FRICTION BLISTERS: PATHOPHYSIOLOGY, RISK FACTORS, AND PREVENTION

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Friction blisters are one of the most common injuries an active individual can experience. They are usually a minor annoyance, generally requiring only simple first aid and a short period of limited activity. However, it is possible for blisters to develop into more serious problems such as cellulitis or sepsis (1). This article reviews the pathogenesis of blisters, examines factors that influence blister formation, and examines the evidence-based interventions that decrease the probability of blister formation. This article is based on an earlier review, updated with more recent information (2).

Frictional forces that oppose the movement of materials or objects across the skin appear to be the cause of most blisters seen in physically active individuals. When the skin is in contact with an object (e.g., shoe, sock, prosthetic device) and an external force attempts to move the object across the skin, a frictional force (F_f) will oppose the movement. As the external force increases, friction increases and movement will occur when the external force exceeds the F_f. The magnitude of the frictional force is proportional to the normal force (F_n, force of contact or perpendicular force) according to the formula $F_f=\mu*F_n$, where μ= coefficient of friction. Experimental studies using rubbing techniques have been used to produce and study friction blisters (3). In these investigations, a variety of mechanical probes are used to apply a constant force that repeatedly cycles over the skin in a linear or circular fashion. Studies using these techniques have demonstrated that a relatively uniform series of events are involved in blister formation. At first there is a slight exfoliation of the stratum corneum, and erythroderma is noted around the zone of the rubbing. With continued rubbing the subject may suddenly experience a stinging or burning sensation and a pale, narrow area forms around the reddened region. This pale area enlarges inward to occupy the entire zone where the rubbing is applied. The pale area becomes elevated over the underlying skin as it fills with fluid. Histological studies indicate that the pale area is a separation of cells at the level of the stratum spinosum, presumably due to mechanical fatigue. Normal, necrotic, and degenerated prickle cells are seen on both sides of the cleft, with the basal cell layer usually showing little insult and the junction between the dermis and epidermis remaining undamaged. Hydrostatic pressure presumably causes the cleft to fill with fluid. Compared with plasma, the blister fluid has a lower protein but similar electrolyte concentration. Recovery begins after about 6 hours as cells in the blister base increase their uptake of amino acids and nucleosides of RNA and DNA. At 24–30 hours, high mitotic activity is apparent in the base cells and at 48 hours a new granular layer can be found. By 120 hours, cellular proliferation declines and a new stratum corneum can be seen (1, 4).

The probability of blister formation appears to be influenced by a number of factors, including the magnitude of the frictional force, number of shear cycles, external loading, moisture, skin characteristics, cigarette smoking, ethnicity, and foot type. The magnitude of the frictional force and the number of times a material or object cycles over the skin appear to be the major determinates of blister formation: as frictional forces increase, fewer cycles are required for blister formation (5). Related to this is the fact that carrying heavy external loads (e.g., a heavy backpack) during locomotion appears to increase the likelihood of foot blisters, presumably due to higher maximal anteroposterior breaking and propelling forces in the foot (6). Skin characteristics also influence blister formation, since blisters are readily formed in the palms of the hands, soles of the feet, and other areas with a thick stratum corneum and granulosum. This is presumably because frictional surface forces are more likely to result in differential movement of the upper and lower layers of the epidermis, leading to mechanical fatigue. (1, 4).

Moist skin produces higher frictional forces than very dry or very wet skin. Frictional forces on dry skin may result in exfoliation of cells from the stratum corneum and these sloughed cells may provide sliding lubrication analogous to graphite. Very wet skin may produce hydrodynamic lubrication. Moist skin may impede the movement of squamous cells by holding them to the skin through surface tension, thus increasing the frictional effect (1, 7, 8, 4).

During military road marching, blisters were more likely to develop among tobacco users, among those of ethnicities other than Black, and among individuals with flat feet. Tobacco use results in catechoamine release, vasoconstriction in the skin, and skin damage and these factors may reduce the ability to resist frictional forces. In black skin, mechanical stress causes less tissue deformation and this may reduce mechanical fatigue in the stratum spinosum making blisters less likely. Pes planus feet may have a larger surface area exposed to potential frictional forces, possibly making blisters more likely (9).

Interventions to reduce blister incidence have focused on reducing moisture and/or frictional forces. Antiperspirants applied to the foot have been demonstrated to decrease sweating and to reduce the incidence of blisters, as long as they do not contain emollients. However, antiperspirants result in a high incidence of irritant dermatitis and individuals should be monitored closely for this (10, 11).

A closed-cell neoprene insole (Spenco®) reduced the incidence of foot blisters, but a cellular polyurethane substance (Poron®) did not (12-14). Certain types of sock materials appear to move moisture away from the skin and vent it to the environment in the presence of metabolic heat ("wicking"). Acrylic and polyester socks have been shown to decrease blister incidence (15, 16). Tighter fitting nylon socks may reduce friction, if the frictional interface occurs between the sock surface and the shoe, rather the foot and the shoe, thus reducing blister incidence (17, 18).

The effects of skin coverings have been tested for their effects on μ, and reducing μ may reduce blister incidence. Tested skin coverings (with μ values in parenthesis) include Bursatek® (0.57), Dr Sholl's® Moleskin Plus (0.69), Moleskin (0.94), Band-Aid® (1.01), Band-Aid® Plastic

(1.03), Spenco® Second Skin® Blister Pad (1.04), New-Skin® (1.05), Nexcare® Comfort (1.08), Dr Sholl's® Blister Treatment (1.20), Blister Block® (1.37), and Tegaderm® (1.54) (19).

Drying powders have been advocated as a method for preventing blisters, since powders may absorb moisture, but studies using talc-based powders have either shown no difference when compared with a control group or a higher blister incidence among those using the powder (17, 20). Dry talc reduced frictional forces in exposed skin (21, 8), but when the talc was wet, frictional forces increased (21). Further, it is possible that when alkaline sweat combines with foot powder it creates abrasive surfaces as it clumps together.

Several studies indirectly support the idea that blister likelihood is reduced by recent exposure of the skin to repeated frictional forces that are insufficient to cause immediate blister formation (22, 16). Repeated low-intensity frictional forces cause an increase in the thickness of the stratum corneum and stratum spinosum (23).

In summary, blisters appear to be caused by repeated frictional forces that result in a cleft at the level of the stratum spinosum due to mechanical fatigue; the cleft fills with a serum-like fluid due to hydrostatic pressure. The probability of blister formation increases with high frictional forces, more shear cycles, high external loading, moisture, friction on skin with thick horny layers, tobacco use, ethnicity other than Black, and flat feet. Interventions that reduce blister likelihood include the use of antiperspirants, acrylic or polyester socks, and neoprene insoles. Certain types of skin coverages and adaptation to low frictional forces may reduce blisters.

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