PREMIER PODIATRY
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Socks (by Doug Ritchie)

For the serious athlete, socks have become recognized as an essential component of footwear that can determine the difference between success or failure on the playing field. Unfortunately, for the sports medicine professional, the role of socks in preventing injury and in enhancing performance is misunderstood and often neglected in treatment protocols.

Recreational and competitive athletes can receive state-of-the-art information on sock fiber technology and construction techniques from premium sporting goods vendors and technical publications peculiar to their sport. On the other hand, health care professionals receive no formal training on the topics of footwear or hosiery, yet, they are called upon regularly to give information to patients and the lay public in these unfamiliar subject areas. No wonder that physicians and podiatrists are often quoted in consumer magazines giving erroneous information about socks and footwear.

It is refreshing to see the subject of "socks" included in this comprehensive program of topics relative to the field of podiatric sports medicine.

Historical Review:

There were virtually no original scientific articles pertaining to hosiery published in the medical literature until 1989. Then, almost overnight, clinical researchers recognized that major advances had been made during the 1980s in the fields of fiber technology and sock construction techniques. Hosiery now appears like high-tech sports equipment with possible medical applications. A large number of studies were carried out on various patient populations, including athletes, to determine the role of hosiery in preventing pedal pathologies.

A series of articles published by Andrew Boulton and Arisites Veves at the Manchester Royal Infirmary documented the protective effect of hosiery on the feet of diabetic and arthritic patients. At the same time, Herring and Richie published their studies demonstrating the superiority of acrylic fibers over cotton fibers in preventing the frequency and severity of friction blisters in running athletes.

A significant amount of published research then followed, documenting attempts to utilize hosiery products to treat various clinical conditions. Ufer and co-workers studied the effect of hosiery to warm the feet of patients with spastic quadriplegia. Wolfe and Palladino conducted a study to determine the effect of hosiery on friction blisters and racquetball players. The effect of over-the-calf sports socks to reduce swelling in the feet and legs was reported by Brown and Brown.

The United States military, plagued with ever-increasing blister frequency in military recruits, carried out their own research documenting the ability of various sock systems to reduce friction blisters. These prospective studies demonstrated the highest level of scientific investigation attempting to determine the effect of various sock fiber combinations on the feet of a large number of human subjects engaged in marching and running.

The principles proven and validated by these studies is the foundation of this presentation. The subject areas covered are those of most interest to the sports medicine health care professional: fiber technology, friction blisters, sports specific challenges and shoe-fitting applications.

Socks and Foot Pathologies

The following foot pathologies can be directly affected by the type of hosiery worn by the athlete:

Toenails: subungual hematoma, onychomycosis, onychogryphosis

Integument: friction blisters, hyperkeratoses, heloma dura/molle

Infections: dermatophyte, yeast, bacteria, viral (verruca)

Mechanical or Shear Induced Injury of Subcutaneous tissue: capsulitis, bursitis, calcaneal fat pad atrophy

Mechanical or Shear Injury Against Bone Prominence: retrocalcaneal exostosis, sesamoiditis, hallux valgus, tailor's bunion, accessory navicular, tibial crest periostitis, medial and lateral malleolar contusion

Causes:

The forces involved in generating the above-mentioned tissue injuries include ground reaction forces, tangential shearing forces, and a combination of pressure and shear induced by athletic footwear.

Numerous researchers have demonstrated that ground reaction forces can approach or exceed three times body weight in a running athlete. In addition, vertical plantar pressures against the calcaneus and metatarsals are significantly increased in the running athlete as well as special patient populations with foot deformities, i.e., rheumatoid arthritis and diabetes mellitus with neuropathy.

Shearing forces result from forward or sideways momentum of the athlete whether walking, jumping, running, or lunging. Spence and Shields identified four types of dynamic forces that can be associated with running gait: vertical forces, fore and aft shear, lateral shear, and torque. Shearing force on the skin surface of the foot is exacerbated by the type of playing surface, type of footwear, type of insole, and type of sock material. Shearing forces are thought to be more damaging to the feet than ground reactions forces. The combination of abnormal pressure and shear results in the formation of friction blisters in athletes and ulcerations on the feet of patients with diabetes mellitus.

In addition to the abnormal forces generated by the specific movements of the sport, the type of footwear worn by the athlete can generate unique damaging pressure and shear in specific areas of the feet or legs. The following unique forms of athletic footwear and the various locations of potential skin or deep tissue damage are illustrated in the following tables.

The Fiber Story

The ability of a sock to dissipate damaging forces on the surface of the foot rests partly on the fiber composition and more significantly on the construction technique of the manufacturer. It is the lack of understanding of fiber technology that leads most health care professionals to make erroneous recommendations to their patients regarding selection for sporting activities.

Fibers that absorb moisture are termed hydrophilic while fibers repelling moisture are hydrophobic. Cotton fiber retains three times the moisture of acrylic and fourteen times the moisture of CoolMax®. When exposed to ambient air, socks composed of cotton retain moisture ten times longer than acrylic. In descending order of hydrophilic ranking, the following fibers are listed: cotton, wool, acrylic, CoolMax®, polypropylene.

During initial activity, moisture absorption from the feet becomes a desirable feature. In athletic activity, perspiration output on the feet can exceed one pint per foot. A large part of this moisture may actually accumulate in the feet as it is produced elsewhere on the body surface and drips down the legs due to gravity. Nonetheless, this volume of fluid far exceeds the absorptive capacity of any sock product. Therefore, to minimize moisture accumulation on the skin surface, the sock must set up a wicking gradient to the shoe.

Ideally, a wicking gradient occurs when the shoe upper is breathable (i.e., nylon mesh) so that ambient air encourages evaporation of water vapor. More commonly, a shoe liner or upper will contain hydrophilic fibers that draw moisture from the hydrophobic sock material. Socks that are extremely hydrophobic (i.e., polypropylene) are thought to repel water so effectively that wicking cannot occur. Socks of intermediate hydrophobic range, i.e., wool and acrylic, allow movement of water but will not absorb and retain water like cotton fibers will. Degrees of hydrophobic qualities alone, however, don't determine overall wicking capacity.

The mechanical structure of the fiber and compressibility of the fiber will determine overall wicking potential. CoolMax® fibers have four channels built into their cross-sectional geometry giving a 20% higher perimeter area than traditional round fibers. The result is higher water/vapor transport through enhanced surface exposure for capillary action.

Natural fibers (cotton-wool) when laden with moisture, compress more easily than synthetic fibers (acrylic, CoolMax®). Thus, cotton and wool socks have a higher resistance to sweat transport of wicking. When wet, acrylic fibers swell less than 5% while cotton swells 45% and wool swells 35%. Swollen fibers that are compressed reduce air spaces and thus reduce moisture transport. Thus, cotton socks exhibit a 2.4 times higher resistance to moisture transport.

When combining hydrophobic qualities and mechanical fiber qualities, the fibers that wick moisture best are, from best to worst: CoolMax®, acrylic, polypropylene, wool, cotton.

In studies conducted on runners wearing synthetic fiber socks vs. cotton socks, other significant differences surfaced regarding preferability of fiber composition. Cotton fiber socks, when wet, were observed to stretch and lose their shape inside the shoe. This led to bunching and wrinkling of the socks compared to acrylic fiber socks. After multiple wash-wear cycles, cotton fiber socks were noted to become abrasive leading to potential irritation on the skin surface of the athlete.

In some sport applications, the thermal-insulation quality of the fiber composition becomes critical. New synthetic fibers composed of a hollow core material known as Thermax¨ have been shown to effectively insulate against heat loss. Natural wool fiber socks are still preferable in the outdoor industry because of their remarkable ability to maintain heat while wet. However, the abrasive nature of 100% wool fiber socks has required the blending of wool into other high-tech synthetic fiber materials.

Blisters and Other Skin Injuries

Friction blisters are among the most common foot injuries affecting the athlete. Blisters on the feet are even more prevalent and debilitating in military recruits. A study performed on 357 marine recruits at Parris

Island, South Carolina, revealed a 69% prevalence of blisters during a four-month period of training. Blisters serious enough to warrant medical evaluation at sick call occurred in 24.4% of all trainees. It has been estimated that over 5,000 Basic Trainees at Lackland Air Force Base were treated for friction blisters during one calendar year in 1990.

Factors necessary for friction blisters are shear force, pressure and moderate levels of moisture. All of these forces can be mitigated by a proper sock system.

Herring and Richie investigated the role of fiber and sock construction techniques in the prevention of blisters on the feet of running athletes. Their findings demonstrated that acrylic fiber socks will have less blisters and smaller blisters than cotton fiber socks. In addition, athletes were able to determine a drier foot with acrylic socks compared to cotton.

These findings were significant only when socks were constructed with dense terry padding rather than in generic "cushion-sole" socks.

Plagued with ever-increasing frequency of blisters, the United States Military conducted three randomized prospective studies on various sock systems. The standard military issue sock is a 50% cotton and 50% wool cushion-sole sock. The three studies attempted to compare newer fiber construction techniques and double-layer technology to reduce blister frequencies.

In a study of 357 marine recruits on Parris Island, South Carolina in 1992, the use of a CoolMax® liner with a heavily padded terry design outer sock using a wool/polypropylene blend significantly reduced blisters compared to a single layer sock (40% vs. 69%). Adding a CoolMax® liner to the standard sock significantly reduced sick call visits (24.4% standard vs. 9.4% standard with liner).

Another study of 1,079 soldiers in 1993 tested five sock systems on blister frequency and acceptability by soldiers. Synthetic fiber socks significantly outperformed the standard wool sock. Adding a CoolMax® liner to the wool sock significantly reduced blisters. When comparing single, extra-thick acrylic padded socks to double layer sock-systems, the double-layer system was superior owing to the shielding of the open terry loops from the skin surface and the movement interface created by the double-layer system. Three other military studies have demonstrated a blister prevention superiority of double sock systems vs. single layer socks.

Fitting

Proper fitting of athletic footwear is critical for comfort, injury prevention, and performance. Fitting of shoes, particularly athletic shoes, is a lost art in the modern retail marketplace. The emergence of high-tech sports hosiery products has made the shoe-fitting process even more difficult.

Shoe and foot measurement techniques are archaic in today’s modern athletic footwear industry. The Brannock measuring device was developed in 1927, long before athletic shoes were developed and long before high-sports specific hosiery products were invented. The majority of modern-day athletic footwear are manufactured overseas in third world countries where sizing parameters vary significantly even within the same single factory.

In 1995, the author conducted a shoe fit study for a premium sports hosiery company. The results of this study revealed the following:

1) Measuring feet barefoot with a Brannock device successfully predicted accurate athletic shoe size only 30% of the time.

2) When subjects wore a standard cushion-sole sock and were measured, accuracy for shoe size improved 10%.

3) When measuring a subject barefoot (as recommended by the Brannock Company), and then fitting the subject with athletic shoes and thick sports specific socks, the Brannock measurement was accurate only 15% of the time (an 85% failure rate!).

4) When measuring a subject with thick sports specific sock standing on the Brannock device, the accuracy for predicting proper shoe size improved by 10%.

5) When wearing properly fitted shoes with a generic sports sock, adding a thick heavily padded sock demanded an increase in length of shoe 77% of the time.

Therefore, measuring an athlete with a Brannock measuring device has minimal value when correlating with shoe sizes of modern day athletic footwear. Still, the skill of the fitter can allow translation of the shoe size to an "adjusted size" based on a knowledge of inventory and peculiarities of brand-size characteristics. The athlete should be measured and fitted wearing the specific sock that will be ultimately worn with the footwear. This is a reversal of the normal fitting process in most athletic shoe stores where socks are purchased as a "add-on" after shoes have been fitted.

Sports Specific Applications

Sports-specific socks were pioneered by ThorLo in the early 1980's. Soon, all major sock manufacturers followed with socks packaged and presumably designed for specific sports, i.e., tennis, golf, running, etc. What began as functional differentiation for a few key sports has led to a bevy of sock packaging techniques and marketing hype with products designed for every conceivable activity. In reality, there is very little technical difference within any particular company in the design of their hosiery products for various individual sports. In the end, however, the zeal of the American public to purchase socks specific for each sport has spawned a $250,000,000 industry.

Socks should be designed specific to the shoe, rather than the sport itself. The biomechanical movement and stresses of recreational and competitive sporting activities vary greatly. Designing a sock to mitigate those stresses has resulted in very similar features, despite the varieties of foot stresses found in each sport. What carries more variation are the shoe designs and the environmental challenges of the sport. Here, sock design in the upper and fiber composition can be varied greatly to meet the demands peculiar to the sport.

The following table gives examples of sock design and fiber variations as well as the sports applications that are best suited.

Construction Techniques of Athletic Hosiery

Upper Design & Sport Activity

- **Over-the-calf:** Baseball, Basketball, Outdoor (including liners) Ski, Snowboard, Soccer
- **Mid-calf:** Skate
- **Slouch:** Aerobics
- **Crew:** Running, Golf, Tennis, Racquetball, Hiking

Construction

- **Thin or Thin Double Layer Outdoor(liners)**, Cycling, Running (racing), Skiing

- **Padded or Thick Double-Layer** Jogging, Skiing, Hiking, Tennis, Basketball

Fibers

- **Acrylic:**Golf, Tennis, Hiking

- **Acrylic/Wool:**Outdoor-Cold

- **Acrylic/Thermax®:**Outdoor-Cool
- **Acrylic/CoolMax®:** Outdoor-Warm
- **CoolMax®:** Running, Cycling, Liners
- **MicroSafe®:** Therapeutic Hosiery, i.e., Diabetes

Tips

- Pick the right sock for the right sport.
- Use synthetic material. Use proper shoes and fit them with the socks you plan to wear while playing ball.