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The blister guard [trademark symbol] system teflon® sock

Jeb M. Burns
San Jose State University

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THE BLISTER GUARD™ SYSTEM TEFLON® SOCK

A Thesis

Presented to

The Faculty of the Department of Human Performance

San Jose State University

In Partial Fulfillment

of the Requirements for the Degree

Master of Arts

By

Jeb M. Burns

May 1998

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APPROVED FOR THE DEPARTMENT OF HUMAN PERFORMANCE

Dr. Bethany Shifflett

Dr. Barbara J. Combs

Kyle Bodyfelt

APPROVED FOR THE UNIVERSITY

Serena H. Stanford

ABSTRACT

THE BLISTER GUARD™ SYSTEM TEFLON® SOCK

by Jeb M. Burns

The purpose of this study was to determine if there was a significant difference in the occurrence of friction blisters with the use of the Blister Guard™ System Teflon® sock when compared to the use of a non-Teflon® athletic sock. Seventy seven San Jose State University students (76 female, 1 male) enrolled in four aerobics classes taught by the same instructor participated in the study. Subjects wore either the Blister Guard™ System Teflon® sock or a non-Teflon® athletic sock during participation. The subjects participated in eight classes over a 4 week testing period. They reported the results of blister occurrence daily and gave personal ratings of the socks upon completion of the experiment. No statistically significant difference in the occurrence of friction blisters was found between the Blister Guard™ System Teflon® socks and the non-Teflon® athletic socks. Both groups reported high ratings for various characteristics of the socks.

DEDICATION

I would like to dedicate this project to my family David, Nancy, Sidra and Jasmine for their unconditional belief and faith in my ability to accomplish anything that I want. I also dedicate this project to Charlie Murdach, Dawn Carter, and Rosa Lua for their undying friendship and their constant support throughout the development of this thesis.

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Chapter 1

INTRODUCTION

For as long as individuals have been active, friction blisters have been associated with prolonged activity. Blisters are the skin's response to repeated rubbing against a frictional surface (Bergeron, 1995). The frictional surface induces a shear stress that causes the skin to separate into two layers and the resulting space fills with fluid (Elston & Bergfeld, 1994). Friction blisters could potentially occur anywhere on the human body, but are primarily found on the soles and palms. Bergeron indicates that these are areas with a thick stratum corneum, or outermost skin layer. Consequently, this thickened area of skin is less susceptible to abrasions but more likely to form blisters. The soles and palms also are the two areas of skin that frequently come into contact with shearing forces, such as found with running, rowing, and aerobics.

Friction blisters commonly occur on the soles of the feet (Reichel & Laub, 1992). Unfortunately, friction blisters can be very painful, which can result in either an impairment, or complete cessation of an activity. Active people who are on their feet for prolonged periods of time can find a blister to be very disabling. Whether it is an athlete or military personnel, a friction blister can temporarily prevent physical activity.

Over the years, people have come up with various ways to minimize the occurrence of friction blisters in active individuals (Knapik, Reynolds, Staab, Vogel, & Jones, 1992). Techniques currently used include padded or multiple layers of socks, petroleum jelly, and moleskin. No technique currently used today has been proven to significantly prevent the occurrence of friction blisters. Since friction blisters continue to be an every day problem, research has attempted to find effective and efficient ways to treat friction blisters (Bergeron, 1995). A common treatment for friction blisters is the application of an occlusive dressing, which aids in expediting the healing process and prevention of possible infection. Unfortunately, this is only treating the symptoms and not preventing the cause.

The primary purpose of this study was to investigate a new product's ability to prevent friction blisters from occurring. The new product used in this experiment was a sock which incorporated Teflon® fibers into its construction. This Teflon® sock was called the Blister Guard™ System and promotional materials advertised its ability to reduce frictional forces against the skin of the foot. In theory this reduction in frictional forces would help to diminish the occurrence of friction blisters.

Research has demonstrated that friction is the primary cause of blisters found around an active individual's foot (Akers & Sulzberger, 1972). Experiments conducted over the past 40 years have attempted to find ways to reduce the amount of friction surrounding the foot. Knapik et al. (1992) demonstrated that either a very dry or very wet surface will result in a decrease of friction. This is compared to the relatively high friction found around a moist foot, such as with a sweaty sock. According to Herring and Richie (1993) most research has involved techniques that attempt to keep the foot as dry as possible. The theory being explored was that a dry foot would experience minimal friction with the sock and/or shoe. Consequently this reduced friction would diminish the occurrence of blisters. Herring and Richie stated that some of these studies have demonstrated a decrease in the occurrence of friction blisters. However a method of blister prevention has yet to be discovered.

There has also been research which examined the effect lubrication of the human skin has on the occurrence of friction blisters (Sulzberger, Cortese, Fishman, & Wiley, 1966). Both Akers (1985) and Naylor (1955a) used different types of lubrication, materials, and methods in order to demonstrate a decrease in friction on the skin. Although a moist area can increase the coefficient of friction around the skin, Akers and Naylor's research examined the effect that hyper-hydrating the skin or lubrication has on reducing the amount of surrounding friction. However, an effective means for keeping the foot hyper-hydrated and/or well lubricated over a long period of time has yet to be developed.

Other studies also attempted to demonstrate whether different types of material would cause a decrease in the amount of friction on the skin (Comaish & Bottoms, 1971; Naylor). Materials studied in these experiments include different cloth types, metals, and Teflon®. A number of these types of studies were conducted in the 1950's through the early 1970's. Typically the experimental designs involved the formation of actual blisters on human subjects. Due to the necessary constraints placed on the use of human subjects in research conducted today, the replication of these studies would not be possible. However, the experiments did investigate the prevention of friction blisters.

The most efficient way to deal with friction blisters would be to prevent them from occurring. Due to the high incidence and debilitating characteristics of friction blisters there is a definite need to find an appropriate means of prevention. Prevention of friction blisters would spare many active individuals from the inconvenience and impairment that they cause. This would result in a significant decrease in the loss of time from activity and/or work.

Purpose of Study

Can friction be diminished to the point that friction blisters are prevented from occurring on the human foot? The purpose of this study was to determine if there is a significant difference in the occurrence of friction blisters with the use of the Blister Guard™ System Teflon® sock when compared to the use of a non-Teflon® athletic sock.

Hypothesis

There will be no statistically significant difference in the proportion of subjects sustaining blisters as a function of sock type.

Limitations

The study was limited to the following factors:

1. The individual skill level of the participants.

2. The type of shoes worn during participation.
3. The condition of the shoes worn during participation.
4. The height and weight of the participants and the resultant variance in shear forces placed on each individual's feet.

Delimitations

The study was delimited to:

1. San Jose State University students enrolled in four Human Performance aerobics classes taught by the same instructor during the spring semester, 1998.
2. Students who participated in an average of two workouts per week for the first 4 weeks of instruction. This resulted in each student participating in a total of eight aerobics class workouts.
3. The use of either the Blister Guard™ System Teflon® sock or a non-Teflon® athletic sock, dependent upon random group assignments, for each of the aerobics classes attended during the testing period.

Assumptions

1. Two aerobic class workouts per week were sufficiently intense to result in the occurrence of friction blisters.
2. Individual's motivation and intensity levels were similar to each other and sufficient enough to potentially produce friction blisters.
3. Participants responded honestly to the Personal and Health Questionnaire.
4. Participants reported friction blisters accurately and as soon as they occurred.
5. Participants reported only friction blisters that occurred as a result of participation in the San Jose State University Human Performance aerobics classes.

Definition of Terms

Friction. Friction is a force between two objects that attempts to prevent them from moving over one another (Akers, 1985).

Coefficient of Friction. The coefficient of friction is the largest amount of friction between two objects that must be overcome for movement to occur (Knapik, Reynolds, Duplantis, & Jones, 1995).

Shearing Forces. A shearing force is a force applied parallel to the planes of an object but opposite in direction to whatever force is present (Knapik et al., 1995). During active movements the foot can experience lateral, horizontal, vertical, and/or rotational types of shearing forces.

Importance of the Study

The purpose of the study was to examine whether or not the use of Blister Guard™ System Teflon® socks resulted in a difference in the occurrence of friction blisters when compared to non-Teflon® athletic socks. Athletic socks are commonly worn during physical activity. According to Herring and Richie (1993) among individuals using athletic socks during physical activity, there continues to be a high incidence of friction blisters. The debilitating characteristics and high incidence of blisters demonstrates the need for an appropriate means of prevention. A significant decrease in, or prevention of, friction blisters would spare many active people the inconvenience and impediment that they cause. Diminished blister occurrence could also result in a decrease in the loss of time from activity and/or work. Research exploring the potential for blister prevention has not been conducted for some years now. This experiment can facilitate future investigations and experiments regarding the decrease in the incidence of friction blisters.

Chapter 2

REVIEW OF LITERATURE

Introduction

Over the years there have been a number of theoretical ideas and empirical studies that have focused on friction blisters. Akers and Sulzberger (1972) documented studies on the cause and prevention of friction blisters that primarily began in the military during the 1960's. To this day there are still discrepancies concerning the appropriate means for preventing friction blisters. To demonstrate the need for continued research in prevention of friction blisters research has been done on the epidemiology of such skin lesions (Knapik et al., 1992). Given that there is a need for improved methods of prevention, there have been a variety of studies trying to demonstrate a decrease in friction blister occurrence when using antiperspirants, drying powders, and varied sock fiber composition (Knapik et al., 1995). More traditional research has studied conventional methods of prevention, such as breaking in new shoes, conditioning the foot, and use of moleskin.

Nature of Musculoskeletal Injuries

A recent survey conducted by the National Center for Health Statistics recorded more than 4.3 million sports and recreational injuries annually in the United States. Sports accounted for 36% of injuries from all causes (Bernhardt, 1997). Not only are injuries abundant in nature, but they occur in a variety of areas as well. With respect to soft-tissue injuries the structures that are injured include muscles, tendons, and ligaments. However, for a thorough description of musculoskeletal injuries, bone damage must be described as well.

Muscles, tendons and ligaments are tissues frequently injured during athletic activity. Arrington and Miller (1995) stated that skeletal muscle constitutes the single largest tissue mass in the body, making up 40% to 45% of the total body weight. It is no wonder that this tissue is commonly injured. Skeletal muscles' primary function is to bring

about movement. Arrington and Miller described skeletal muscle as being attached to bones via tendinous insertions. When a muscle contracts it shortens in length, pulling on a tendon and its' bony insertion, resulting in joint motion and locomotion. Most muscle injuries are caused by a direct stress. Direct injuries to a muscle can include muscle strains, contusions, and cramps.

Tendons are comprised of dense fibrous tissue and serve as the connective medium which attach muscle to bone (Anderson & Hall, 1995). The force of a muscle contraction pulling on a tendon causes a bone to move, which can result in joint and limb movement. An acute injury to a tendon is usually in the form of a strain. A chronic injury to a tendon is typically termed "tendinitis", which means inflammation of a tendon (Anderson & Hall).

Ligament is another connective tissue comprised of dense fibrous tissue. According to Anderson and Hall (1995) a ligament's primary function is to connect bone to bone. Ligaments are found in all joints of the body and play an important role in maintaining a joint's integrity. Arnheim and Prentice (1993) stated that the primary protection for a joint comes from the dynamic aspect of muscles and tendons, while ligaments act as a protective backup.

Bone serves to provide body support, organ protection, movement, a reservoir for calcium, and the formation of blood cells (Arnheim & Prentice, 1993). Through the action of the attached muscles, bones are moved enabling locomotion to occur. Buckwalter (1996) indicated that immobilizing a limb or gross inactivity can cause bone to weaken and become more susceptible to injury. As seen in soft-tissue injuries, bone is also susceptible to acute and chronic injuries. Acute injuries to bone include bone contusions and a large variety of fractures. Stress fractures are a very common chronic injury seen in bones.

Acute Musculoskeletal Injuries

The musculoskeletal system is often times inflicted with a variety of acute types of injuries. The unique functions and large mass of muscles make this soft tissue susceptible

to a variety of acute injuries including contusions, cramps, and strains. Arrington and Miller (1995) described a muscular contusion as being a blunt injury to the muscle where external forces are in either direct or indirect contact with the tissues, thereby transferring energy from the object to the body. A contusion can result in damage and partial disruption of the muscle fibers (Bernhardt, 1997). A few sources indicated that lower extremity contusions are more common than upper extremity contusions, and are primarily seen in the quadriceps muscle group (Arrington & Miller; Bernhardt; Best, 1997). A contusion can cause damage to capillaries leading to intramuscular bleeding, which can result in the formation of a hematoma. Arrington and Miller defined a hematoma as a collection of pooled blood within the intramuscular space that can cause pain and a reduction in muscle strength.

Muscle cramps are an acute soft-tissue injury commonly seen in both active and inactive people. A muscle cramp is an involuntary contraction of the muscle and can be very painful (Zecher & Leach, 1995). The exact cause of muscle cramps is not known, however, theoretical causes include dehydration, muscle fatigue, and electrolyte imbalance. Although muscle cramps are not a serious injury they can be painful and debilitating.

A very common and painful acute soft-tissue injury seen in the active environment is an acute muscle strain. Best (1997) defined muscle strains as a tearing of a muscle most commonly seen in explosive movements when the muscle is eccentrically contracting. An eccentric contraction is when the muscle is contracting while being lengthened. Examples of explosive movements causing muscle strains are sprinting and jumping. Eccentric contractions involved with lowering a weight during weight lifting is another common cause of muscle strains. Muscle strains, which vary in severity, can range from being a minor nuisance to preventing activity over a prolonged period of time.

Acute tendon injuries include strains, ruptures, and contusions. Similar to muscle injuries, tendons can be injured in the same fashion. According to Best (1997), explosive

and/or eccentric motions that can cause a muscle strain could also strain a tendon. These same actions could potentially cause a much more severe acute injury, a tendon rupture. Zecher and Leach (1995) indicated that the Achilles tendon and biceps brachii tendon are most commonly ruptured. In order for a return to pre-injury status, surgery is usually required with a tendon rupture. Comparatively less severe, a tendon contusion may be accompanied by mild pain and minimal cessation from activity.

Bernhardt (1997) defined the acute injury to a ligament resulting in some degree of tearing as a sprain. As stated earlier, ligaments serve to attach two bones together and can resist forces in several directions. Therefore, ligaments can be damaged from a variety of forces such as rotation, valgus, or varus forces (Bernhardt). Ligament sprains can be very painful and debilitating depending upon which ligament is injured and the severity of the damage. Most ligaments are allowed to heal on their own. However, a torn anterior or posterior cruciate ligament, found in the knee joint, is commonly surgically replaced. Surgery is indicated in these situations in order to return to full activity.

Arnheim and Prentice (1993) indicated that contusions or fractures are acute injuries to bone. A blow to the bone can result in a bone contusion. Bone contusions are not severe, as far as structural damage is concerned. However, they can be very painful. Arnheim and Prentice described fractures as the most common acute injury seen in bones. They defined a fracture as a partial or complete interruption in a bone's continuity. Any bone is susceptible to being fractured. In most cases a fracture must be immobilized over a period of months in order for proper healing to occur. Consequently, activity must be modified in order to accommodate the wearing of a cast or a brace.

Chronic Musculoskeletal Injuries

Chronic injuries to the musculoskeletal system can involve a muscle, tendon, or a bone. Chronic muscle strains occur from over working muscle, which can cause muscle fatigue (Arrington & Miller, 1995). Arrington and Miller also stated that chronic muscle

strains can be caused by prolonged over use or a single episode of over activity. Chronic muscle strains are typically not as severe as an acute strain. However, they do serve as an important indicator of when too much of an activity is being performed.

Anderson and Hall (1995) defined tendinitis as the inflammation of a tendon and is a highly prevalent chronic injury. Similar to a chronic muscle strain, tendinitis can be caused by prolonged over use or a single episode of over activity. The inflammation can inflict the tendon or the synovial sheath of the tendon, termed tenosynovitis (Arrington & Miller, 1995). Tendinitis can occur in any overworked tendon in the body. The symptoms of pain are more prevalent in the mornings and decrease once the tendon has warmed up.

Stress fractures are a common chronic injury sustained by bones (Arnheim & Prentice, 1993). Stress fractures are believed to be the result of a change in training methods or intensity that introduces a new repetitive stress (Zecher & Leach, 1995). Reeder, Dick, Atkins, Pribis, and Martinez (1996) stated that stress fractures can be caused by repetitive, cyclic loading of bone which overwhelms the reparative ability of the skeletal system. In general, a repeated stress to a bone causes it to be broken down faster than it can repair itself, resulting in a stress fracture. Reeder et al. indicated that stress fractures are not readily visible on an x-ray and typically present pain localized to the site of the fracture.

Various symptoms of musculoskeletal injuries can inhibit performance. Most soft-tissue injuries result in pain and inflammation. The level of activity that can be maintained after a soft-tissue injury has occurred is dependent upon the amount of tissue damage and individual pain tolerance. Chronic and acute soft-tissue injuries with small amounts of inflammation can often times be tolerated with only minor modifications in activity. Severely painful and inflamed tissue may require either cessation or a significant modification in activity. The amount of time needed for full recovery is dependent upon

many factors including severity of injury, age, health, and the healing capabilities of the individual involved.

Stress and acute fractures of a bone usually result in a large modification of activity. An acute fracture will typically have to be placed in a cast or braced. Activities allowed during this time period include those that do not involve stressing the fractured bone in a negative manner. Overall, musculoskeletal injuries can occur in many different situations and must be treated appropriately to prevent further complications from arising.

Having reviewed the general characteristics of musculoskeletal and soft-tissue injuries, and given the focus of this study, a more thorough description of musculoskeletal and soft-tissue injuries is needed. Therefore, a detailed explanation of common injuries to the lower extremities will be discussed in the following sections.

Common Lower Extremity Injuries Related to Athletic Activity

Athletic activity can cause a variety of injuries to the ankle and foot. Sprains, fractures, stress fractures, tendinitis and an assortment of skin conditions are all examples of injuries to the ankle or foot. All of these injuries can be brought on by different types of athletic activities, making any active individual potentially susceptible to injury.

Musculoskeletal Injuries to the Lower Extremity

Studies have reported that ankle sprains are the most common injury among recreational and competitive athletes (Bennet, 1994; Clanton & Porter, 1997; Grana, 1995). The general consensus within these studies was that 80% to 90% of ankle sprains occur on the lateral side. Feit and Berenter (1993) described the mechanism of injury for a lateral ankle sprain as a combination of plantar flexion and inversion, otherwise known as “rolling the ankle in.” The severity of a lateral ankle sprain is graded upon the amount of ligament damage incurred and the number of ligaments involved. Hamilton (1994) described a grade one sprain as a partial tear, usually of the anterior talofibular ligament. A grade two sprain is usually a tear of the anterior talofibular ligament with the calcaneofibular ligament

remaining intact. Grade three sprains are a tearing of both of these ligaments, with possible posterior talofibular ligament involvement. Bennet indicated that a grade one sprain may have minimal or no swelling. This is in contrast to grade two or grade three sprains, which may have large amounts of swelling and require the use of crutches.

Grana (1995) stated that a majority of ankle sprain patients recover uneventfully, returning to full function and normal activity within four to eight weeks. Unfortunately, inadequate rehabilitation or a return to activity too soon can result in chronic ankle problems. Clanton and Porter (1997) characterized a chronic ankle sprain as one that an athlete relates to as a recurring problem, or may complain of looseness of the ankle and frequent “turning under” or “giving away.” Grana described that patients suffering from a chronic ankle sprain also complain of difficulty walking on uneven ground, locking, crepitation (grinding sensation within the joint), swelling, and stiffness. Fortunately, with proper treatment and rehabilitation, a patient suffering from either an acute or chronic ankle sprain can recover fully.

Fractures to the foot are a common injury and are usually the result of direct trauma (Maier & Pietrocarlo, 1991). Clanton and Porter (1997) wrote that fractures at the base of the fifth metatarsal, which are called Jone’s fractures, are the most common metatarsal fracture seen. Maier and Pietrocarlo described a Jone’s fracture as commonly seen with and caused by an inversion ankle sprain. Although any bone in the foot is susceptible to fracture, the metatarsals are the most commonly fractured. The typical treatment for foot fractures is to cast and/or immobilize the bone. The immobilization period is typically six to twelve weeks, but is dependent upon various factors influencing healing times such as the type of fracture and the health of the injured individual. Hamilton (1995) indicated that the Jone’s fracture is most likely to be surgically operated upon due to its high incidence of non-union. However, most fractures heal uncomplicated with quick return to activity.

Maier and Pietrocarlo (1991) defined lower extremity stress fractures as being caused by repetitive stress on the foot for prolonged periods of time or a rapid, unaccustomed increase in activity. They are most commonly seen in the metatarsals, but may involve any of the bones of the foot. Manusov and Lillegard (1996) presented the second metatarsal as the most common foot bone afflicted by stress fractures. Stress fractures are one result of overuse activities or doing “too much, too soon.” The physiological response causing stress fractures occurs when the ability of a bone to repair the micro-damage of repetitive loading is exceeded (Reeder et al., 1996). Gellman and Burns (1996) reported that typical signs of stress fractures include pain with prolonged activity and point tenderness over a discrete local area. The treatment protocol for stress fractures involves a modification of activity that allows for as much pain free activity as possible. Only in extreme cases is immobilization or bracing of a stress fracture necessary.

Gellman and Burns (1996) gave the simple definition of tendinitis as inflammation of a tendon. Tendinitis can present itself acutely or chronically and is an injury that often afflicts tendons of the foot. It was indicated in the literature that the tendons of the foot and ankle most commonly afflicted with tendinitis are the Achilles, posterior tibialis, and peroneus longus tendons (Gellman & Burns; Hamilton, 1994). Lutter (1994) identified the Achilles tendon as the most common of these three tendons to demonstrate signs and symptoms of tendinitis. Clanton and Porter (1997) associated acute cases of Achilles tendinitis with a large increase in athletic work load. However, they described chronic Achilles tendinitis as being caused by an acute process that was never eliminated, or more commonly, a process that has become recurrent and episodic. Treatments of tendinitis were commonly described in literature as utilizing one or more of the following: correction of training errors, stretching, heel lifts, anti-inflammatory medications, and a short period of cross-training (Clanton & Porter; Lutter; Maier & Pietrocarlo, 1991). Many cases of

Achilles tendinitis can be cured with the use of conservative treatment, however, severe cases lasting over prolonged periods of time may need to be surgically corrected.

An injury similar to tendinitis seen in the foot is plantar fasciitis. Gellman and Burns (1996) defined the plantar fascia as the primary source of support for the longitudinal arch of the foot. They also described plantar fasciitis as one of the most common disorders encountered in runners and walkers. According to Clanton and Porter (1997), plantar fasciitis is a chronic inflammation of the fascia and typically presents pain near the heel. This pain is typically worse in the mornings and at rest, yet can decline with activity. Treatment involves ice, stretching, and modifying activity.

Common Toe Injuries

The toenails are commonly afflicted with a variety of injuries. Injuries to the toenail often times are associated with athletic activity (Maier & Pietrocarlo, 1991). Incurvation of the nail border, termed onychocryptosis, was defined by Burns (1996) as being either congenital or acquired. This condition is also known as an ingrown toenail. Causes of ingrown toenails cited by Manusov and Lillegard (1996) include tight-fitting shoes, improper nail trimming, pressure from the adjacent toe, ground reactive forces, and/or a congenitally thick nail plate. Treatment for an ingrown toenail includes correct nail trimming and proper fitting shoes. In extreme cases, removal of all or part of the nail may be indicated. According to Burns, oral antibiotics and warm soaks may be temporarily effective, but they do not eradicate the problem.

A possible consequence of an ingrown nail is paronychia. Paronychia is defined by Manusov and Lillegard (1996) as inflammation that results from the border of the nail plate growing into the adjacent nail fold. Along with the local inflammation, Burns (1996) stated that infection of the tissue may also occur. Katchis and Hershman (1993) characterized paronychia as being common in athletes and may present swelling, erythema, pain, and a purulent (puss like) discharge. Treatment for paronychia is the same for an ingrown

toenail, as it is usually caused by the nail applying undue pressure to the surrounding tissue.

Another injury to the toenail associated with athletic activity is subungual hematomas. Subungual hematomas are defined by Katchis and Hershman (1993) as a hemorrhage under the nail causing pressure and pain with the possibility of lifting the nail off its' bed. In simpler terms, a subungual hematoma is bleeding underneath the nail. Causes of this nail injury include a crushing injury to the nail or shearing forces transmitted to the nail with repeated jamming of the toe into the tip of the shoe (Katchis & Hershman; Maier & Pietrocarlo, 1991). If the resultant pressure under the nail is too painful to continue with activity it can be relieved with a small hole bored into the nail . The nail should be preserved for as long as possible as it provides protection to the underlying tissue.

Two injuries to the big toe resulting from athletic activity are turf toe and bunions. According to Manusov and Lillegard (1996) turf toe is caused by hyperdorsiflexion of the first metatarsophalangeal (MTP) joint, resulting in a severe sprain of the plantar aspect of the joint. Injury to the first MTP joint was identified by Clanton and Porter (1997) as being common in athletes active on hard surfaces while wearing flexible shoes. Artificial grass, or turf, is one hard surface that hyperdorsiflexion of the first MTP joint commonly occurs on. Hence, the name "turf toe." Treatment of turf toe utilizes immobilization of the first MTP joint and protected weight bearing if needed. Activity may be restricted to a few days or as long as six weeks depending upon the extent of the injury (Clanton & Porter).

Bunions are defined by Manusov and Lillegard (1996) as the development of a prominent metatarsal head at the first MTP joint, scientifically termed hallux valgus. The enlargement of the side of the big toe, known as bunions, is caused by a lateral deviation of the big toe (Maier & Pietrocarlo, 1991). Lateral deviation of the big toe can be caused by tight-fitting shoes and high heel shoes. The deviation of the big toe strains the MTP joint

and exposes part of the joint to possible irritant factors such as rubbing against the side of the shoe. According to Maier and Pietrocarlo, bunions can cause pain, swelling, and redness over the deformity. Treatment may consist of better fitting shoes or in extreme cases, surgery to remove the painful bump and straighten the toe.

Common Skin Lesions of the Foot

Improperly fitted shoes in conjunction with physical activity can lead to skin disorders of the foot. These skin disorders include calluses, corns, and blisters. A callus is defined by Maier and Pietrocarlo (1991) as a localized thickening of the skin caused by excessive pressure. Katchis and Hershman (1993) site other factors as possible causes such as improper footwear, structural abnormalities of the foot, and wounds on the plantar aspect of the foot. Many calluses on the foot are asymptomatic. Thus, it is only the symptomatic or painful calluses that pose a problem. Conservative treatment of calluses outlined by Maier and Pietrocarlo consists of applying moisturizing creams or lotions, padding the area with felt or moleskin, and wearing properly fitted shoes. If conservative methods fail then the callus may need to be removed.

A corn, according to Katchis and Hershman (1993) is a conical wedge of keratinized tissue with the apex pointing toward the subcutaneous tissue. Compared to calluses, corns are more localized and have a deeper central core. Similar to calluses, corns can also be caused by improperly fitting shoes or pressure on one toe by the adjacent toe. Painful corns can be treated conservatively by preventing undue pressure to the afflicted area. Katchis and Hershman stated that painful corns in between the toes can be alleviated by separating the toes or applying moleskin over the area. In more severe cases, removal of the corn may be necessary for an individual to function athletically and/or normally.

Similar to the mechanism of injury for corns and calluses, blisters are a skin condition also caused by improperly fitted shoes. Maier and Pietrocarlo (1991) described blisters as being produced by excessive friction and pressure between the skin of the foot

and either the socks or lining of the shoe. They defined a blister as a separation of the superficial layers of skin with the resultant accumulation of fluid between them. Friction capable of causing blisters can occur in a variety of places within the shoe. Due to the high incidence of friction blisters there are a variety of treatments available. One treatment technique outlined by Katchis and Hershman (1993) included draining and dressing the blister prior to future activity. Other modes of treatment include the use of padded donuts and moleskin. However, according to Katchis and Hershman the best treatment is prevention. Prevention would obviously eliminate the need for treatment, yet an effective method for prevention has not been found. As the occurrence of friction blisters continues to be a problem the need for an effective means of prevention will also continue to exist.

As described, there are a number of musculoskeletal and soft-tissue injuries that can inflict the lower extremity. Of these injuries, friction blisters are one of the most common injuries seen. A more detailed examination of the prevalence, cause, and possible prevention of friction blisters is described next.

Blisters

According to Knapik et al. (1995) friction blisters are one of the most common injuries an active person can experience. Friction blisters may be only a minor annoyance, requiring simple first aid and a short period of limited activity (Knapik et al., 1995). However, Hoeffler (1975) demonstrated that friction blisters could lead to more serious problems such as cellulitis. Friction blisters could also potentially keep an athlete from competing or military personnel from working.

Discussion of friction blisters must cover three important topics. First, a working definition and the biomechanical causes of friction blisters. Second, factors that influence the formation of friction blisters. Finally, the prevalence of friction blisters and the need for studies dealing with the prevention of these injuries.

Biomechanical Causes

Knapik et al. (1995) attributed most blisters seen in athletic and military activities to frictional forces developed between the skin and various objects. The frictional forces causing blisters on the foot are found between the skin of the foot and the surrounding sock or shoe. Knapik et al. (1995) explained that when the skin is in contact with an object (e.g. shoe or sock) and an external force attempts to move the object across the skin, a frictional force will oppose the movement. As an external force on an object is increased, the force of friction between the two objects will increase. Movement occurs when the external force on an object exceeds the force of friction between the two objects. During movement, the force of friction between two objects is exceeded, but not diminished. Force of friction was described by Ramsey (1992) as shearing forces to which the skin may respond either by thickening (callus) or forming blisters. According to Ramsey, blister formation is a two step process. The first step is a tearing between skin layers caused by the shearing forces, which forms a cleft in the mid to lower epidermis. The second process that occurs is a filling of the cleft with fluid via hemodynamic forces.

Bergeron (1995) illustrated the two areas of the skin that form blisters. The two areas described are under or within the epidermis. The epidermis is the outermost layer of skin. Where the epidermis is thin, such as on the sides of the toes, the cleavage (blister) occurs between the epidermis and the underlying dermis. In contrast, where the epidermis is thick, such as the palms and soles, cleavage and subsequent fluid collection often occurs within the epidermis. When comparing these two friction blister sites it is apparent that blisters are more superficial in areas of skin with a thick stratum corneum, or outermost layer of skin, such as the soles of the feet and palms of the hand (Levine, 1982).

Influential Factors In Blister Formation

There have been a variety of experiments using human subjects to examine the cause and prevention of blisters on the human skin (Akers, 1985; Highley, Coomey,

DenBeste, & Wolfram, 1977; Sulzberger et al., 1966). The purpose of these studies was to determine what types of materials increase and decrease friction against the human skin.

Sulzberger et al. (1966) conducted an experiment using the palm of the hand as the testing site. Their testing of water as the lubricating agent had results similar to other studies (Highley et al., 1977; Knapik et al., 1995). Sulzberger et al. found that very low amounts and very high amounts of wetness reduced friction. They also found that moderate levels of wetness increased friction. Sweat could play a large role in the decrease of friction depending upon the material worn next to the skin. The less permeable and absorbent a material is the more it would allow for the sweat to act as a lubricant against the skin. Ideally this could result in decreasing the occurrence of friction blisters.

Comaish and Bottoms (1971) studied some of the factors which affect the coefficient of friction between skin and other materials. The liquid materials used in this experiment included propylene glycol, silicone fluid, liquid paraffin, and dry talcum powder. The sheet materials used were composed of either polythene, nylon, or Teflon® and knitted material composed of either terylene, nylon, or wool. Comaish and Bottoms' experiment tested how different combinations of liquid and sheet materials affected the coefficient of friction against the skin. All three of the sheet materials demonstrated a decrease in the amount of friction measured when combined with either of the four liquid materials. Conversely, all three of the knitted materials resulted in an increase in the amount of friction when combined with the liquid materials. The combination of either silicone fluid or liquid paraffin with either polythene or nylon resulted in the greatest decrease in friction against the skin. Comaish and Bottoms concluded that an appropriate mixture of liquid lubricants and a non-absorbive material lining could decrease the occurrence of friction blisters.

Highley et al. (1977) conducted an experiment on the singular and combined effects Teflon®, polyethylene, water and oil have on the amount of friction against the skin.

Highley et al. demonstrated a lower coefficient of friction for Teflon® compared to that of polyethylene. It was concluded that wetting of the skin with water results in a surface with high friction. In contrast, this experiment demonstrated that a substantial and prolonged decrease in friction is observed with the use of oil. This is dependent, however, on a constant and consistent amount of mineral oil supplied to the area of skin being tested.

Naylor (1955a, 1955b) conducted two experiments dealing with different types of materials and lubricants and the effects they had on the amount of friction against the human skin. Naylor's (1955a) first experiment conducted tests to identify if either silver or polythene friction heads caused a greater decrease in the amount of friction against the skin. No difference was detected between the two types of materials. However, it was concluded that if a rise in temperature can contribute to an increase in friction blisters then a silver material would be more beneficial. This is due to the fact that silver has a higher thermal conductivity compared to polythene. Thus, silver would be able to absorb and conduct heat away from the skin faster.

Naylor's (1955b) second experiment focused on the capabilities of moisture to decrease the coefficient of friction between a material and the skin. Lubrication of surfaces can reduce the amount of friction between them. Thus, Naylor investigated the effects of water and sweat on the coefficient of friction. In this experiment the subject was made to sweat through the use of blankets, hot water bottles, and increased room temperature. Measurements of the coefficient of friction between the skin and the polythene material demonstrated a sharp rise as soon as the subject began to sweat. However, as the amount of sweat increased, the coefficient of friction dropped from 1.0 down to 0.5. Similar results were demonstrated with the use of water as a lubricant. A small amount of water caused an increase in the coefficient of friction compared to a decrease in friction demonstrated with a larger amount of water. Naylor concluded that friction between the

skin and polythene is reduced if the skin is dry, greasy, or very wet. Another conclusion was that friction is increased if the skin is moist.

Nacht, Close, Yeung, and Gans (1981) conducted an experiment which studied the friction reducing capabilities of petroleum jelly. Nacht et al. used a Newcastle Friction Meter to test the friction reducing capabilities of various substances. They found that the application of petroleum jelly caused an immediate decrease in the friction coefficient. As the petroleum jelly was dispersed and absorbed into the skin a constant rise in the friction coefficient was observed. Thus, Nacht et al. concluded that petroleum jelly would prevent the occurrence of friction blisters, but for only a very short period of time.

Epidimeology of Friction Blisters

Knapik et al. (1992) found that friction blisters on the foot were the most common injury associated with road marching in a military sample. In this study the subjects were not sampled randomly and one half of the data was based on self reports. The data did suggest, however, that friction blisters to the foot would be one of the most common injuries encountered when participating in strenuous road marches. Knapik et al. also observed that friction blisters caused the highest number of limited duty days. An interesting aspect of this article was that the doctors examining the feet of the military personnel, who participated in the march, found a much higher incidence of blisters than the number that the participants reported themselves. This suggests that a large number of blisters go unreported.

Ressman (1972) found that many friction blisters occurred in military personnel during basic training. The data was collected using actual military medical records and a random survey of military personnel. The information collected from the medical records provided an accurate source of information on the number of friction blisters that were treated at the military clinic. This information demonstrated that almost 30% of the dermatological problems treated were friction blisters. The random survey was used to

demonstrate that the actual percentages of blisters that occurred might have been substantially higher than those treated. The survey demonstrated that there was a much larger percentage of friction blisters prevalent in the military sample, as many of the blisters did not require clinical treatment. This corroborated with the data by Knapik et al. (1992) that suggested that many friction blisters go either unreported or untreated.

A study done by Hoeffler (1975) demonstrated that a large number of cellulitis cases incurred in the Navy were caused by friction blisters. The data were collected through the use of medical records, a questionnaire, and random surveillance of military personnel. This study concluded that cellulitis of the feet was often times a result of friction blisters. The cellulitis also caused various degrees of disability in Navy personnel. Although there were other causes of cellulitis found, friction blisters were the one predisposing factor most often noted.

Friction Blister Treatment Protocols

Until an appropriate means of blister prevention is found a variety of blister treatments will continue to be utilized. Ramsey (1992) accurately stated that the treatment goals for blisters include maintaining comfort, promoting rapid healing, and preventing infection. An analysis will follow, outlining the two general blister types treated: blisters that are still intact and blisters that have torn, or are no longer intact.

Treatment of an untorn blister entails one of two options. These two options are blister padding and blister aspiration. According to Bergeron (1995) accidental rupture of smaller blisters, as well as the resulting open wound, can be avoided by taping a doughnut-shaped pad over the blister. Two advantages of padding a blister are protection against unintentional rupture and reduction in patient discomfort. Ramsey (1992) described the use of felt ring-shaped pads to protect small blisters, while larger lesions may need larger pads applied around, but not directly on the blister. Blister pads can be bought commercially pre-made or can be custom made from either thin felt or foam padding material.

According to Bergeron (1995), when the blister is larger than approximately 5 mm and on a weight-bearing area, the best tactic is to drain the blister. Aspiration, draining of the blister, can result in less discomfort and promote rapid healing. Ramsey (1992) stated that the best dressing for an untorn blister is its own roof. Also, an intact blister is more comfortable and less prone to infection. Ramsey also indicated that healing progresses more rapidly if the top of the blister reattaches to the underlying skin. The only way for the top to reattach itself is to aspirate the fluid and compress the blister with a bandage. Ramsey outlined the best way to aspirate the blister with the use of a sterile needle or scalpel. Upon aspiration, sterile bandaging techniques can help to prevent infection.

The treatment of a torn blister utilizes a combination of antibiotic creams, dressings, and bandaging. Prior to the application of a dressing or bandage, the use of an antibiotic cream may be indicated. Antibiotic creams should be used with torn blisters due to an increased risk of infections (Katchis & Hershman, 1993). Ramsey (1992) recommended the use of bacitracin due to its antiseptic capabilities and low incidence of allergic reactions.

Both Bergeron (1995) and Knapik et al. (1995) stated that the blister roof provides the best and most comfortable “dressing.” However, when the blister roof has been completely rubbed off or is partially torn, other means of wound protection are necessary. Levy, Barnes, and Rijswijk (1987) conducted a study using DuoDerm dressings on superficial wounds, including blisters. This study reported a decrease in wound healing time and a positive patient review of DuoDerm. Rheinecker (1995) also recommended the use of dressings for treating superficial wounds such as blisters. Rheinecker cited benefits associated with the use of dressings for wound management as increased comfort, decreased risk of infection, and decreased healing time.

The use of bandaging for torn and untorn blisters was examined by Ramsey (1992). With an untorn blister that has been aspirated, a bandage such as telfa or gauze pads could serve to pad and protect the blister from possible infection and pain. An open

or torn blister could also be treated with the application of an antibacterial cream and a bandage. The bandage serves as an adequate means of treatment, primarily if the use of a dressing is unavailable.

The ever-present incidence of friction blisters has brought about a variety of means of treatment. The types of blister treatment utilized today allow for improved comfort, rapid healing, and the prevention of infection. However effective the means of treatment, prevention will always be preferable.

Current Means for Prevention of Friction Blisters

The high incidence of friction blisters in athletic activity has led to a variety of experiments attempting to find an appropriate means of prevention. Methods used for the potential prevention of friction blisters includes antiperspirants, drying powders, varied sock fiber composition, and petroleum jelly. Other methods examined for the prevention of blisters have included shoe and skin conditioning.

Antiperspirants

It has become common knowledge that blisters are caused by excessive amounts of friction (Knapik et al., 1995). Since friction increases with moist skin, one of the best ways to diminish this friction and prevent blisters would be through drying the skin as much as possible (Knapik et al.). One possible means for keeping the foot dry could be through the use of antiperspirants.

Darrigrand, Reynolds, Jackson, Hamlet and Roberts (1992) examined the ability of antiperspirants to prevent blisters. This study used two different antiperspirants to test the decrease in the amount of foot sweat. Theoretically, a decrease in the amount of sweat would decrease the amount of friction and consequently reduce blisters occurrence. The protocols used in the above research involved only 19 subjects. The study found that there was a decrease in foot sweat accumulation, but no difference in the occurrence of blisters. A similar study by Reynolds et al. (1995) also found that the use of antiperspirants did not

experimental design as the previous study, Herring and Richie (1993) found no significant differences in the friction blister prevention capabilities of acrylic fiber versus cotton fiber. This resulted in Herring and Richie (1993) questioning their previous study.

Insoles

A method that is used to this day for the prevention of friction blisters is the use of insoles (Knapik et al. 1995; Levine, 1982; Ramsey, 1992). Spence and Shields (1968b) did a study that investigated the ability of insoles to prevent friction blisters. The experiment consisted of 200 subjects who had a history of blisters. These subjects used the new insole in one shoe, while the other shoe, which had no insole, served as the control. The insoles used in the one shoe took up space. Thus, the foot would be more snug in the shoe with the insole, compared to the shoe without the insole. The researchers gave no protocols for their methodological design. The subjects were allowed to wear whatever shoes and/or socks they wanted. Subjects reported no blisters on their feet using insoles, thus, Spence and Shields concluded that the new insoles were practically 100% effective in preventing friction blisters. A total of 25% of the subjects reported blisters on their feet without insoles, while only one person reported a blister on the foot with an insole. However, no statistical analysis was used to examine the significance of these findings. Due to the weak design of the study, the findings remain inconclusive.

In contrast to the conclusions drawn by Spence and Shields (1968a, 1968b), Smith, Walter, and Bailey (1985) found that insoles were not 100% effective in preventing friction blisters. Smith et al. used a stronger design. The experiment consisted of a control group using no insoles, and two experimental groups. One experimental group used Poron insoles, while the other group used Spenco insoles. The results did show a decrease, though not significant, in the incidence of friction blisters with the use of insoles.

Petroleum Jelly

A method commonly used today, which causes an increase in slipperiness around the foot, is petroleum jelly (Maier & Pietrocarlo, 1991). This is in contrast to the other

previously mentioned methods of prevention which focus on decreasing the amount of wetness or lubrication around the foot. Friction around the skin can be diminished by either significantly decreasing or increasing the amount of surrounding wetness (Knapik et al., 1995). The use of petroleum jelly greatly increases the amount of slipperiness surrounding the foot. This large increase in slipperiness greatly diminishes the amount of friction. Thus, there is a decrease in the occurrence of friction blisters. The one problem with the use of petroleum jelly is that it is easily dispersed, which diminishes its friction reducing capabilities. Hence, petroleum jelly only works for a short period of time.

Conventional Methods for Preventing Friction Blisters

One of the oldest methods used for preventing friction blisters is to appropriately condition a new shoe (Knapik et al. 1995). A shoe that is too tight may place undue pressure on the foot resulting in a blister. In contrast, a shoe that is too loose may allow the foot to slide around excessively also resulting in blisters. Ideally, a person will properly condition a new shoe before wearing the shoe for prolonged periods of activity. Properly conditioning a shoe incorporates a period of breaking the shoe in. A shoe is conditioned and/or broken in by wearing it during participation in low impact activities such as walking. This period of conditioning allows for the shoe to conform to the foot prior to use in high impact situations commonly found with athletic activity. This is especially important for athletes and military personnel. Wearing a new shoe for prolonged periods of activity could result in a blister. This could consequently prevent the athlete from continuing with the athletic activity. Such is also the case with military personnel. However, a study by Patterson, Woolley, and Lednar (1994) found little correlation between improperly conditioned boots and the increased occurrence of friction blisters. The study by Patterson et al. was well controlled and calculated a similar risk factor for blister incidence with boots that were not broken in compared to boots properly conditioned. Although this study found no correlation between friction blisters and boot

condition, other studies have (Hoeffler, 1975; Knapik et al. 1992; Ressman, 1972). The studies by Hoeffler, Knapik et al. and Ressman were well controlled. However, the comparison of blister rate in boots not broken in versus boots properly conditioned was made subjectively.

Another theory related to preventing friction blisters is that properly conditioning the skin is of the utmost importance (Patterson et al., 1994; Ramsey, 1992). The idea behind conditioning the skin is that when someone begins a new activity it is best to gradually increase the work load. This allows for the skin to toughen and/or adapt to the new activity without forming a blister. The conditioning of the skin often times comes in the form of a callus (Bergeron, 1995). The callus is a thickening of the skin which allows for greater resistance to frictional shearing forces, thus decreasing the likelihood that a friction blister will form.

A common method used for the prevention of friction blisters is the use of moleskin (Knapik et al., 1995). Moleskin is a tape like material that has a tacky side used to adhere to the skin. The idea behind the use of moleskin is that the friction will occur between the outer surface of the tape and the inner surface of the sock. This could potentially result in a decreased amount of friction on the surface of the skin.

A variety of experiments have attempted to find an appropriate means for blister prevention. Some studies were successful in demonstrating a decrease in the occurrence of skin lesions, yet no conditions resulted in total blister prevention. The continued prevalence of blisters alone indicates the need for further research in the area of preventing friction blisters.

The Blister Guard™ System

The Blister Guard™ System Teflon® socks are manufactured by PTFE, Inc. (1997). The Blister Guard™ System utilizes a patented technology of knitting, 100% DuPont Teflon® brand fiber into the heel, pad, and toe of the sock. PTFE, Inc. advertised

that “this significantly reduces friction between the sock and the skin, eliminates blisters and other irritations, and guarantees the comfort and performance an active individual demands.”

A few tests have been conducted on the Blister Guard™ System, using intercollegiate athletes at three different universities. The Blister Guard™ System was also tested on United States Military Infantry. Laboratory tests in a washing machine using hot water have also been conducted demonstrating an almost 0% loss of Teflon® fiber after 50 washes (PTFE, Inc.).

Studies on the Blister Guard™ System were conducted on intercollegiate athletes utilizing participants from the University of North Carolina, Cornell University, and Villanova University. Participants from the University of North Carolina included twenty football players and fourteen women’s field hockey players. This study did not give design protocols. Even though the results were not statistically significant, the athletes responded positively to the Blister Guard™ System Teflon® sock. Of the football players previously experiencing blisters, 2 of the 12 had additional blisters, while only one of the other eight using the socks experienced minor blisters. Women’s field hockey players who experienced blisters while wearing the Teflon® socks totaled 1 of 14. It was noted that the players found the socks to be cool, comfortable, and durable.

At Cornell University the socks were tested on 18 athletes. The sports these athletes participated in was not mentioned. This study did not give design protocols. Of the 18 players wearing the Teflon® socks, 1 experienced a blister. The test was conducted over the period of one practice per day, 6 days per week, for 4 weeks. The players responded favorably to the use of the Teflon® socks and indicated that the socks were durable. Cornell University also tested the socks on 20 athletes from winter sports teams involving primarily men’s basketball. This study indicated that all participants had a history of friction blisters. The Teflon® socks were worn during practice and games, 5

days a week, for 12 to 16 weeks. During the testing period none of the Teflon® socks incurred any defects and there were no reports of blister problems. However, this study also had an inadequate testing design with no control, random sampling, or control for researcher bias. Even though the findings were positive they remain tentative.

At Villanova University, 39 football players participated in a study using the Teflon® socks. Reports indicated that none of the players experienced blisters during the testing period of 2 months. The participants indicated that the Teflon® socks held up very well and showed little signs of wear.

The Teflon® socks were tested on 67 marines in December, 1995 (Morley, 1995). The marines were instructed to wear only the Teflon® socks, one pair at a time, for the duration of the six day hike. At the end of the six day testing period responses on comfort and blister prevalence were collected. The overall performance ratings indicated that the socks were easy to get on and off, felt and looked good, reduced blistering, and fit well in their boots. A total of 83% of the participants said they incurred no blisters with the Teflon® socks. Suggestions for improvements on the socks included improving the wicking capabilities (ability to remove sweat away from the skin), increasing the thickness, making the socks taller, and to add Teflon® to the bottom of the socks. Overall, the test socks were well received and performed well with regard to reducing the incidence of blistering during the testing period.

Upon review of the suggestions for improvement, changes were made to the Teflon® socks. The improved Teflon® sock was then tested again on military infantry in February, 1996. The participants of this study involved 32 marines for another six day hike. Upon completion of the hike the participants completed a survey evaluating the test socks and comparing them to the socks that they normally wore. The results indicated a high rating on the performance of the test socks. None of the respondents reported blisters

when wearing the test socks. All of the participants reported a preference to the Teflon® sock over their normally worn socks.

The studies conducted thus far on the Blister Guard™ System Teflon® socks have reported positive results. The general consensus of the test participants was that the socks were comfortable, durable, and decreased the incidence of friction blisters. However, the studies conducted at the three universities did not utilize scientific methodological designs that would allow for the data collected to be considered statistically significant. The tests at the three universities resembled a pilot study. The two studies using participants from the marines incorporated methodological designs that would enable the results to be considered more conclusive than the three university studies. Although the results indicated that the Blister Guard™ System Teflon® socks have a high performance rating, the need for further research still exists.

Summary

The prevalence of blisters has been demonstrated in a variety of investigations (Hoeffler, 1975; Knapik et al., 1992). Many physical activities can lead to friction blisters, primarily occurring on the soles of the feet. Friction blisters are not only prevalent in physically active athletes, but in military personnel as well (Ressman, 1972).

Current means for the prevention of friction blisters includes the use of antiperspirants, drying powders, and varying sock fiber compositions. Darrigrand et al. (1992) concluded that not only do antiperspirants fail to reduce the amount of friction blisters, but that they can possibly increase the occurrence of irritant dermatitis. Jagoda et al. (1981) attempted to find an inexpensive means for the military to prevent friction blisters through the use of a drying powder and varying sock combinations. Even though the experimental group using drying powders did show a decrease in friction blisters, the occurrence of blisters was still prevalent.

A common method practiced in the attempt to eliminate friction blisters is the use of different types of sock fiber combinations. Herring and Richie (1993) concluded that it was not the sock fiber type that demonstrates a difference in the occurrence of friction blisters, but, the construction of the sock. Experimentation found that some materials are more capable of decreasing the coefficient of friction against skin (Comaish & Bottoms, 1971). Sheet material such as polythene, nylon, or Teflon® was shown to be capable of decreasing friction. In contrast, the knitted material used by Comaish and Bottoms resulted in an increased amount of friction against the skin.

It has become apparent that conventional methods are not providing enough protection against the occurrence of friction blisters. Therefore, new areas of research may be necessary to find a more efficient means for blister prevention. The favorable results found with the conjunction of sheet material and lubricants to decrease the amount of friction need further examination. An option would be to construct a sock that could be worn by the average person to prevent friction blisters from occurring. PTFE, Inc. (1997) claims to have produced a sock to accomplish this objective: the Blister Guard™ System Teflon® sock. The following chapter outlines the methodology used to test the efficacy of this Teflon® sock.

Chapter 3

METHOD

This chapter outlines the methodology for this study. A complete description of the participants, apparatus, procedures, design, and analysis of data is included. Can friction be diminished to the point that friction blisters are prevented from occurring on the human foot? The purpose of this study of students engaged in aerobic activity classes was to determine if there would be a significant difference in the occurrence of friction blisters with the use of the Blister Guard™ System Teflon® sock when compared to the use of an athletic sock.

Participants

Using a conservative estimate of blister rate (0.3 for the athletic sock group and 0.1 for the experimental Teflon® sock group) it was determined that 60 subjects were needed in each group to achieve a power value of 0.8. The participants used in this study were taken from a population consisting of San Jose State University students. Students enrolled in four Human Performance aerobics classes taught by one instructor were selected for this experiment. Volunteers from the group of four classes were asked to participate.

Apparatus

There were two different socks used in this experiment. Participants in group 1 wore the Blister Guard™ System Teflon® socks. The Blister Guard™ System utilizes a patented technology of knitting 100% DuPont Teflon® brand fiber into the heel, pad, and toe of the sock. These Teflon® socks were obtained from PTFE, Inc. Participants in group 2 were required to wear a non-Teflon® athletic sock, which was also obtained from PTFE, Inc. The athletic sock used for group 2 subjects had the same material type and construction as the group 1 sock. However, the group 2 socks did not contain the Blister

Guard™ System Teflon® fibers. Both the Blister Guard™ System Teflon® socks and the non-Teflon® athletic socks were constructed of almost 100% cotton with a 108 needle and 18-gauge cushioning. Both socks had full body cushioning and the same top and foot cross stretch. The use of an athletic sock for group 2 participants of almost identical construction to the Teflon® sock used for group 1 participants allowed for a larger amount of scientific control between the two testing groups. This controlled for the results in Herring and Richie's (1993) experiment, where statistical variance in friction blisters occurrence was attributed to variance in sock fiber composition. Therefore, the results of this experiment can be attributed more accurately to the Blister Guard™ System.

Procedures

Upon Human Subjects approval for this experiment, clearance was given by the instructor to use the four aerobics classes as a means for obtaining subjects for this study. The instructor was queried about the variance of intensity level of the class throughout the semester. At the end of the first day of instruction, the instructor allowed a 10 minute period of time to explain the study to each of the four classes and recruit subjects. The subjects were asked to read and sign the Agreement to Participate in Research form (Appendix A). Prior to participation, the subjects were asked to complete the Personal and Health Questionnaire (Appendix B). Instructions were also detailed and given in written form to the subjects (Appendix C). The participants were randomly assigned to the two groups.

The instructions explained that participants should wear only the given socks for each of the aerobics classes attended during the 4 week testing period. The socks were to be dry prior to use in each class. The use of the socks was also reserved solely for aerobics class participation. Subjects were also instructed not to wear two or more pairs of socks at once during the testing period. Subjects were asked to participate in both aerobics

classes per week for the 4 week testing period. However, they were allowed to make up missed classes with other sections of aerobics classes taught by the same instructor. This allowed for a total number of 8 days of class participation to be reached within the 4 week testing period.

Subjects were instructed to fill out the Daily Report form (Appendix D) after participation in each aerobics class. This form utilized a picture of the human foot that the participants were instructed to mark in the appropriate place each day if they incurred a blister during class. Space provided allowed for the description of the number and size of blisters incurred. Subjects were allowed to indicate blisters on the Daily Report form even if the blister was noticed after the subject had left class. The Satisfaction Inventory form (Appendix E) asked for responses about comfort, satisfaction, and durability of the sock worn. Participants were instructed to fill this form out upon completion of the 4 week testing period.

Analysis of Data

The software used was Statistical Package for the Social Sciences (SPSS) for windows. The dependent variable was blister occurrence and the independent variable was sock type. Descriptive information on subjects included frequency distribution tables. For continuous variables, central tendency and variability information was calculated. Data from Appendix D (Daily Report) was summarized using frequency distribution tables. Data from Appendix E (Satisfaction Inventory) was summarized by reporting mean ratings along with the range of responses.

To answer the primary research question, a Z test was conducted (Blommers & Forsyth, 1977) to determine whether or not there was a statistically significant difference in the proportion of blisters incurred as a function of sock type. In addition, an interval estimate for a population proportion was calculated for both groups.

Related questions examined, using descriptive statistics were: 1. Does satisfaction differ between the groups using the Blister Guard™ System compared to the normal athletic sock. 2. What characteristics other than sock type influenced blister formation.

Chapter 4

RESULTS

The purpose of this study was to determine if there was a significant difference in the occurrence of friction blisters with the use of the Blister Guard System™ Teflon® sock when compared to the use of an athletic sock. Factors related to the primary focus of this study included the subjective ratings for the two types of socks. Characteristics other than sock type that may have influenced friction blister occurrence were examined as well. This chapter outlines the demographic data, statistical analysis, and gives a summary of the information obtained related to the Blister Guard™ System Teflon® sock.

Demographic Data

This study was conducted in four Human Performance aerobics classes taught by the same instructor during the spring semester, 1998. There were a total number of 77 subjects, who participated in the study. The population was composed of 76 females and 1 male. The mean age of the subjects was 21.4 ± 5.4 years. The minimum and maximum ages for the subjects were 18 and 53 years, respectively. The subject population had a mean height of 63.9 ± 2.6 inches and a mean weight of 135.1 ± 28.9 pounds. The data are presented in Table I.

Data which indicates the months of aerobic class participation of the subjects were composed of 3 categories. These categories were 0-6 months, 7-11 months, and 12+ months of aerobic class participation. The mean ages of the subjects in each of the three months of aerobic class participation groups were compared. The groups of 0-6 months, 7-11 months, and 12+ months had mean ages of 20.9 ± 5.4 years, 21.6 ± 2.0 years, and 25.0 ± 6.0 years, respectively. This comparison demonstrated a trend of older subjects having more months of aerobic class experience. The data are shown in Table I.

Prior to participation in the study, the subjects were asked to rate their perceived intensity level during the aerobics class workout. Their perceived intensity level was rated

on a scale of 1 to 7 with 7 being the highest intensity rating. The distribution of the subjects intensity level ratings are presented in Table II. The mean perceived intensity level of the subjects in each of the three “months of aerobic class participation” groups were compared. The groups of 0-6 months, 7-11 months, and 12+ months had mean perceived intensity levels of 4.6 ± 1.2 , 5.0 ± 1.1 , and 5.8 ± 0.9 , respectively. This comparison demonstrated a trend of increasing perceived intensity levels with an increase in the months of aerobics class participation. This information is presented in Table I. The aerobics class instructor indicated that the intensity level of the class did not vary throughout the semester. The variance in intensity level varied only among the individual subjects.

Table I

Mean Ratings of Demographic Data

<u>Variable</u>		<u>Mean</u>	<u>Std Dev</u>	<u>Min</u>	<u>Max</u>	<u>n</u>
Age (years)		21.4	5.4	18	53	77
Height (inches)		63.9	2.6	58	70	77
Weight (pounds)		135.1	28.9	95	240	76
Age of Participant by Months of Aerobic Class Participation						
1	0-6 Months	20.9	5.4	18	53	61
2	7-11 Months	21.6	2.0	19	25	8
3	12+ Months	25.0	6.0	19	38	8
Perceived Intensity Level by Months of Aerobic Class Participation						
1	0-6 Months	4.6	1.2	1	7	60
2	7-11 Months	5.0	1.1	4	7	8
3	12+ Months	5.8	0.9	4	7	8

Table II
Frequency Distribution of Perceived Intensity Level

<u>Value</u>	<u>Frequency</u>	<u>Percent</u>
1	1	1.3
2	1	1.3
3	9	11.7
4	21	27.3
5	25	32.5
6	12	15.6
7	7	9.1

The ethnicity of the subjects was limited to five categories. The categories were White, Black, Asian, Hispanic, and Other. The percentages of the subjects within these five categories were as follows: White (31.2%), Asian (29.9%), Hispanic (23.4%), Black (9.1%), and Other (1.3%).

Statistical Analysis

The hypothesis of this study was that there would be no statistically significant difference in the proportion of subjects sustaining blisters as a function of sock type. To answer this primary research question a Z test was conducted. For this type of research question the null hypothesis would be:

$$H_0: \phi_1 = \phi_2$$

There were a variety of steps involved in conducting a statistical test of the null hypothesis. The first step was to select an alpha level. Since this was an exploratory investigation and making a type II error would be more serious than making a type I error, an alpha level of 0.1 was used. The next step was to determine the critical value for a two-tailed test from the Z table. The critical value for an alpha level of 0.1 is 1.645. Once the Z

statistic was calculated it was then compared to the critical value. If the Z statistic was greater than the critical value the null hypothesis could be rejected.

The first step in calculating the Z statistic was to calculate the pooled proportion (p) value to be used in the standard error formula. This p value was calculated using the following formula:

$$p = \frac{n_1 p_1 + n_2 p_2}{n_1 + n_2}$$

For the statistical analysis of the null hypothesis the data from only the subjects who completed all 8 days of aerobics class participation were used. In this study 36 of the 77 subjects completed all 8 days of aerobics class participation during the 4 week testing period. These 36 subjects were made up of 14 subjects wearing the non-Teflon® athletic socks and 22 subjects wearing the Blister Guard System™ Teflon® socks. There were 2 of the 14 subjects wearing the non-Teflon® athletic socks who sustained a friction blister. Thus $n_1=14$ and $p_1=0.143$. There were 3 of the 22 subjects wearing the Blister Guard System™ Teflon® socks who sustained friction blisters. For this group $n_2 = 22$ and $p_2 = 0.136$. These values were then used to calculate a pooled value (p) of 0.139. The p value was then used in the following formula to calculate the standard error for the difference in proportions:

$$\sigma_{p_1 - p_2} = \sqrt{\frac{p(1-p)}{n_1 - 1} + \frac{p(1-p)}{n_2 - 1}}$$

The standard error for the difference in proportions was calculated to be 0.122. The data were then used in the following formula to calculate the Z statistic:

$$Z = \frac{p_1 - p_2}{\sigma_{p_1 - p_2}}$$

The Z statistic for this study was 0.053. Since the Z statistic was not greater than the critical value of 1.645 the null hypothesis could not be rejected.

Since the sample size of 60 subjects per group was not obtained an estimate of power was calculated. Using $n_1=14$, $n_2=22$, $p_1=0.143$, and $p_2=0.136$ power was calculated to be 0.06. An optimal value would have been 0.8.

Interval Estimates for Population Proportion

The sample proportion of the subjects who sustained friction blisters in this study was used to construct an interval estimate for a population proportion. The following formula was used:

$$\phi = p \pm \sigma_p(z)$$

The p in this formula represents the sample proportions of the subjects who sustained friction blisters. The p values for the group wearing the Blister Guard System™ Teflon® sock ($N=22$) and the group wearing the non-Teflon® athletic sock ($N=14$) were 0.136 and 0.143, respectively. The value for the standard error of the proportion was calculated using the following formula:

$$\sigma_p = \sqrt{\frac{p(1-p)}{n-1}}$$

The standard error of the proportion value was calculated to be 0.075 for the Blister Guard System™ Teflon® sock group and 0.097 for the non-Teflon® athletic sock group. These values were then multiplied by the Z score. For this interval estimate a 95% confidence interval was used, which has a Z score of 1.96. The sample population wearing the Blister Guard System™ Teflon® socks resulted in an interval estimate for a population proportion being 0.136 ± 0.193 or a range of 0 to 0.329. The sample population wearing the non-Teflon® athletic socks resulted in an interval estimate for a population proportion being 0.143 ± 0.250 or a range of 0 to 0.393. Therefore, with a 95% confidence interval, 0 to 32% of a population wearing the Blister Guard System™ Teflon® socks could be expected to incur friction blisters. Also with a 95% confidence

interval, 0 to 39% of a population wearing the non-Teflon® athletic socks could be expected to incur friction blisters.

Related Questions

Questions related to the study were examined using descriptive statistics. For the related questions data from all of the 77 subjects were used. There were two questions that were investigated in detail. The first question was whether the satisfaction ratings differed between the group wearing the Blister Guard System™ Teflon® socks and the group wearing the non-Teflon® athletic socks. The second question investigated characteristics other than sock type that may have influenced blister formation.

The Satisfaction Inventory form (Appendix E) was completed by the subjects at the end of the 4 week testing period. This form asked the subjects to indicate their personal ratings of the five characteristics on a scale of 1-10 with 10 being the highest rating. The five characteristics were as follows: overall comfort, durability, kept your feet from getting hot, kept your feet from getting sweaty, and overall satisfaction. The category “Overall Comfort” received a mean rating of 8.68 ± 1.86 from the non-Teflon® athletic sock group and a mean rating of 8.90 ± 1.32 from the Blister Guard System™ Teflon® sock group. The category “Durability” received the highest mean ratings out of the five characteristics. The mean ratings for “Durability” were 9.44 ± 1.32 and 9.17 ± 1.12 for the non-Teflon® athletic sock and Blister Guard System™ Teflon® sock groups, respectively. The category “Kept your feet from getting hot” had the lowest group means of 6.96 ± 2.73 and 7.10 ± 1.75 for the non-Teflon® athletic sock group and Blister Guard System™ Teflon® sock group, respectively. The mean ratings for “Kept your feet from getting sweaty” were 7.48 ± 2.43 for the non-Teflon® athletic sock group and 7.10 ± 2.19 for the Blister Guard System™ Teflon® sock group. The mean ratings for “Overall Satisfaction” were 8.32 ± 1.60 and 8.67 ± 1.12 for the non-Teflon® athletic sock group and Blister Guard System™

Teflon® sock group, respectively. All of the means and standard deviation values for Appendix E are presented in Table III.

Table III					
<u>Mean Ratings for Satisfaction Inventory Form</u>					
<u>Variable</u>	<u>Mean</u>	<u>Std Dev</u>	<u>Min</u>	<u>Max</u>	<u>n</u>
Overall Comfort					
Entire Population	8.80	1.58	3	1	55
Non-Teflon® Sock Group	8.68	1.86	3	10	25
Teflon® Sock Group	8.90	1.32	5	10	30
Durability					
Entire Population	9.29	1.21	6	10	55
Non-Teflon® Sock Group	9.44	1.32	6	10	25
Teflon® Sock Group	9.17	1.12	6	10	30
Kept Your Feet From Getting Hot					
Entire Population	7.04	2.23	1	10	55
Non-Teflon® Sock Group	6.96	2.73	1	10	25
Teflon® Sock Group	7.10	1.75	4	10	30
Kept Your Feet From Getting Sweaty					
Entire Population	7.27	2.29	1	10	55
Non-Teflon® Sock Group	7.48	2.43	1	10	25
Teflon® Sock Group	7.10	2.19	1	10	30
Overall Satisfaction					
Entire Population	8.50	1.36	5	10	55
Non-Teflon® Sock Group	8.32	1.60	5	10	25
Teflon® Sock Group	8.67	1.12	6	10	30

Characteristics other than sock type, which may have influenced the occurrence of friction blisters, were also examined. The characteristics examined included the months of participation, ethnicity, perceived intensity level, and height to weight ratios for the subjects.

The “months of aerobic class participation” variable contained three categories of 0-6 months, 7-11 months, and 12+ months. The “0-6 months” category resulted in 11.5% of the subjects incurring friction blisters. There were 12.5% of the subjects in the “12+ months” category who also incurred friction blisters. The “7-11 months” group had the highest percentage of friction blisters with 50% of the subjects being afflicted. The ethnicity of the subjects may have played a role in the occurrence of friction blisters. The percentages of subjects incurring friction blisters were 8.7%, 16.7%, 20.8%, and 28.6% for the Asian, Hispanic, White, and Black subjects, respectively.

The perceived intensity level of the subjects may have also played a role in the incidence of friction blisters. The mean intensity level for the subjects who incurred friction blisters was 5.00 ± 1.09 . The subjects who did not incur friction blisters had a lower mean intensity level of 4.69 ± 1.27 . These data are represented in Table IV.

Table IV

Mean Ratings Related To Blister Incidence

<u>Variable</u>	<u>Mean</u>	<u>Std Dev</u>	<u>Min</u>	<u>Max</u>	<u>n</u>
Perceived Intensity Level By Blister Incidence					
Entire Population	4.74	1.25	1	7	77
Blisters Incurred	5.00	1.09	1	7	12
No Blisters Incurred	4.69	1.27	2	7	65
Height to Weight Ratio (lb./ in.) By Blister Incidence					
Entire Population	0.491	0.087	0.28	0.64	76
Blisters Incurred	0.451	0.106	0.28	0.64	12
No Blister Incurred	0.498	0.082	0.34	0.64	64

The pounds per inch for each subject was calculated to investigate if the height to weight ratio played a role in the occurrence of friction blisters. An increased height to

weight ratio could have potentially increased the shearing forces on the foot and resulted in a higher incidence of friction blisters. The mean height to weight ratio for the entire subject population was 0.491 ± 0.087 lb./in. The mean ratios of height to weight were 0.498 ± 0.082 lb./in. and 0.451 ± 0.106 lb./in. for the non-Teflon® athletic sock group and the Blister Guard System™ Teflon® sock group, respectively. The data are presented in Table IV. There were 12 subjects in this study who incurred friction blisters, of which, 5 demonstrated a mean height to weight ratio greater than that of the entire population (0.491 ± 0.087 lb./in.). These 5 subjects had height to weight ratios of 0.50, 0.52, 0.53, 0.58, and 0.64 lb./in. The 3 subjects with the largest height to weight ratios of 0.53, 0.58, and 0.64 lb./in. were all in the Blister Guard System™ Teflon® sock group.

There were 12 of the 77 subjects in this study who incurred friction blisters. These 12 subjects incurred a total number of 17 friction blisters. Fifty nine percent of the friction blisters occurred on the left foot of the subjects. Friction blisters that were small in size (less than 1/4 in. in diameter) accounted for 88% of all the blisters incurred. The other 12% of friction blisters incurred were medium in size (less than 1/2 in. in diameter). The friction blisters occurred on two areas of the foot. Fifty nine percent of the blisters occurred on the toe area. The other 41% of friction blisters occurred on the metatarsal area of the subjects' feet. No blisters incurred were large in size (less than 3/4 in. in diameter) and no blisters occurred on the heels of the subjects. The data on friction blister occurrence are presented in Table V.

Table V

Friction Blister Size and Location

<u>Variable</u>	<u># of Blisters</u>	<u>% of Total</u>
Left Foot	10	59
Right Foot	7	41
Small Sized Blisters (less than 1/4 in.)	15	88
Medium Sized Blisters (less than 1/2 in.)	2	12
Large Sized Blisters (less than 3/4 in.)	0	0
Toe Area	10	59
Metatarsal Area	7	41
Heel Area	0	0

Chapter 5

CONCLUSION

The conclusion of the Blister Guard System™ study focused on three primary areas. First, the Blister Guard System™ study was compared to studies with related purposes and results. Next, the results themselves were summarized in detail. The chapter concludes with suggestions for future study.

Related Studies

The two areas of skin on the human body most commonly afflicted with friction blisters are the palms of the hands and the soles of the feet (Bergeron, 1995). Knapik et al. (1995) attributed most blisters seen in athletic and military activities to frictional forces developed between skin and objects in contact with the skin. The foot is one of the most common areas afflicted with friction blisters. This study examined the effectiveness of the Blister Guard System™ Teflon® sock compared to a non-Teflon® athletic sock at preventing friction blisters from occurring in an aerobics class setting. The results of this study can also be compared to previous studies conducted on the occurrence of friction blisters in the active environment. Topics of comparison include population percentages, location, and ethnicity of those who incurred friction blisters.

The Blister Guard System™ Teflon® sock and the non-Teflon® athletic sock groups demonstrated friction blister population proportions of 13.6% and 14.3%, respectively. Knapik et al. (1992) investigated injuries associated with strenuous road marching in infantry soldiers. The infantry soldiers had a population proportion of 10%, who incurred friction blisters. Two other studies investigated the occurrence of friction blisters in the military, as well. Patterson et al. (1994) found a 42.1% population proportion of ROTC cadets who incurred friction blisters during a summer camp. Jagoda et al. (1981) examined friction blister population proportions of three different groups of marines during training hikes. Group I wore a green issue sock and presented a friction

blister population of 58%. Group II wore a combination of nylon socks and white athletic socks with drying powder placed in between the two. Group II resulted in 40.0% of the subjects incurring friction blisters. Group III was composed of subjects wearing a white athletic sock under a green athletic sock with drying powder in between the two. Group III presented with 21.6% of the subjects incurring friction blisters. Other than the study by Knapik et al. all the other studies reported population proportions of friction blister occurrence significantly higher than the Blister Guard™ System study. While the Blister Guard™ System study had population proportions of friction blister incidence of 13.6% and 14.3% the studies by Patterson et al. and Jagoda et al. had population proportions ranging from 21.6% to 58%. Thus, the Blister Guard System™ Teflon® sock and non-Teflon® athletic sock groups tested in the aerobics environment incurred a lower percentage of friction blisters.

The Blister Guard System™ study resulted in the occurrence of 17 friction blisters on 12 of the subjects. The toe area was the site where 59% of these 17 friction blisters occurred. The other 41% of the friction blisters occurred on the metatarsal area of the subject's feet. There were no friction blisters that occurred on the heels of the subjects. Two separate investigations by Herring and Richie (1990, 1993) presented similar findings to the Blister Guard System™ study. Both of the studies composed by Herring and Richie were on the effect sock fiber composition had on friction blister occurrence. Herring and Richie's (1990) first study presented friction blister percentages of 61.8, 33.2, and 6.3 for the forefoot, midfoot, and rearfoot, respectively. Herring and Richie's (1993) second study resulted in friction blister percentages of 62.2, 36.6, and 11.0 occurring to the forefoot, midfoot, and rearfoot, respectively.

Ressman (1972) composed a year long study on the epidemiology of friction blisters in the military setting. Ressman's study presented 50% of the friction blisters occurring to the heel and 20% occurring on the toes. No other areas of friction blister

occurrence were reported. The Blister Guard System™ study and both of Herring and Richie's (1990,1993) studies demonstrated similar findings on the percentages of friction blisters occurring to the various areas of the foot. Only Ressman's study demonstrated a significant difference in the location of the friction blisters incurred.

The role ethnicity plays in the occurrence of friction blisters is another factor that was examined. The Blister Guard System™ study resulted in percentages of subjects incurring friction blisters of 8.7, 16.7, 20.8, and 28.6 for Asian, Hispanic, White, and Black participants, respectively. Patterson et al. (1994) used White, Non-White, and Black as categories for ethnicity. In the study conducted by Patterson et al. the friction blister occurrence rate per 100 cadets was 21.1, 44.1, and 26.7 for Black, Non-White, and White groups, respectively. Jagoda et al. (1981) examined the percentage of friction blisters occurring as a function of either fair or dark skin. There were 33.5% of the fair skinned subjects who incurred friction blisters. There were 45.1% of the dark skinned subjects who incurred friction blisters. The Blister Guard System™ study did not have similar percentages of friction blister occurrence as a function of ethnicity compared to the studies by Patterson et al. and Jagoda et al.

Summary of Results

The null hypothesis of the Blister Guard System™ study was that there would be no significant difference in the proportion of subjects sustaining blisters as a function of sock type. The calculation of a Z statistic lower than the critical value of 1.645 prevented the rejection of the null hypothesis. There are a variety of factors which may have resulted in the low proportion of friction blisters between the two sock type groups. Factors which may have played a role include the intensity of the activity, the duration of the experiment, similarities between the two sock types, and the high quality of the socks.

The aerobics class setting provided an activity in which a total of 17 friction blisters were incurred over a 4 week testing period. Activities like basketball, tennis, and

racquetball involve constant stop and go type of movements. Stop and go type of movements result in increased shearing forces on the foot, which could result in an increased incidence of friction blisters. Although the aerobics class participation did cause 17 friction blisters to occur, an activity which places higher shearing forces on the foot could present more friction blisters. An increase in friction blisters could then potentially result in a larger difference in the proportion of subjects who incurred the blisters as a function of sock type.

Due to time constraints the aerobics class study was conducted over a 4 week period. An increase in the experimental time period would allow for the subjects to participate in more aerobics classes. An increase in aerobics class participation days would expose the subjects to a longer experimental time period in which they could incur a friction blister. Consequently, a larger difference in the proportion of subjects between the two groups who incurred friction blisters might be demonstrated.

The factor which may have played the largest role in the similarity of friction blister incidence between the two groups was sock type. The two sock types used in the Blister Guard System™ study were of almost identical construction and of very high quality. The primary difference was the Teflon® fibers added into the forefoot and heel area of one type of sock. The similarity in the construction of the two sock types allowed for a high degree of control in the study. However, the two sock types were of a higher quality and construction compared to the normal athletic sock. The two experimental socks were thicker in construction and had full cushioning in the body of the sock. Normal athletic socks are thinner in construction and typically have cushioning only in the sole area of the sock. The quality and construction of the non-Teflon® athletic sock used in the aerobic class study probably resulted in this group demonstrating a lower incidence of friction blisters compared to what may have been observed if the subjects had worn normal cotton athletic socks. Thus, the quality and similarity between the Blister Guard System™

Teflon® sock and the non-Teflon® athletic sock were probably the primary factors causing the small difference of proportion of subjects incurring friction blisters. Had the Blister Guard System™ Teflon® sock been compared to a normal cotton athletic sock in the experimental setting, a significant difference in the proportion of subjects incurring friction blisters may have been observed.

Herring and Richie (1993) examined the effectiveness of identically constructed cotton versus acrylic socks at preventing friction blisters from occurring. Both the cotton and acrylic socks in Herring and Richie's study were constructed with a 108 needle 18-gauge cushioned sole. The socks had the same top and foot cross stretch and were 16 inches in foot length. The only difference between the two socks was sock fiber content. Therefore, Herring and Richie could attribute any differences in the proportions of friction blister occurrence to the sock fiber content of the socks.

The Blister Guard System™ study had similar sock composition requirements to Herring and Richie's (1993) study. The Blister Guard System™ Teflon® sock and the non-Teflon® athletic socks were produced with the same 108 needle and 18-gauge cushioning used in Herring and Richie's study. However, Herring and Richie's socks had cushioning only on the sole, where as the Blister Guard System™ Teflon® socks and non-Teflon® athletic socks had cushioning around the entire foot. The Blister Guard System™ Teflon® socks and non-Teflon® athletic socks also had the same top and foot cross stretch, as well as the same foot length. The primary difference between the two socks in the Blister Guard System™ study was the use of Teflon® in the forefoot and heel areas of the Blister Guard System™ Teflon® sock. Therefore, any differences in the proportions of friction blister incidence could be attributed to the Teflon®.

Herring and Richie's (1990) first study demonstrated a significant difference in the occurrence of friction blisters as a function of sock fiber type. However, Herring and Richie (1990) concluded that their findings were not valid due to the difference in

construction used for the two sock types. In their second study Herring and Richie (1993) were unable to demonstrate a significant difference in the proportion of friction blister incidence as a function of sock fiber type. The study of the Blister Guard System™ Teflon® sock compared to non-Teflon® athletic sock of identical construction was also unable to demonstrate a statistically significant difference in the proportion of friction blisters incurred. Both Herring and Richie's (1993) study and the Blister Guard System™ study demonstrated the importance of using socks of identical construction when examining the occurrence of friction blisters. Herring and Richie's (1993) study and the Blister Guard System™ study were well controlled and could be used to facilitate future investigations and experiments regarding the decrease in the incidence of friction blisters.

Recommendations for Future Study

Recommendations for future study include the increased control of variables related to the Blister Guard System™ study. Controlling more variables could demonstrate significant results, which could be more generalizable to the public. Gender distribution, varied activity levels, shoe type, and sock type are all variables which could be controlled in future studies.

The Blister Guard System™ study utilized 77 subjects. The subjects were composed of 76 females, and 1 male. The low number of male subjects was a result of the low number of males that were enrolled in the four aerobics classes used for the research. Future studies would benefit from an increased number of male subjects. An even number of female and male subjects would allow for differences in friction blister incidence between genders to be analyzed. The results would also be more generalizable.

Another recommendation for future study is to test the Blister Guard System™ Teflon® socks with an activity other than aerobics. Activities that potentially cause higher amounts of shearing forces on the foot than aerobics include tennis, racquetball, and basketball. The high amounts of shearing forces found associated with these activities

could result in an increased amount of friction blisters. These activities would therefore serve as a good avenue for future study. Testing the Blister Guard System™ Teflon® socks on an intercollegiate athletic team over an entire season might also demonstrate significant results. Athletic teams that could be used include football, tennis, basketball, and soccer. The use of an intercollegiate athletic team would control for each subject participating in the same activity. The results would demonstrate the rate of friction blister incidence over a 3-4 month long period of time.

Activities composed of a single sustained event such as marathons or foot races of various duration's could be utilized. Testing the Blister Guard System™ Teflon® socks in this type of environment would demonstrate how effective the socks are during a single activity, which is longer in duration than the 30 minute aerobics workout. The use of a foot race would also enable the experimental data to be collected in one day. A testing period that utilized one day of participation could result in a small number of subjects who drop out.

Another method for future study would be to test the Blister Guard System™ Teflon® socks in an environment where each participant is wearing the same exact shoe. Having each participant wearing the same shoe would control for any factor that shoes may have on the incidence of friction blister occurrence. The use of intercollegiate football, basketball, and soccer teams would be a possible source of participants since many teams are sponsored and supplied with a single type of athletic shoe to be used throughout the season. The use of athletic teams wearing one type of shoe would also examine how the Blister Guard System™ Teflon® socks perform during the breaking in period of the shoe when friction blister incidence is often times increased (Patterson et al., 1994). Another method that could be utilized to control for any factors that shoes may have on the incidence of friction blister occurrence is to have subjects wear the Blister Guard System™ Teflon® sock on one foot and the non-Teflon® athletic sock on the other.

One suggestion for future study is to examine how the Blister Guard System™ Teflon® socks perform compared to a traditional white cotton athletic sock. Both the Blister Guard System™ Teflon® socks and the non-Teflon® athletic socks used in this study were of high quality and composition compared to the traditional cotton athletic sock worn by the general public. Significant differences may be observed when testing how the Blister Guard System™ Teflon® socks perform compared to a traditional athletic sock under a variety of activities.

Future studies should build upon the methodology of previous experiments so that methodological improvements can be made and a stronger link between studies can be demonstrated. The construction of the socks used is an important part of the methodology that should remain considered. Herring and Richie's (1990, 1993) two experiments demonstrated the need for the consistency in sock construction when examining the occurrence of friction blisters. Due to the difference in sock construction used for the two types of socks, Herring and Richie (1990) concluded that their results were not valid. Herring and Richie (1993) then conducted a second experiment using two socks of identical construction. This experiment demonstrated that sock construction, not fiber content, plays an important role in the occurrence of friction blisters. Thus, future studies should consider using socks constructed with the same 108 needle and 18-gauge cushioning used in Herring and Richie's (1993) study and the Blister Guard™ System study.

Future studies should also continue to examine cultural differences in the occurrence of friction blisters. The sample population should be proportional to the general population and factors such as age and years of experience should be held constant. The results would then be less confounded by extraneous variables and could be generalizable to the public. A daily report on intensity level should also be obtained. The Blister Guard™ System study obtained an intensity level rating from the subjects prior to their

participation in the study. However, obtaining a daily rating on the intensity level of the subjects would result in a more accurate measure of intensity level which would facilitate a better examination of the correlation between intensity level and friction blister occurrence.

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Appendix A

Agreement to Participate in Research

I, _____, volunteer to participate in a research study examining the occurrence of friction blisters in an aerobic class setting. Prior to testing, I will complete a personal and health questionnaire. I understand that the testing will be performed in the San Jose State University Human Performance departments' aerobics classes. I agree to wear only the given athletic socks during the testing period. Testing will be conducted over a 4 week period, including participation in a total of eight aerobics classes. I will fill out the Daily Report form after participation in each aerobics class session. I will also complete the Satisfaction Inventory form upon completion of the 4 week testing period. This testing protocol does not increase the risks that are inherent with participation in a low impact aerobics class.

I understand that there will be no alternative method of testing, no compensation for participation, and that my withdrawal will incur no penalty. I understand the data will be reported in group form and may be published. I am aware that individual data will be kept confidential and destroyed after the study is completed. Questions about the research may be addressed to Jeb Burns at (408) 279-4628. Complaints about the research may be presented to Dr. James Bryant, Chair, Human Performance Department, at (408) 924-3010. Questions or complaints about research, subjects' rights, or research-related injury may be presented to Serena Stanford, Ph.D., Associate Academic Vice President for Graduate Studies and Research, at (408) 924-2480.

Subjects' Initial _____

No service of any kind, to which a subject is otherwise entitled, will be lost or jeopardized if a person chooses to “not participate” in this study. I understand that participation in this study is voluntary and by signing and dating below indicates that I have received a copy of this consent form and that my consent is given voluntarily.

Participant's Signature

Date

Participant's Printed Name

Investigator's Signature

Date

Appendix B

Personal and Health Questionnaire

Identification Number _____

Personal Information

Name _____

Age _____ Gender _____ Ethnicity _____

Health

Height _____ Weight _____

Months of Aerobics Class Participation: 0-6_____, 7-11_____, 12+_____

Perceived Skill Level: Novice (no experience)_____, Beginner (1-3 months)_____,
Intermediate (4-8 months)_____, Advanced (9+ months)_____Perceived Intensity Level During This Class Low Moderate HighCircle A Number

1	2	3	4	5	6	7
---	---	---	---	---	---	---

Other Aerobic Activity (i.e. running, biking) _____

Athletic Shoe Brand Worn During This Class_____, Size_____, High Top/Low Top

Sock Type Usually Worn With This Shoe_____

Style: Thin(non-terry)_____, Medium (normal terry)_____, Thick (heavy terry)_____

Fiber Type Of This Sock: Cotton_____, Acrylic_____, Nylon_____, Other_____

Appendix C

Instructions

Upon agreement to volunteer for this study you will be asked to fill out the Agreement to Participate in Research form and the Personal and Health Questionnaire. You will be asked to wear only the given sock during the testing period. The socks are to be dry prior to use and only one pair of socks is to be worn during participation in this aerobics class. The testing period consists of a 4 week period, totaling eight aerobics classes. You are able to make up missed aerobics classes by attending another aerobics class taught by the same teacher. This will allow for a total of eight aerobics classes to be attended within the 4 week testing period.

After each day of participation you will be asked to fill out the Daily Results form designating whether or not you experienced blistering. You will also be asked to describe the size and number of any blisters incurred. On this form you will also be asked to designate any blisters with a small "X". The "X" is to be drawn on the foot model at the location where you sustained a blister or blisters. If a blister is noticed after you have left the class, you will be allowed to indicate this blister on the Daily Report form. This can be done when you return for the next class session. Upon completion of the 4 week testing period you will be asked to complete the Satisfaction Inventory form.

Appendix D

Daily Report

Identification Number _____

Date _____

In the appropriate spaces indicate for each foot if a blister was incurred and the number sustained as well. For blisters sustained, size is designated as small (S) being less than 1/4 in., medium (M) being less than 1/2 in., and Large (L) being greater than 1/2 in.

	<u>Right Foot</u>	<u>Left Foot</u>
Blister Incurred	<u>Yes / No</u>	<u>Yes / No</u>
<u>If Yes:</u>		
Number Incurred	_____	_____
Blister #1	<u>S / M / L</u>	<u>S / M / L</u>
Blister #2	<u>S / M / L</u>	<u>S / M / L</u>
Blister #3	<u>S / M / L</u>	<u>S / M / L</u>
Blister #4	<u>S / M / L</u>	<u>S / M / L</u>

Indicate on the foot model with an X the location of the blisters incurred.

Appendix E

Satisfaction Inventory

Identification Number _____

On a scale of 1-10 with 1 being the lowest and 10 being the highest rating indicate your personal ratings of the following characteristics for the socks worn.

	Poor					Excellent				
Overall Comfort.....	1	2	3	4	5	6	7	8	9	10
Durability.....	1	2	3	4	5	6	7	8	9	10
Kept your feet from getting hot.....	1	2	3	4	5	6	7	8	9	10
Kept your feet from getting sweaty.....	1	2	3	4	5	6	7	8	9	10
Overall Satisfaction.....	1	2	3	4	5	6	7	8	9	10

IMAGE EVALUATION TEST TARGET (QA-3)

APPLIED IMAGE, Inc
1653 East Main Street
Rochester, NY 14609 USA
Phone: 716/482-0300
Fax: 716/288-5989

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