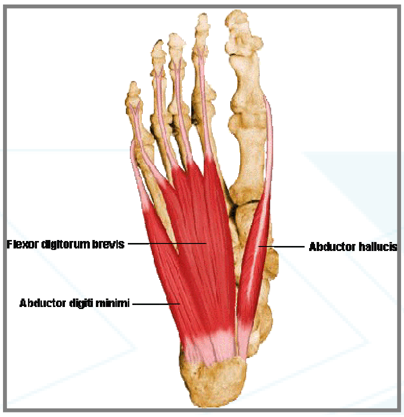
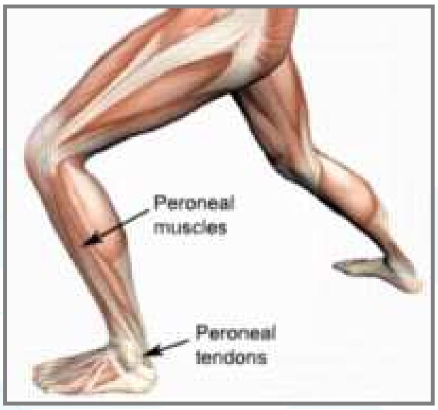
ATHLETIC PERFORMANCE

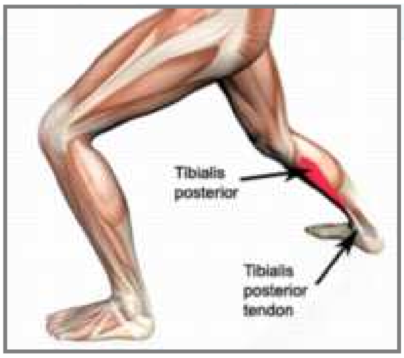
Traditional training programs designed to improve athletic performance factors such as agility, running speed, and jumping ability have focused on strengthening the larger muscle groups of the upper and lower legs (Unger and Wooden, 2000; Chaouachi et al, 2009). However, the intrinsic muscles of the feet (image #1) are often neglected in athletic strength training programs because their importance is not always fully recognized, and they can be difficult to strengthen effectively. A number of research studies have clearly shown that significant improvements in athletic performance can result from strengthening the intrinsic foot muscles (Adams et al, 1988; Kokkonen et al, 1988; Unger and Wooden, 2000; Goldmann et al, 2012). Optimal strengthening of the smaller muscles that control movements around the ankle joint, such as the ankle evertors (image #2), inverters (image #3) and dorsiflexors/invertors (image #4), is also critical to optimize performance, due to their role in ankle joint stability and multi-directional propulsion and braking.



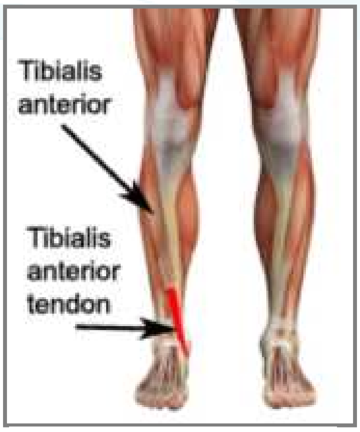
1. Source: Center for Podiatric Care and Sports Medicine



2. Source: Physio.com



3. Source: Physio.com



4. Source: Physio.com

Agility

Agility is defined as the ability to move and change direction and position of the body quickly and effectively while under control. Agility is a physiological prerequisite in any sport or activity that involves sudden directional changes, such as basketball, baseball, dance, tennis, football, soccer, and volleyball. Improvements in agility require the ability to:

- decelerate rapidly so that direction can be changed quickly;
- push off forcefully and rapidly from the ground in any direction;
- maintain balance while the body is in motion (dynamic balance).

The ability to decelerate rapidly is highly dependent on the magnitude and rate of eccentric muscle force production. Research has shown that both eccentric and concentric force production is increased to a greater extent with eccentric loading (i.e. additional resistance placed on the muscle/tendon unit during the eccentric contraction, in a controlled manner, that increases in magnitude in a progressive fashion over time) in comparison to traditional resistance training (Roig et al, 2009). Eccentric loading has also been shown to result in significant improvements in the rate of force generation, as demonstrated by a faster muscle contractile velocity following eccentric loading training (Martin et al, 1995; Valour et al, 2004).

The ability to push off forcefully and rapidly in any direction is dependent on concentric force production, rate of force production, and efficient force transfer to the ground. Efficient force transfer to the ground is dependent on proximal-to-distal muscle activation to allow for energy transfer and summation of joint forces (torques) from the proximal to the distal joints of the lower limb (Jacobs et al, 1996; Umberger, 1998). Mann et al (2008) reported that the average agility score (T-test of agility) for a group of male university varsity basketball players, who participated in a 12-week foot and ankle strengthening program using the AFX, was approximately 0.5 seconds faster than a control group (p=0.27) (equivalent to a 5% improvement), and all experimental subjects reported noticeable improvements in sprinting speed down the court and speed with which they could change direction.

Dynamic Balance

Dynamic balance, or the ability to maintain balance while the body is in motion, is dependent on joint stability, mobility, and proprioception (i.e. the ability of the central nervous system to sense joint position). Lateral ankle joint stability plays a major role in dynamic balance, and is dependent on concentric and eccentric strength of the peroneal muscles that control movement around the lateral aspect of the ankle joint (Hartsell and Spaulding, 1999; Yildiz et al, 2003; Arnold et al, 2009). Mann et al (2008) reported statistically significant improvements in bilateral dynamic balance in the posterior and lateral directions in a group of male university varsity basketball players who participated in a 12-week foot and ankle strengthening program using the AFX.

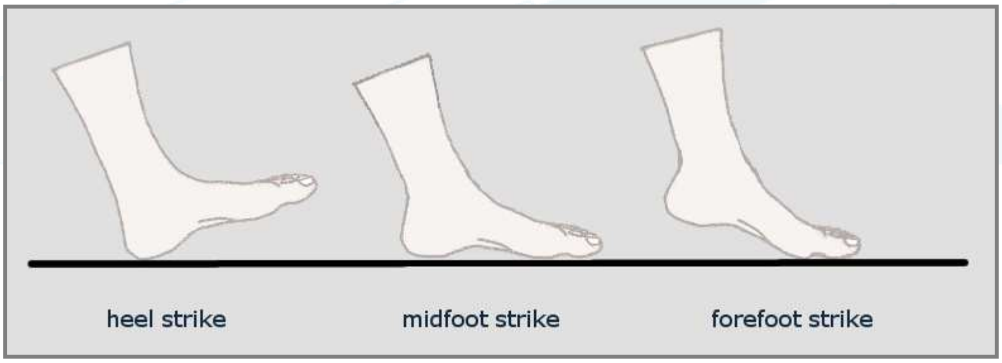
Dynamic balance can also be enhanced with exercises such as the Wobble board and the Bosu™ stability platform – these exercises should be done initially with the eyes open, and then progress to doing them with the eyes closed. These exercises can also be done progressing from double-leg to single-leg stance and, where applicable, employing functional sport activities such as throwing, catching, and ball dribbling. Barefoot training on sand that incorporates rapid changes in direction (e.g. beach volleyball), is also an effective method to improve dynamic balance. Core strengthening has also been found to be an important factor in enhancing dynamic stability (Samson, 2005).

Running Speed

During sprinting or long-distance running, optimal summation of joint torques will occur if forces are generated around the hip (extension), knee (extension), sub-talar (inversion), ankle (plantar flexion), and metatarsal phalangeal (flexion) joints in the proper sequence, and with the appropriate timing. A relative lack of strength or power at any of these joints can affect the summation of forces and power output at the distal end of the kinetic chain, which will affect running speed and acceleration.

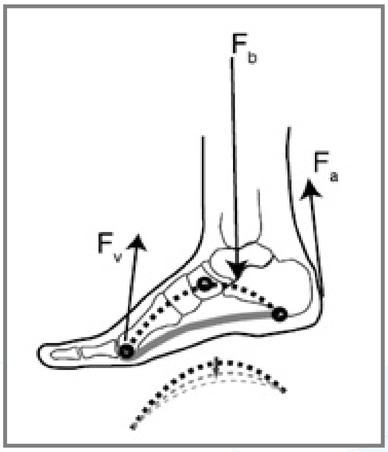
Running speed and acceleration can also be impacted by the ability of the lower limb joint tendons and other elastic tissues to store and release elastic energy during the stretch-shortening cycle (i.e. eccentric contraction of a muscle followed by an immediate shortening (concentric contraction) of that same muscle) that occurs between foot strike and mid-stance. In particular, the Achilles tendon, plantar fascia, and tendons under the arch of the foot have been shown to store and release considerable energy during the stance phase of running (Perl et al, 2012). Due to its elastic nature, a healthy Achilles tendon has been shown to recover approximately 35% of the mechanical energy that the body generates with each step (Ker et al, 1987; Alexander, 1991), while the longitudinal and transverse arches of the foot, which are supported by the plantar fascia, toe flexor, tibialis posterior and anterior tibialis tendons, recover an estimated 17% of the mechanical energy generated per step due to the deformation and reformation of the arch that occurs between foot strike and toe-off (Ker et al, 1987). This storage and release of elastic energy helps to push the body's center of mass upward and forward during the propulsive phase (Biewener, 2003). Storage of elastic energy can be increased above normal values by increasing the amount of stretch of these tissues, and by increasing their spring stiffness. Studies have shown that eccentric loading results in an increase in the spring stiffness of the muscle/tendon unit, and a subsequent increase in storage and release of elastic energy (Reich et al, 2000; Lindstedt et al, 2002; LaStayo et al, 2003). The second factor that can influence storage of elastic energy, the amount of stretch of the elastic tissues, is affected by the type of foot strike.

Affect of Foot Strike on Running Speed

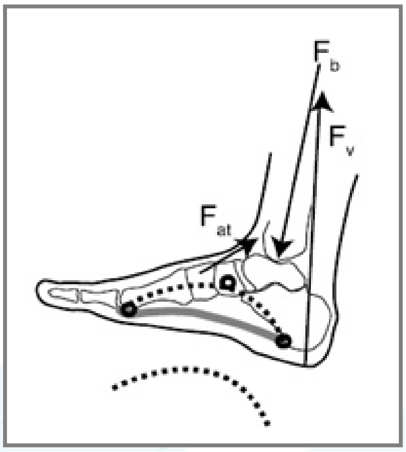


5. Source: Somastruct

There are 3 types of foot strikes that are used in running (image #5). Perl et al (2012) reported that the forefoot strike (FFS) results in an increased tensile force (F_a in image #6) in the Achilles tendon and triceps surae muscle group (i.e. gastrocnemius and soleus) that develops to resist an external dorsiflexion moment that is created around the ankle joint. The dorsiflexion moment is the result of the ground reaction force (F_v) that is located at the metatarsal heads, and is resisted by an internal plantar flexor moment. The tension developed in the Achilles tendon and triceps surae results in stretching of the Achilles, along with storage of elastic energy. In contrast, a heel strike (HS) results in a ground reaction force (F_v) that is located posterior to the ankle joint, resulting in a plantar flexor moment, which is resisted by a dorsiflexor moment generated by anterior tibialis (F_{at}) (image #7). As a result, there is no additional tension on the Achilles in a heel strike. Therefore, the tensile force that is generated in the Achilles tendon during a FFS will result in increased stretching of the Achilles, with subsequent storage and release of elastic energy that can be used during the propulsive phase to improve running efficiency and force production. A mid-foot strike (MFS) would have a ground reaction force located at the metatarsal heads and heel, of nearly equal magnitude. As a result, the magnitude of the dorsiflexion moment about the ankle joint would be reduced relative to that seen in the FFS, resulting in a smaller tensile force generated in the Achilles tendon, along with less elastic energy storage.



6. Source: Perl et al (2012)



7. Source: Perl et al (2012)

In addition, FFS runners load the arch in 3-point bending from the instant the ball of the foot contacts the ground (image #6), with the body's center of mass (F_b) located almost mid-way between the ground reaction force (F_v) and the force in the Achilles (F_a), near the mid-point of the arch, which results in arch deformation before foot flat (see change in position of dashed lines at the bottom of image #6) and stretching of the elastic tissues under the arch of the foot. In contrast, HS runners experience little or no arch compression at impact due to the lack of 3-point bending (image #7); these forces likely stiffen the arch until mid-stance, preventing storage of any elastic energy that initial impact generates (Perl et al, 2012). Therefore, in a forefoot strike, the arch of the foot behaves much more like an elastic spring, stretching from the instant of foot strike until mid-stance, and then recoiling during the second half of stance; in a rear foot strike, the forces that bend the arch cannot do so until foot flat (Perl et al, 2012).

In conclusion, a forefoot strike will result in greater storage and release of elastic energy in comparison to a heel strike or mid-foot strike, with an associated increase in concentric force production during the propulsive phase of running. Increasing the spring stiffness of the Achilles tendon, plantar fascia, toe flexors, and sub-talar inverters with eccentric loading will increase the energy-storing capacity of these tissues, along with a subsequent increase in running speed and acceleration. Increased eccentric strength of the triceps surae, tibialis posterior, anterior tibialis, and toe flexors may also result in stronger eccentric contractions between foot strike and mid-stance, which would increase the amount of stretch of the associated tendons, along with an increase in elastic energy storage, and further enhancement of performance. Increased concentric strength and power of these muscles will result in increased force production during propulsion, with a subsequent increase in running speed and acceleration.

Affect of Footwear on Running Performance

Perl et al (2012) reported that the type of footwear (shod vs. unshod) can affect the amount of elastic energy stored in the arch of the foot. Barefoot and minimally shod (image #8) runners are likely to store more elastic energy because external arch supports in standard shoes lessen vertical arch compression during stance, limiting how much the arch can stretch and recoil. Additionally, individuals who wear stiff-soled shoes with arch supports may have weaker intrinsic foot muscles than individuals who are habitually barefoot or minimally shod (Bruggemann et al, 2005). Because the strength of the intrinsic foot muscles can affect elastic energy storage in the arch, running economy and performance in barefoot and minimally shod runners may be improved over that of runners who wear standard shoes (Perl et al, 2012). Sprinting barefoot on sand is a common training method (Alcaraz et al, 2011), which has been shown to reduce impact forces, thereby reducing risk for injury (Gaudino et al, 2012). Sprint training on sand is also an effective method to improve intrinsic foot muscle strength.

8. Source: Akintaju (2011)

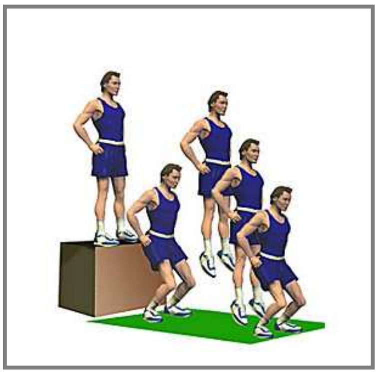
VERTICAL AND HORIZONTAL JUMPING

Similar to running, vertical and horizontal jumping ability is dependent on optimal summation of joint forces in the lower extremity, and elastic energy storage. A relative lack of strength or power at any of the joints of the lower limb can affect the summation of forces and power output at the distal end of the kinetic chain, which will affect vertical jump height, or horizontal jump distance. Therefore, increased concentric and eccentric strength and power of the muscles of the foot and lower leg will help to increase force and power production during jumping activities. Studies have shown that strengthening the intrinsic muscles of the feet (toe flexors) can have a significant effect on horizontal and vertical jumping ability (Kokkonen et al, 1988; Unger and Wooden, 2000; Goldmann et al, 2012). Mann et al (2008) reported statistically significant improvements in the one-step vertical jump in a group of male university varsity basketball players who participated in a 12-week foot and ankle strengthening program using the AFX (experimental group = 7.6 cm or 3.0 inches; control group = 1.6 cm or 0.6 inches).

Plyometric Training

Plyometric training (PT) is defined as the performance of stretch-shortening cycle (SSC) movements that involve a high intensity eccentric contraction followed immediately by a rapid and powerful concentric contraction, and has been shown to significantly improve vertical jump height, with the average effect ranging from a 4.7% to 8.7% improvement (Markovic, 2007). PT has been found to be more effective than static-jump training (i.e. concentric-only) because of its ability to enhance the elastic and neural properties of the neuromuscular system through use of the stretch-shortening cycle (Wilson et al, 1993).

PT for the lower extremities includes exercises such as: drop jumps (image #9), countermovement jumps (image #10), alternate-leg bounding, and hopping. Plyometric training is also effective if performed barefoot on a more compliant surface such as sand to reduce impact forces, which will reduce risk of injury (Impellizzeri et al, 2009). Plyometric training on sand has also been shown to improve sprinting ability (Impellizzeri et al, 2009).



9. Source: Sport Technology

10. Source: Wise Coach

How AFX Helps

- Scientifically proven* to improve multi-directional dynamic balance and vertical jump (Mann et al, 2008);
- Allows for full range of motion eccentric loading (images #11 to 17) to improve:
  - spring-like quality of the arch of the foot and the Achilles tendon;
  - multi-directional movement speed;
  - acceleration (explosiveness); and
  - deceleration (braking);
- Engages the toe flexors through a full range of motion (image #11);
- Allows for high-speed movements, to improve multi-directional power output;
- Full range of motion stretching and mobility exercises in a non-weight bearing position allows for optimal improvements in muscle flexibility and joint mobility.

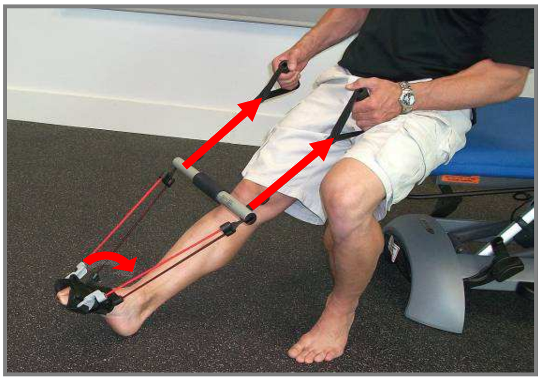
***** An independent research study was conducted to evaluate the effectiveness of the AFX on athletic performance in male university varsity basketball players during their regular season. For an electronic copy of the research paper, please contact rick@progressivehealth.ca.

Eccentric Loading - Precautions and Guidelines

- Eccentric loading may result in significant muscle soreness one or two days after the exercise session. To keep this soreness to a minimum, begin eccentric loading with only one or two higher resistance eccentric repetitions at the end of each set. Each workout, add an additional higher resistance eccentric repetition to each set, until all the repetitions are done like this;
- Gradually work up to 8 to 12 repetitions per set performed in this manner with no more than 3 sets per exercise;
- Perform eccentric loading slowly (4 to 6 seconds for each repetition);
- Initial increases in eccentric tension should be approximately 10 to 20% greater than concentric tension, followed by a gradual increase over time.

Eccentric loading of toe flexors and plantar flexors (including Achilles tendon)

11. Plantar flexion and toe flexion



12. Increase resistance by pulling back on handles and resist movement with foot

Eccentric loading of foot/ankle inverters

13. Inversion – start

14. Start of eccentric loading – increase resistance

15. Eccentric Inversion – mid position

Eccentric loading of anterior tibialis

16. Dorsiflexion – start

17. Eccentric dorsiflexion – increase resistance by pulling back on knee as foot is lowered to start position

~ Rick Hall, M.Sc.

Rick is the Principal Scientist for Progressive Health Innovations, and co-inventor of the AFX. Rick has a M.Sc. in Biomechanics, and has conducted research in athletic performance enhancement, exercise physiology, and injury prevention for over 20 years. He is a member of the International Foot and Ankle Biomechanics Community, and is also a reviewer for the Journal of Biomechanics.

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Images

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