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FOOTWEAR AND STRESS FRACTURES

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Most injuries sustained during walking, marching, and running activities are overuse injuries, such as stress fractures. The causal factors associated with stress fractures include training errors, anatomic factors, surfaces, and footwear. Loading, cyclic and impact, play an important role in the cause of stress fractures.[8, 25] The amount of load, the number of repetitions, and the frequency of loading all determine when bone will fail.[3] Bone fails when the stress exceeds the reparative process and a fracture results.[9] The forces causing stress fractures are generated primarily when the foot strikes the ground.

The structure of the foot can also determine how much force is absorbed by the foot or is transferred to bone (Fig. 1). The rigid high arch of a cavus foot does not absorb much stress, but passes it on to the tibia and the femur whereas the flexible flat foot absorbs stress in the musculoskeletal structures of the foot. Therefore, tibial and femoral stress fractures have been reported as more common in individuals with cavus feet. Likewise, the incidence of metatarsal stress fractures is higher in individuals with flat feet.[12, 19, 27] Normal feet with lower arches are thought to be better shock absorbers than the normal foot with a high arch;[27] therefore, with lower arches, less stress is passed on to the bones of the tibia and the femur.

Stability of the foot during weightbearing requires active muscular contractions, and fatigue of these muscles can also contribute to the cause of stress fractures. In fact, the increase in the number of loading

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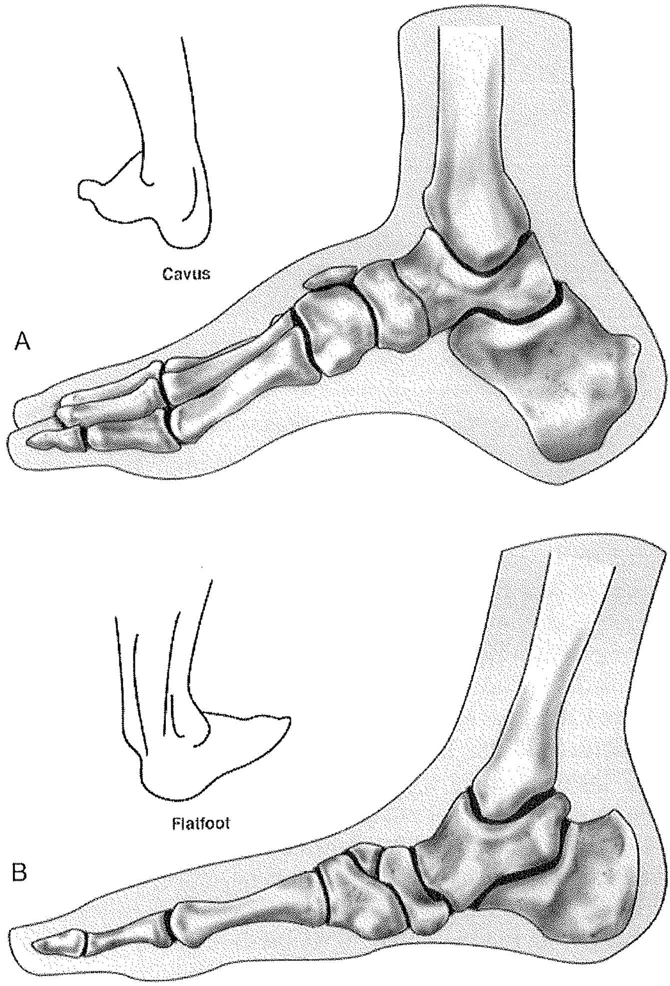

Figure 1. *A*, The rigid, high arch of a cavus foot does not absorb as much stress as a flexible flat foot, but passes it on to the tibia and the femur. *B*, A flexible, flat foot absorbs more stress in the musculoskeletal structures of the foot than a cavus foot. The incidence of stress fractures in the foot is higher in individuals with flat feet.

cycles the bone is exposed to may have less importance than the increase in peak strain imposed by tired, uncoordinated muscles.[26]

Because foot loading, structure, and stability have a significant impact on the development of stress fractures, it is logical that footwear can play an important role in the development, treatment and prevention of stress fractures.

SHOES

The most important characteristic of athletic shoes that can be modified easily is the amount of cushioning provided. Several studies have indicated that improved shock absorption by footwear can reduce the incidence of stress fractures.[15, 17, 24, 25] Conversely, lack of cushioning in shoes has been implicated as a cause of running injuries.[10] Regardless, the primary purpose of an athletic shoe cushioning system is to protect the body from the consequences of repeated impacts between the foot and the ground. The shock absorbing and attenuating properties of an athletic shoe are mainly determined by the material characteristics and construction of the midsole (Fig. 2).

The cost of a running shoe, a possible indicator of the overall quality and shock absorbency of the shoe, has not been found to be associated with the incidence of stress fractures.[13] On the contrary, the age of the shoe is thought to be a good indicator of the condition of the midsole materials, and thus the shock absorbency, and has been correlated with an increased incidence of fractures. In addition, age also has a negative effect on the support provided by the shoe, which places the foot at risk for stress fractures.[6, 10]

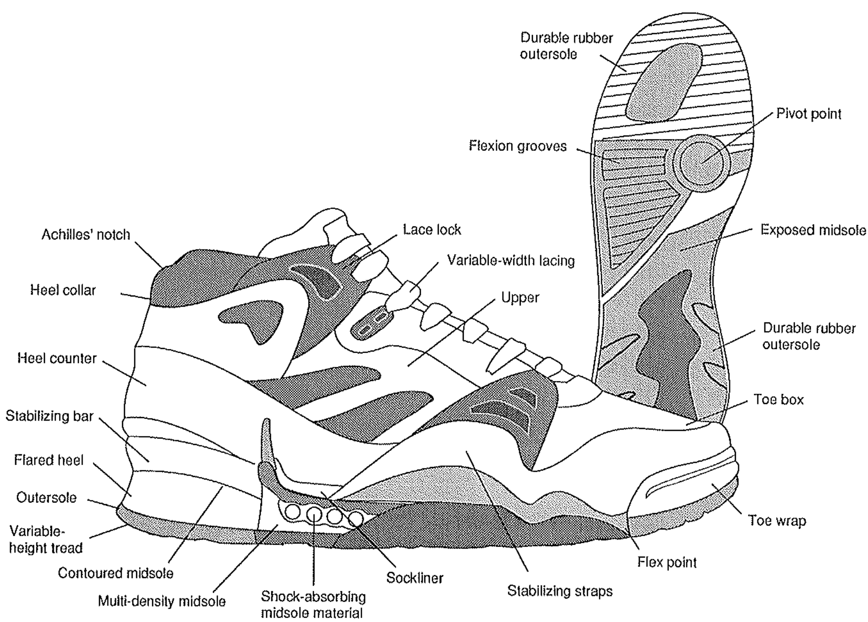

Figure 2. The anatomy of an athletic shoe. The shock-absorbing and attenuating properties of an athletic shoe are mainly determined by the material characteristics and construction of the midsole of the shoe.

the forefoot is smaller. Even so, athletic shoes are often undercushioned in the forefoot because of overriding flexibility requirements.

Proper shoe selection is also important because of differences in foot flexibility. Rigid cavus feet are inherently more stable than flexible flat feet, but need more cushioning because they transmit more stress. Flexible feet absorb more shock than a rigid foot, but are less stable and need more stability features in a shoe.

The force of impact during aerobic dance exercise is relatively low. Aerobic shoe cushioning needs are, therefore, not as high as they are for shoes worn in activities where impacts are higher, such as running and jumping. Cushioning is still required to redistribute load across the plantar surface of the foot, reducing local pressure.

MIDSOLE MATERIALS

Most of the recent advances in the athletic shoe industry have been made in midsole design and materials. The midsole and heel wedge are sandwiched between the upper and the outsole, attaching to both. These components provide cushioning, shock absorption, lift, and control.

COMBINATION OR PREFABRICATED SOLES

Midsoles are manufactured from a combination of two basic materials: ethyl vinyl acetate (EVA) and polyurethane. EVA is light, has excellent cushioning properties, and can be manufactured in various densities. The firmest densities in a multidensity midsole are usually designated by a darker color. These can be placed at critical points in the midsole to aid in motion control. Polyurethane is a denser, heavier, and more durable material than EVA. New forms of lighter polyurethane are being developed. Both EVA and polyurethane are used to encapsulate other cushioning materials, such as air bags (NIKE), gel (ASICS), silicone (BROOKS), honeycomb pads (REEBOK and PUMA), and EVA (NEW BALANCE).

Some midsoles can be contoured to the foot and are referred to as more stable "anatomic" midsoles.

AIRSOLES

First introduced in 1979 by NIKE, this concept used encapsulated air units in the midsole to enhance cushioning. Ambient air (ETONIC) or freon (NIKE) can also be used. Depending on the model, the air units may be in the heel, forefoot, or both. Initial reports noted that, although air systems had superior shock absorption and potential energy rebound, stability was poor.[26] Shoes with very soft, well-cushioned midsoles allow significantly more motion than firmer shoes, and a poor design can encourage instability. Newer designs have addressed the stability problem with success.

Air systems are not as susceptible to compaction as EVA, polyurethane (PU) and other midsole materials, and are, therefore, thought to be more durable.

ENERGY RETURN

Compression of a viscoelastic midsole material allows a small amount of strain energy to be stored in the compressed elastic components of the midsole. Theoretically, when weight is released, the elastic components spring back and stored energy is returned to the athlete. It has been suggested that by increasing the energy return of a shoe, the oxygen cost of an activity can be reduced and performance enhanced. There is little evidence to support these claims.

INSOLES AND ORTHOTIC DEVICES

There are conflicting reports on the effectiveness of viscoelastic inserts in prevention of stress fractures. Several reports have indicated that viscoelastic materials can lower the force of impact at foot strike[13] and that this property can provide protection from injuries secondary to cyclic vertical loading.[16, 17, 18, 19, 29] Others have reported, however, that viscoelastic insoles do not reduce load on the musculoskeletal system, and, therefore, has little shock-absorbing capacity.[20] One study reported that when added to a military boot, a viscoelastic insole did not significantly decrease the incidence of stress fractures.[11] Furthermore, viscoelasticity has not been shown to significantly reduce vertical impact forces when compared with conventional running shoe insoles.[20]

In one study, Sorbathane was found to reduce the stress transmitted at heel strike by less than 10%.[5] Others have reported that viscoelastic inserts reduce the amplitude of shock waves during gait by 42%.[29, 30]

A recent study compared the material properties of viscoelastic and neoprene insoles, and found neoprene insoles to be less rigid, resistant to shear compression force, and able to reduce transmitted force better than viscoelastic insoles.[2]

Spenco has been investigated as a shock-absorbing insole material in military recruits wearing standard military footwear.[25] It was found that shock-absorbing neoprene insoles can significantly reduce the overall incidence of overuse injuries, specifically tibial stress fractures. They were found to be durable and comfortable by most of the subjects.

It should be noted that not all inserts are useful, and that they may result in more energy consumption when added to a shoe. Furthermore, one study reviewed soft and rigid orthotic devices and no orthotic device in running shoes. Stipes[29] found that the rigid orthotic may diminish the cushioning effect of running shoe and decrease its ability to absorb vertical impact force.

TREATMENT WITH INSERTS

Patients suffering from a metatarsal stress fracture report pain with the push-off[1] phase of gait, when the toes are dorsiflexed and the heel is off the ground with weight borne on the metatarsal heads. If during gait the foot is held rigid, this will eliminate the motion at the metatarsophalangeal joints, and the pain will decrease. This can be accomplished with a steel bar placed on the sole of the shoe,[1] a rocker sole, or other stiff material placed in the midsole. A patient may also get pain relief by a felt pad placed along the medial longitudinal arch to redistribute weight. A custom-molded semiflexible insert with a medial longitudinal arch support may also be used for the same purpose.

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