise joint mobility, muscle balance, neuromuscular isolation.
2. Continue the improvement of muscle balance, static stability, balance and reflex training, movement skill, neuromuscular isolation.
3. Improve movement skill, neuromuscular coordination, aerobic endurance, dynamic stability.
4. Improve functional strength, aerobic endurance, reactive strength, sport-specific muscle movements.
5. Functional power, reactive strength, specific endurance, prehabilitation.
6. Functional power, speed, reactive strength, prehabilitation.

One argument raised against core training for athletic performance is that the exercises and strengthening routines are rarely performed at the same speeds or subject to the same accelerations and loads as athletes experience in actual high performance competitions. The reality is that core strength for athletes is preparatory for a solid platform of movement, but it is very likely that current core strength protocols are not maximising athletic potential for gains in performance efficiency.

'An overall strength and conditioning programme needs to include mobility, flexibility, technical quality and core stability'

More research needs to be carried out in this field to enable athletes to become even more specific in their core stability training – within the bounds of safety, of course. Nevertheless, core strength training will still generate benefits for any athlete prepared to put some time and effort into the process.

Conclusion

Core stability is a valuable tool for rehabilitation and performance enhancement, provided the movement patterns are biomechanically efficient and improve functional movement. Along with core stability, athletes need to be able to maintain and develop other key aspects of performance – just adding a core routine and expecting miracles is not realistic. An overall strength and conditioning programme needs to include mobility, flexibility, technical quality and core stability.

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Lower limb training to raise your game

Think about the physical requirements of a sprinter in full flow, and its the powerful thigh muscles that invariably come to mind. But as* John Shepherd *explains, neglecting lower limb training not only increases the risk of injury, but also limits an athlete's potential to maximise athletic power and injury avoidance.

The main muscles below the knee are the two calf muscles, the larger gastrocnemius and the smaller soleus. Both contribute to ankle extension. Gastrocnemius is the larger of the two and resides on the outer portion of the lower leg, while soleus is smaller and is positioned to the inside.

The calf muscles interact with the ankle joint through a myriad of smaller muscles that stabilise and control the movement of this joint and the foot. Crucial in this lower limb soft tissue movement chain is the Achilles tendon. This band of soft tissue connects the heel bone to the calf muscles. It acts as a kind of cable that 'pulls' on the heel, through the action of the calf muscles, to create ankle movement. It also has a crucial shock absorption role, which can significantly contribute toward the development of the type of athletic power needed for running, jumping and agility movements (more later).

To the front of the lower legs, running over and around the shin, is further soft tissue that also stabilises and controls ankle and foot movement. This includes the muscle peroneus longus and tendons, such as the extensor hallucis longus. The foot structure contains over 100 muscles, ligaments and tendons and 24 bones. As we'll see later, it too can contribute significantly to athletic power, balance and stability.

The action of lower legs in walking, running and sprinting

Walking

Researchers from California have spent some time analysing the role of the main lower leg muscles involved in walking[1]. The team examined the individual contributions of the gastrocnemius and soleus muscles at a walking speed of 1.5 metres per second. At any instant in the gait cycle (the walking or running action), the work required by these muscles to support the body and move it forward was defined by its contribution to the trunk's vertical and horizontal velocity, and its contribution to moving the legs forward during the swing phase of the gait cycle.

The stance phase occurs when one foot is on the ground and the other is swinging forward (the swing phase) in preparation for the next foot strike (ground contact) and ensuing stance phase. During the stance phase the body is normally held in an upright position.

For lower leg muscles, the researchers found that the gastrocnemius and soleus provided trunk support during the single-leg stance and pre-swing phases of the walking action. As the body moves forward into early single-leg stance, the muscles accelerate the trunk vertically but decelerate forward progression of the trunk. In mid-single-leg stance, the gastrocnemius delivers energy to the leg, while the soleus decelerates it.

However, these functions are reversed in the action on the trunk. In the late single-leg stance, just prior to the foot leaving the ground, both major calf muscles perform a concentric muscular contraction as they accelerate the trunk forward while decelerating the downward motion of the trunk (basically they act to prevent the ankle collapsing back to the floor). However, the soleus acts to accelerate the trunk forward, while the gastrocnemius delivers almost all its energy to accelerate the leg to initiate its swing.

Running/sprinting

The action of the lower leg muscles is very similar during running/sprinting, although the hip muscles play a far greater role in generating speed in terms of the upper legs[2]. Sprinting also involves far greater impact forces than walking (up to three times body weight) even though the foot may only be in contact with the ground for around 0.8 seconds for an elite sprinter. During the foot strike, pre- and mid-stance phases, the calf muscles have to absorb this force, before contributing to pushing the athlete forward into the next stride, whilst stabilising the trunk. This is akin to walking, but with a far greater shock absorbency requirement.

The calf muscles work with the Achilles tendon to absorb and return this force. This is achieved by lengthening as they contract (eccentric muscular contraction). Sports scientists refer to this muscular action during sprinting as requiring considerable 'joint stiffness'. Reduced stiffness is seen to impair speed generation. Think of it like a pogo stick made of jelly, rather than one made from very resilient rubber; the latter will of course return much more energy than the former. In fact, sports scientists argue that, during sprinting, the prime role of the ankle (and knee) is to create high joint stiffness before and during the contact phase, while the hip flexors (muscles at the tops of the thighs) function as the prime forward movers of the body[3].

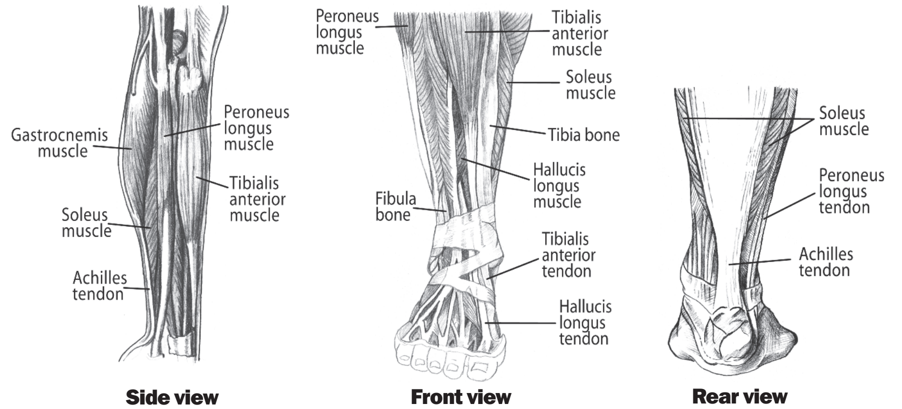
It's during the foot-strike phase of the sprinting/running action that calf muscles (and even more commonly) Achilles tendons, can be strained. Conditioning the lower limbs to accept greater eccentric strength can reduce injury potential and improve performance by increasing 'stiffness' (more later).

Reducing injury through lower limb strengthening

There are a multitude of exercises that can be used to strengthen the lower limbs (examples of which are given below), but how effective are they?

A Norwegian study looked at how ankle and knee injuries could be reduced in teenage handball players during the 2002-03 season[4]; 1,837 players were split into an intervention group and a control group. The intervention group performed exercises designed to improve awareness and control of the ankles and knees during standing, running, cutting, jumping,

Major lower leg and foot structures



and landing. The exercises included those with a ball, the use of wobble boards and covered warm-up, sport technique, balance and strength. The control group continued with their normal training methods. The main results were as follows:

- For the group as a whole, 262 players (14%) were injured at least once during the season;
- The intervention group had lower risks than the control group when it came to sustaining acute knee or ankle injuries;
- The incidence of moderate and major injuries (defined as absence from play for 8 to 21 days) was also lower for the intervention group for all injury types.

The researchers concluded that, 'the rate of acute knee and ankle injuries and all injuries to young handball players was reduced by half when players followed a structured programme designed to improve knee and ankle control during play.'

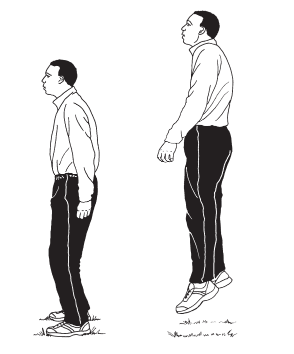
Lower limb strengthening exercises

Straight-leg jumps

Stand with your feet slightly beyond shoulder width apart. Swing your arms back behind your body and very slightly bend your knees. Swing your arms down, as they pass your hips jump into the air, using your calf muscles and ankles to provide most of the power. Land without undue yielding (in order to increase joint stiffness and improve eccentric force absorption) and spring immediately back into another jump.

Suggested routine: 3x10 exercises with 1-minute recovery between sets.

Straight-leg jumps



Eccentric calf raises

Eccentric calf raises have been identified as being as effective at combating and treating the majority of Achilles tendon injuries as other treatments, including surgery. When performing this exercise, concentrate on the lowering phase of the movement, lowering to a count of 4 and lifting to a count of 1. To gain familiarity, select a medium to heavy weight that creates fatigue after 8-10 repetitions, before progressing to heavier weights that create fatigue after 4-6 repetitions. Use a standard calf raise machine. After gaining familiarity and strength with this exercise, perform freestanding versions from a double- and then eventually from a single-leg stance, using similar loads and repetitions.

NB. Standing calf raise exercises target the gastrocnemius, while seated calf exercises hit the soleus. To fully strengthen the main calf muscles combine both exercises in your training programme.

Foot and toe strengthening exercises

Toe clawing

To perform this exercise stand barefoot on carpet. Scrunch the toes of one foot and try to claw/pull yourself forward. Persevere, as you will be able to achieve some forward movement in time. Once mastered continue to pull yourself forward with your toes, using each foot in an alternate fashion.

Even toes matter!

As indicated earlier, the foot, and even toes, can influence running power. A team from Canada studied the energy contribution of the big toe or metatarsophalangeal (MP) joint when running and sprinting[5]. The team wanted to discover what the contribution of the MP joint was to the total mechanical energy involved in running and sprinting. Data was collected from ten trained male athletes (five runners and five sprinters).

The team discovered that during the stance phase, the joint absorbed large amounts of energy during running and sprinting. In terms of biomechanics this led them to conclude that lack of plantar flexion (toe-down position) of the MP joint resulted in a lack of energy generation during take-off; energy was absorbed at the joint and dissipated in the shoe and foot structures and was not returned to propel the athlete forward. Although it would be physically difficult to specifically train the big toe to contribute more to the sprint and running action, concentrating on a more active push off from the forefoot through the toes could allow the MP joint to generate more propulsive force.

Performing sprint drills/running barefoot

Olympic medallists Roger Black (400m) and Jason Gardener (4x100m) both employed barefoot training to develop greater foot and ankle strength and flexibility. You can also strengthen your feet by performing sprint drills barefoot and even by running (although the latter should be carefully progressed to). If you run barefoot, do so only over moderate distances (40-60m) and on soft grass, making sure there are no sharp objects. Distances should be only gradually increased as your lower and upper limbs become used to the higher forces that running without shoes generates. This will reduce the chances of sustaining an injury and condition the feet, ankles and legs gradually.

NB. running barefoot involves greater impact than barefoot sprint drills, hence the need for greater caution.

Barefoot high knee lift with ankle extension

Stand with your feet slightly apart. Lift the thigh of one leg to a position parallel to the ground, whilst at the same time pushing up onto the toes of the grounded foot. Claw forward with the suspended leg and then let the foot come down to the ground whilst lifting and pulling the previously grounded foot up toward your buttocks and through to perform the next stride simultaneously. You're basically performing a slow paced running action. Coordinate your arms with your legs (opposite arm to leg). You'll find that your feet and ankles have to work harder to control your movement and balance and are consequentially strengthened.

Suggested routine: 4x20m with a slow walk back as recovery.

Barefoot high knee lift with ankle extension

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Core strengthening – can you have too much of a good thing?

Ten years ago it barely got a mention but, in recent years, everybody and his dog seems to be touting plenty of core stabilisation training for improved sports performance. However, according to* Alicia Filley*, the evidence suggests that too much time spent on core training may be misguided

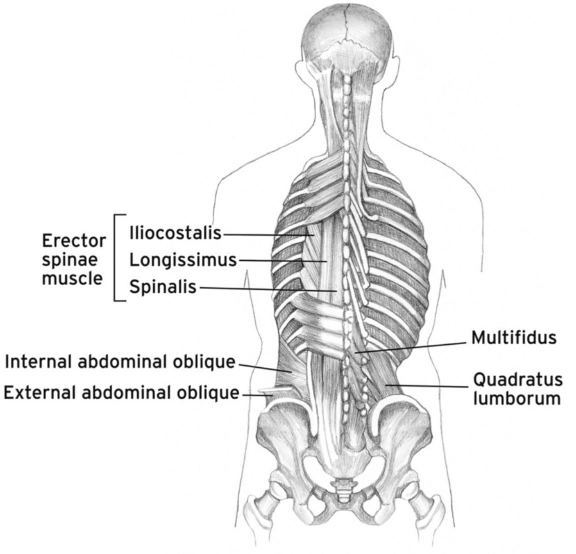
At its most basic, the body's 'core' refers to the region that maintains the body's centre of gravity and provides stability for movement, consisting of skeletal, ligamentous and muscular components from the diaphragm to the pelvis. The bony architecture of the spine, ribs and pelvis, the ligaments that join them, and the thoracolumbar fascia, are considered the passive elements of the core. Without the active support of the muscular components, these elements become unstable under relatively small forces(1). Therefore, it is the muscular components that make the greatest contribution to core stability.

The muscles that contribute to core stability are those of the abdomen, spine, pelvis and hips. The large, superficial muscles of the abdomen and hips are the prime movers of the trunk complex. It is these muscles that also provide the greatest hip and trunk stiffness to resist external forces upon the body. However, the smaller, intrinsic muscles along the spinal column also contribute to the stability and rotation of the spine. Some of the key core muscles in the spinal, abdominal and hip regions are shown below in figures 1-3 (overleaf).

Figures 1-3: Key core muscles

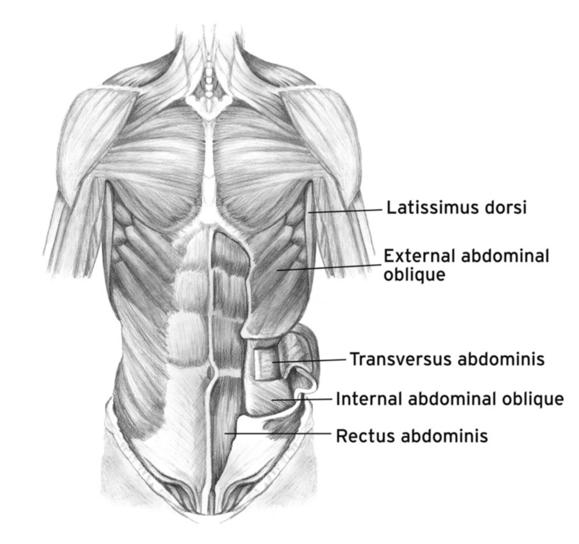
Spinal:

- **Multifidus:** Provide inter/intra-vertebral stabilisation primarily in the sagittal plane. Co-contract with abdominals to increase intra-abdominal pressure and trunk stiffness;
- **Erector spinae:** Function in the sagittal plane to provide inter-vertebral stabilisation and eccentrically decelerate trunk flexion and rotation;
- **Quadratus lumborum**: Frontal plane stabiliser that works with the gluteus medius and gluteus minimus to stabilise lumbar spine when contracting bilaterally;
- **Latissimus dorsi:** Bridge between upper extremity and the core.

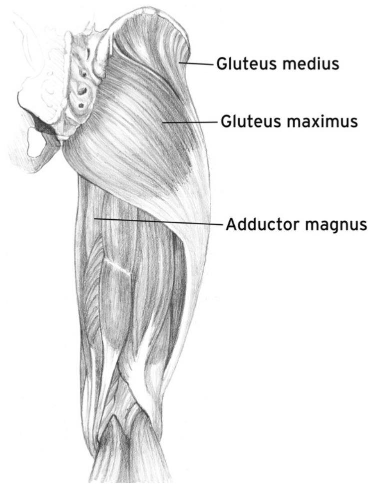


Abdominal:

- **Rectus abdominis:** Active in trunk flexion;
- **Internal and external obliques:** Provide rotation of the trunk;
- **Transversus abdominis:** Works with intrinsic spinal muscles to increase intra-abdominal pressure and provide stability to the lumbar spine.



Hip:
- **Gluteus medius and minimus:** Primary lateral stabilisers of the hip in the frontal and transverse plane. During open kinetic chain activities, abduct the hip. Control femoral adduction and internal rotation and maintain a level pelvis in closed kinetic chain activities;
- **Gluteus maximus:** Provide hip extension and external rotation during open chain movement. Transfers forces from the lower extremities to the trunk;
- **Adductor magnus, longus, and brevis:** Important for hip adduction movement in open chain, with small contribution to core stability.



How core stability is achieved

The muscles that make up the core work together in a complex interaction to provide trunk stability that allows distal mobility. This stability must be active in all three planes of movement. Three mechanisms are activated through muscle contractions to achieve the goal of core stability:
- Increased intra-abdominal pressure;
- Spinal compressive forces (axial load);
- Hip and trunk muscle stiffness[2].

Intra-abdominal pressure contributes to stability by increasing global trunk stiffness. While this is primarily accomplished through the activation of the abdominal musculature, recent studies have highlighted the contribution that the diaphragm and the often-ignored pelvic floor musculature also make to this mechanism[3].

Contraction of these muscles happens before movement is initiated in the limbs, thus readying the trunk for action[4]. Interestingly, only a five to 10% increase in activation of these muscles is required to stiffen the spine for daily activities as well as rigorous work[5,6]. This fact has led some to speculate whether more intense exercises such as Swiss ball crunches are really necessary after all!

Spinal compressive forces result from the co-contraction of muscles along the spine and the opposing abdominal muscles. These forces increase inter-vertebral stiffness, thus improving spinal stability[7]. The downside of this mechanism is that elevated axial loads to the spine through high-level muscular recruitment can result in low back pain.

However, this mechanism is critical for the activation of the muscles that increase stiffness of the hips and trunk. Therefore, it appears that these muscles must function in a highly coordinated way that balances the recruitment of the larger stabilising muscles, but which does not incur injury[2].

Results of core deficits

Rehabilitation professionals have long focused on core deficits when working to restore function in injured persons. In several recent studies, the scientific community has taken a look at core deficits in the athletic population as a way to predict and prevent injury.

Researchers collaborating at Quinnipiac and Yale Universities hypothesised that deficits in neuromuscular control of the trunk could result in knee ligament strain and anterior cruciate ligament (ACL) injury[8]. The trunk displacement response to sudden unloading in all three planes of movement, active proprioceptive repositioning error of the trunk, and history of low back pain, were evaluated in 277 athletes.

These three factors predicted knee injury with 83% sensitivity and 63% specificity in all athletes. Lateral displacement of the trunk was the single strongest predictor of knee injury in all athletes and the only significant predictor of ligament injury in female athletes. The results of this study are significant for female athletes who are more vulnerable to knee injury than males. The limitations of this study are that it did not evaluate all of the components of core control and that they were evaluated in a way that did not mimic athletic function. The findings support the hypothesis that impaired trunk control in response to perturbation can result in increased valgus stress at the knee and therefore increased risk for ACL damage.

Another study at the University of Delaware sought to examine the differences in core stability strength between males and females, and evaluate the relationship between these measures and incidence of lower extremity injury(9). Researchers followed 139 collegiate athletes over two years and found that males demonstrated greater core stability measures than females, primarily in the hip and pelvic musculature.

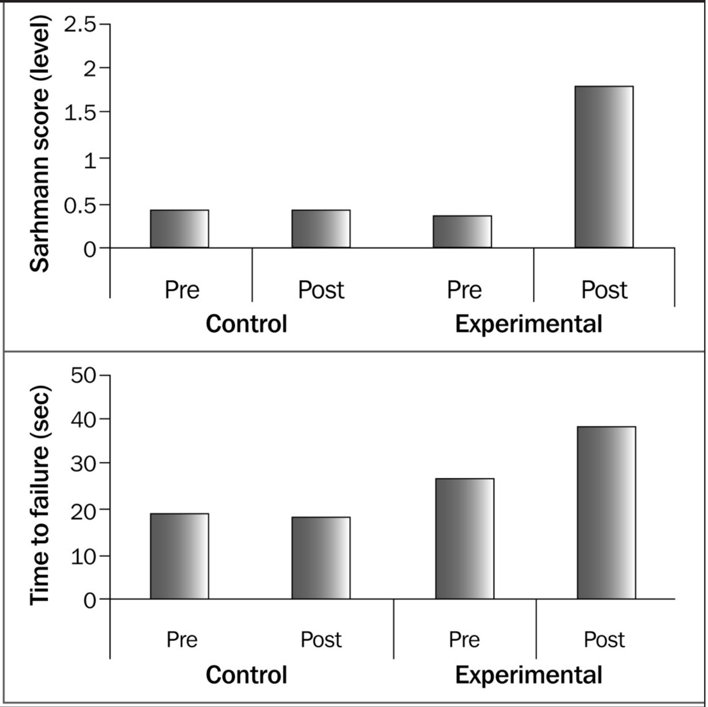
This weakness in females suggests that they may be more vulnerable to external forces experienced in the lower extremity during athletic performance. This study found the primary culprits in this deficit to be hip external rotation and abduction strength, but failed to include all of the elements of core stability in the evaluation. In addition, all measurements were taken in an open chain position that did not approximate athletic function.

Core strength and athletic performance

If core stability is the rock to which distal function is tied, then it makes theoretical sense that a stronger core will enhance athletic performance. Many trainers, athletes, and marketing gurus have taken advantage of this assumption to promote core training regimes and gadgets. This assumption, however, has yet to be proven through scientific research. In fact, many studies have focused on finding the right piece of equipment or technique to activate individual core muscles, without even questioning the necessity of doing so!

Scientists in Australia and the United States asked this very question when evaluating a Swiss ball training programme and its effect on core stability and running economy(10). Eighteen male athletes were divided into two groups. One group undertook a six-week Swiss ball training programme in addition to their normal training. The control group simply continued its normal physical training. At the end of the six-week period, the experimental group showed significantly improved core stability as compared to the control group (*see figures 4 and 5*). However,

Figures 4 and 5: Core strength (top) and time to failure in prone position on Swiss ball (below) after six weeks of Swiss ball training



these improvements did not translate into improved physiologic or postural performance while running. Note that while the gains in core strength in the Swiss ball group were significant, they did not result in any improvements in running posture, oxygen uptake or running economy (the oxygen cost required to maintain a given pace)[10].

An earlier study at the University of North Carolina, Chapel Hill, similarly examined the effects of a six-week Swiss ball training programme on swimming performance[11]. This study also reported improved core stability, but no enhancement of swimming performance.

Most recently, researchers at Indiana State University also discovered that the link between core muscle strength

Views of an expert

Thomas Nesser, PhD, is conducting groundbreaking studies into core strength and athletic performance at Indiana State University, and agrees that the theory of core strengthening makes sense. However, his concern is that athletes and trainers may be trying to gain too much of a good thing. He explains: 'A strong core is just one part of the whole body, and having a strong core doesn't necessarily mean it is going to turn you into a super athlete. It just means you have a strong core.' He emphasised there is really no point in having a strong core if you are ignoring the rest of the body in your training.

Dr Nesser calls the results of his recent study 'a real eye opener for all of us.' He suggests that the drills and exercises designed to strengthen the core play only a small part in performance challenges current training trends. In his professional opinion (which he thinks will be validated in future studies), Dr Nesser believes that there is a minimum strength requirement for the core. Once a person has achieved this minimum strength, anything above and beyond is not contributing anything additional to an individual's performance.

So how should an athlete incorporate core training into his regime? Dr Nesser believes the answer is not to separate specific muscle groups for training, but rather to work the core with specificity to your sport. Analyse the movement needed for your sport. Start with the balance and stability training aspect of core work, but don't go overboard. Dr Nesser asks,

'How much are you really training the body standing on a Swiss ball doing arm curls?' He is also a big believer in single-leg stance exercises since the majority of sports involve running, jumping, and changing direction on one foot. Single-leg stance focuses on training the hip and pelvic musculature, which may decrease an athlete's risk for lower extremity injury.

and sports performance was moderate to poor, and thus inconsistent(12). The core strength of 29 collegiate football players was tested and correlated to the athletes' ability in three strength variables and four performance variables. The findings led researchers to conclude that increases in core strength do not contribute significantly to overall strength and performance and should not be the focus of an athlete's strength and conditioning programme.

In a follow-up study at Indiana State University, the researchers again looked at the relationship between core stability, functional movement and performance[13]. This time a population of male and female non-athletes were examined. Again, while there was some correlation between core strength and isolated strength measures, there was no correlation between core strength and functional movement.

Summary

We all need core strength to maintain an upright posture and perform our activities of daily living. For athletes who push their bodies to the limit, the core acts as a stable base of support that delivers power to the extremities and allows for precision in the smaller distal muscles.

To decide if your core needs further fine tuning, you need to assess your risk factors for injury. Studies show that hip and pelvic weakness in women significantly increases their risk for lower extremity injury, specifically ACL damage. As for enhancing your performance, current research reveals that a stronger core does not translate into improved results. Indeed, researchers in Greece and the United Kingdom showed that general trunk exercises were more effective in treating patients with low back pain than isolated stabilisation exercises with specific core manoeuvres[14]. So, while some core work may be beneficial, classic crunches, push ups, lateral raises and quadruped extremity raises (requiring no equipment) may be better at doing the trick. If you are seeking to push your performance to the next level, your time may be better spent on other aspects of your training!

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Pose: A Beginner's Guide

If running is natural, why do we keep on injuring ourselves? Australian physio* Scott Smith *takes a look at a controversial alternative style that claims to reduce the risk of damage

The popularity of running as a leisure pursuit has increased throughout the past 25 years, reflecting social trends away from organised team sports and towards less time-consuming, more flexible and independent ways of keeping fit and active. Over the same time period there has been an explosion in sports science and sports injury research and therapeutic practice. Among other things, this has produced a wealth of advice on baseline fitness and training for running, and huge advances in footwear technology.

Yet runners keep on injuring themselves. They continue to seek treatment, typically, for Achilles tendinosis, patellofemoral pain, repetitive calf muscle strains, big toe pain and low back pain – and it seems to those of us who have been around the sports therapy world for a while that the incidence of running injuries has not reduced significantly. Is it time to return to the fundamentals of running to find out why so many people are still hurting themselves?

Coaches, trainers, therapists and athletes have no difficulty agreeing that technique has an important role to play in leisure pursuits such as rowing, golf, swimming and ballet, but when I ask my running patients about their technique – whether, for instance, they heel-strike or land with their knees straight – I receive blank expressions. In most sports, enthusiasts will expect to devote months and even years to working on movement technique, whereas with running we tend only ever to focus on how to run faster and/or further, and how much fitter we can get as a result.

In other words, running is practised rather than taught. This leads to the question: is there an optimal running technique that enables athletes to train without fear of injury, with a real reduction in their injury risk – and with the prospect of still being able to improve their performance?

One recently developed technique, called 'pose running', lays claim to be able to do all three things. Pose running was invented by Nicholas Romanov, a Russian scientist now based in Miami and consultant to the British, US and Mexican triathlon associations. During the 1970s and early 80s, Romanov was heavily involved with athlete training in Russia, where he observed that as his athletes turned up the workload, so they would start to break down physically. At that time there was little strength and conditioning training. With a heavy emphasis on improving mileage and speed, the athletes focused on increasing their cardiovascular and respiratory systems, and paid little heed to their underlying running technique.

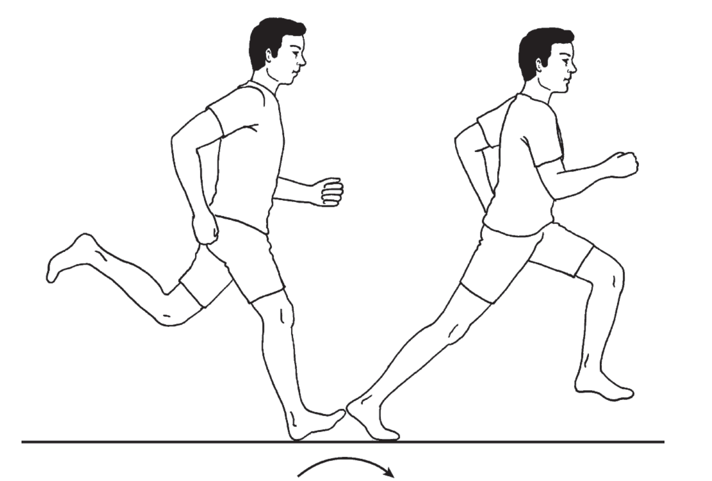
The pose method

Romanov proposes one universal technique for all runners, regardless of speed or distance: a 100m sprinter runs with the same underlying technique as a 10km long-distance runner. The technique is designed to prevent undue strain on the joints and requires a great deal of muscular endurance and resilience.

The elite British triathletes Tim Don, Andrew Johns and Leanda Cave have all adopted the pose method under Romanov's guidance. According to Romanov, the Ethiopian distance champion Haile Gebrselassie and the US sprint legend Michael Johnson are both examples of runners with a natural pose style – 'born with perfect technique'.

The distinguishing characteristic of pose running is that the athlete lands on the midfoot, with the supporting joints flexed at impact, and then uses the hamstring muscles to withdraw the foot from the ground, relying on gravity to propel the runner forward. This style is in clear contrast to the heelstrike method that most runners deploy and which is advocated by some health care professionals (*see Figure 1 opposite*).

Figure 1: Heel-toe running



The concept is simple enough, but the practice is extremely hard to master. It is only with expert tuition and dedicated training that the athlete can perfect the technique. Running in pose is physically demanding, so runners must under--take strengthening drills before starting the programme. Maybe it is this added balance and stability training that allows the athlete to remain injury free? As yet there is no body of research to help answer this question.

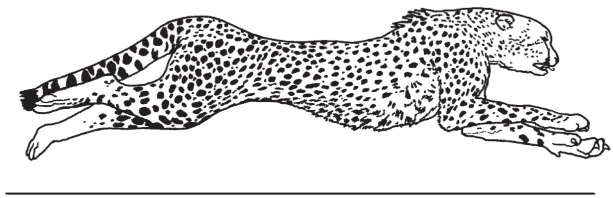
Principles

Running should be easy, effortless, smooth and flowing. We have all seen and heard the heavy runner who pounds away on a gym treadmill. Romanov says the runner is only as good as his change of support and that the runner should have a very high cadence – not a long, extended stride length. In pose running, the key is to maximise your effort in removing your support foot from the ground; good training is essential to ensure that you don't over-stride or create excessive vertical oscillation. The runner should fall forwards, changing support from one leg to the other by pulling the foot from the ground, allowing minimum effort and producing minimum braking to this body movement. The idea is to maximise the use of gravity to pull the runner forward.

The pose method is centred on the idea that a runner maintains a single pose or position, moving continually forwards in this position. Romanov uses two models to explain the rationale behind pose:

- *the mechanical model* – the centre of gravity, which is around the hip position, should move in a horizontal line, without vertical up and down displacement;
- *the biological model* – the rear leg maintains an 'S-like' form, and never straightens. This notion comes from animals such as the cheetah which do not land on their heels but run on the midfoot and deploy a pulling through action using their hamstrings rather than pushing the foot into the ground (*see Figure 2 below*).

Figure 2: The cheetah



Perhaps the most useful imagery to help with this technique is to imagine a vertical line coming from the runner's head straight down to the ground. The raised front leg should never breach this line, but remain behind it. This focuses the effort firmly on pulling the ankle up vertically under your hip rather than extending forward with your quads and hip flexors (front of thighs).

The power behind the pose

Pose is by no means universally accepted by the running fraternity. While top athletes have sought Romanov's help because of injuries, the method does require good scientific research to back it up. It is quite possible that many of the benefits experienced by pose athletes are the result of the rigorous strengthening programmes they undertake.

The training regime's focus on proprioception (joint stability and balance), together with the strong imagery of the technique, changes the physical placement of the limbs and reduces the downward displacement force of the foot on to the ground. That said, I know of people who have tried to run in pose and have sustained injuries such as calf strains and lower back problems, because they did not get their pose stance right and did not have sufficient hip control.

You need to be committed to learning the new technique: once you have decided to learn to run in pose, you cannot expect to chop and change between running styles at will. The technical drills outlined below can be very strenuous and may be harmful if attempted, for instance, at the wrong point in an injured runner's rehabilitation phase. Runners and coaches alike should adopt these drills with proper caution.

Figure 3: Toe running

How to do it: pose drills

If you are embarking on a serious transition to pose, you should practise the drills (building up the level of difficulty) once or twice daily, three sets of 10 to 15 reps per drill. Drills should be practised for at least a week before attempting to run in pose, and should be performed before a run. All drills should be performed barefoot for added awareness of the movements, on a forgiving surface such as grass or a running track.

The drills fall into three sections:

a) Basic drills to reinforce the pose position, the use of the hamstring in pulling the foot from the ground and the feeling of falling forward under the effect of gravity (drills 1-7);

b) Intermediate drills to reinforce these feelings (drills 8 and 9);
c) Advanced drills to aid speed, balance, strength and reflexiveness (none shown here).

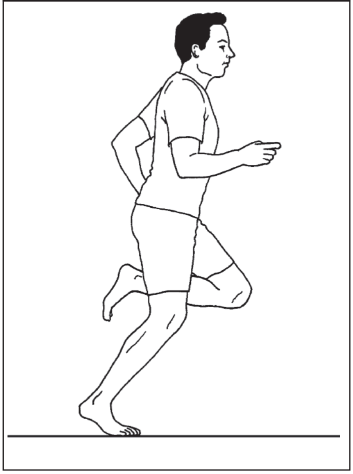
Drill 1 (*Figure 4*):

Pose stance

This to be practised as a static pose, held for up to 30 seconds. It requires good postural control; no support is allowed. The idea is to challenge the mechanoreceptors in the joints and soft tissues to provide feedback to the brain regarding joint position and muscle tone.

- It is the basic position to hold and to practise balance
- The use of a mirror is recommended
- Shoulder, hip and ankle should always be vertically aligned
- Point of contact with the ground is always the midfoot
- Hip is always held over the support point, which is the midfoot.

Figure 4: Pose stance



Drill 2:

Change of support without moving

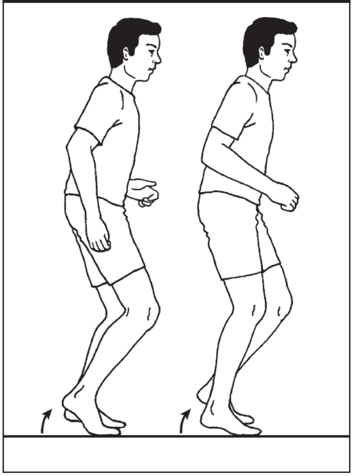
- Shift centre of gravity sideways from one leg to the other, maintaining support on the midfoot
- You must feel the weight shift from one leg to the other before pulling up
- It is important to feel the weight shift and then the acceleration of this movement by the pulling-up of the hamstring
- Pull the ankle up vertically under the hip using the hamstring only, not hip flexors or quadriceps
- Allow the leg to drop to the ground – do not drive it down
- Mental focus is on the pulling-up action, not the leg drop.

Drill 3 *(Figure 5)*:

Pony

- This practises changing support using minimum effort and minimal range of movement
- Simultaneously lift the ankle of the support leg while allowing your body weight to shift to the other leg
- Use only the hamstring. Keep in mind your support point on the midfoot (toes will also be in contact).

Figure 5: Pony

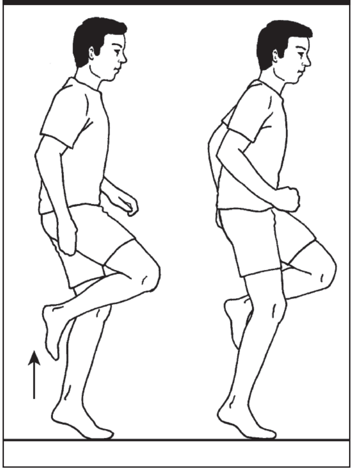


Drill 4 (*Figure 6*):

Forward change of support

- This puts the pony into action; practise slowly at first
- Lean slightly forward and simultaneously pull the ankle up under the hip using the hamstring and allow the non-support leg to drop to the ground under the force of gravity
- Make sure the weight transfer is effortless and that the foot is allowed to fall.

Figure 6: Forward change of support



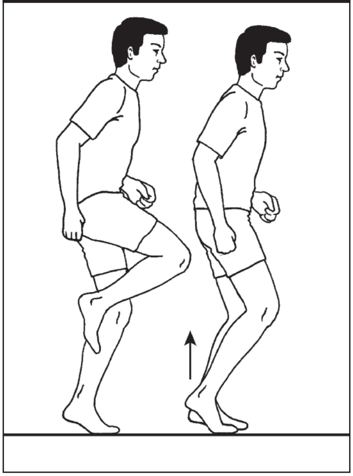
Drill 5 (*Figure 7 overleaf*):

Foot tapping

- Single-leg drill, 10-15 taps per set
- This emphasises the vertical leg action and use of hamstrings rather than driving the knees up and forward using your hip flexors and quads

- It prevents your foot from being too far out in front of the body, which would cause you to land on your heel and create a braking action
- Aim for rapid firing of the hamstring, lifting the foot from the ground as soon as it touches down
- You must feel the muscles fire and then relax. Avoid a forceful pull all the way up. If you are doing it correctly the lower leg will decelerate after the initial firing and accelerate as gravity returns it to the ground.

Figure 7: Foot tapping



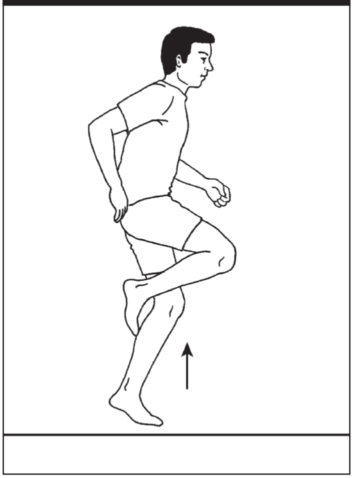
Drill 6 (*Figure 8*):

Hopping

This movement progresses the tapping drill. The momentum for the hopping support leg should come from the hamstring action on the non-hopping leg. Take care: this is an advanced movement which will place unhealthy stress on structures such as the Achilles/calf muscles if not performed correctly.

- Start by pulling up the non-hopping leg with your hamstring and use the reaction force of the ground to aid this recoil effect
- Do not push with the calf but just lift the ankle with the hamstring and make sure the ankle is relaxed between hops.

Figure 8: Hopping



Drill 7:

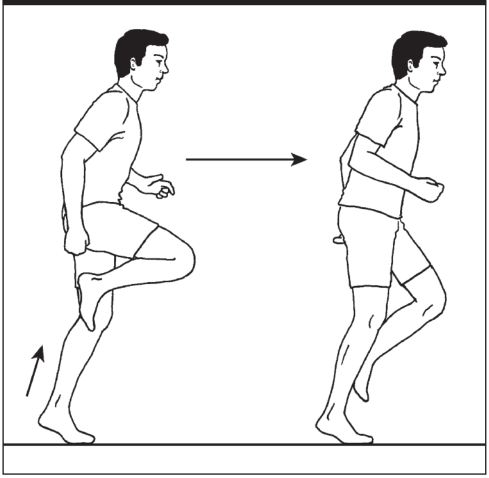
Front lunge

- Single-leg drill which increases the range of movement of the hopping drill
- This truly forces you to isolate the hamstring muscles
- Practise initially on the spot until you are stable enough to allow forward movement
- Keep weight on front leg; the back leg drags behind
- Pull ankle vertically up under the hip, using the hamstring
- Keep contact time with the ground as short as possible
- Allow rear leg to follow loosely
- Remember to land on the ball of your foot
- Forward movement is created not by pushing off but by leaning forward from the hips. You drag the rear leg behind you for balance.

Drill 8 (*Figure 9*):

Switch

Figure 9: Switch



- Both ankles are being picked up
- This time you are picking the rear leg up as well with the hamstring
- Transfer weight from one leg to the other as you alternate support
- Keep contact time with the ground to a minimum, only as necessary to change support
- Keep heels off the ground and land on the balls of your feet
- Always think of the pose stance: good vertical alignment of shoulder, hip and foot.

Drill 9:

Running lunge

- This is pose running, but with a deliberate emphasis on the speed of the hamstring pull-up
- The aim is to teach the working leg to react as quickly as possible, minimising support time on the ground
- The runner pulls the heel up vertically from the ground but allows it to fall easily to the ground.

POSE PRINCIPLES IN SUMMARY

1. Raise your ankle straight up under your hip, using the hamstrings;
2. Keep your support time short;
3. Your support is always on the balls of your feet;
4. Do not touch the ground with your heels;
5. Avoid shifting weight over your toes: raise your ankle when the weight is on the ball of your foot;
6. Keep your ankle fixed at the same angle;
7. Keep knees bent at all times;
8. Feet remain behind the vertical line going through your knees;
9. Keep stride length short;
10. Keep knees and thighs down, close together, and relaxed;
11. Always focus on pulling the foot from the ground, not on landing;
12. Do not point or land on the toes (see Fig 3 on p2: Toe running);
13. Gravity, not muscle action, controls the landing of the legs;
14. Keep shoulder, hip and ankle in vertical alignment;
15. Arm movement is for balance, not for force production.

Further reading

Pose Method of Running by Nicholas Romanov (2002), PoseTech Press ISBN: 0-9725537-6-2

'Reduced Eccentric Loading of the Knee with the Pose Running Method', Arendse, Regan E; Noakes, Timothy D; Azevedo, Liane B; Romanov, Nicholas; Schwellnus, Martin P; Fletcher, Graham in Medicine & Science in Sports & Exercise: Volume 36(2) February 2004 pp272-277. Official website: www.posetech.com

Strength training and lower body biomechanics in female athletes

As indicated in* James Marshall*'s article on page 8 of this issue, female athletes are at proportionately greater risk of lower-limb injury compared to males, especially anterior cruciate ligament (ACL) injury. Strength training is considered a strategy for ACL injury prevention, but little is known about the contribution of strength training to changing knee and hip biomechanics – relevant because some studies have indicated that the incidence of ACL injury is associated with biomechanical imbalances.

To try and throw more light on this issue, US scientists from the University of North Carolina have carried out a study to investigate whether and how lower extremity muscle strength training alters knee and hip biomechanics during a 'stop-jump' task. In the study, 66 female recreational athletes were recruited and split into two groups; the intervention group completing a nine-week strength training programme, which targeted the quadriceps, hamstrings, gluteus medius, and gluteus maximus, while the control group performed no strength training during this period. The researchers collected three-dimensional kinematic and kinetic data for knee and hip movements from athletes before and after the strength training and then looked to see what biomechanical changes had taken place compared with those who had undergone no strength training. Maximum voluntary isometric contraction strength data were also collected for each subject before the stop-jump tasks in each data collection session, and knee and hip joint angles as well as resultant forces and moments were calculated.

The results were somewhat surprising; the subjects in the intervention group increased their strength significantly in all the muscles trained (as expected). Despite this, however, no significant differences were observed in knee and hip kinematics and kinetics between groups before and after the strength-training protocol. The researchers concluded that 'strength training alone does not alter knee and hip kinematics and kinetics in female recreational athletes', but went on to state that further research was needed to determine the effect of strength training in combination with other intervention methods on lower extremity biomechanics. The clinical relevance of these findings is that strength training alone as a single intervention method may not be sufficient to reduce the risk of non-contact ACL injury in female recreational athletes. However, this is not to say that when combined with other training methods such as agility drills and plyometrics, it doesn't have significant value.

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Notes

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