The Advanced Guide to Blister Prevention

by Rebecca Rushton BSc(Pod)

For athletes and sports medicine professionals
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WHY WRITE THIS GUIDE?

Blisters are one of the most common injuries in sport and everyday life. In fact blisters are so common they’re not taken seriously, even when they’re exceptionally painful and limiting. It’s not that they’re an insignificant injury. But it seems that because they are an injury of the skin rather than the musculoskeletal system, they tend to be relegated to an injury of lesser importance. A big part of the problem is that misinformation is rife and management ill-informed.

WHO IS THIS GUIDE FOR?

This guide is for runners and endurance athletes, sports people and active people of all persuasions and anyone who suffers with foot blisters. It’s for podiatrists, sports medicine practitioners and anyone who is responsible for preventative foot care, particularly in sport. If optimal performance and maximum enjoyment matters to you, then truly successful blister prevention is important to you and you should read this guide. Foot blisters deserve more attention and improved outcomes considering their prevalence.

HOW TO USE THIS GUIDE?

The guide is freely available to everyone - each chapter is online so you can access it any time. You can cut to the chase and read Part 2 detailing specific blister prevention strategies. But to get the most of the guide it makes sense to read it all the way through at least once, and then return to it as a reference when needed. And join our list if you’d like to download your own copy.

“The Advanced Guide to Blister Prevention’ is an amazing resource for me as an ultra runner. It is very thoroughly made with a lot of scientific research about why blisters occur and how they are prevented, combined with a lot of practical and helpful details and advice for blister prevention. I can highly recommend this resource to all ultra runners if you want to learn how to prevent blisters for the long haul - Excellent work!”

Christian Madsen Scandinavian representative for the Marathon Des Sables

www.ultrarun.com
PART 1 – FOOT BLISTER CAUSES

CHAPTER 1: THE PROBLEM OF FOOT BLISTERS

Foot blisters are a common injury experienced by active people: runners, hikers and court sport players in particular. But anyone can get blisters, and most of us have! Too often, prevention is neglected and treatment is the fall-back. The problem with this approach is it rarely provides 100% pain relief, requires ongoing intervention and you need to have the right gear on-hand, at that very moment in time.

TAKE ME TO CHAPTER 1 >

CHAPTER 2: THE INJURY MECHANISM

The mainstream understanding of what causes foot blisters is a very simplistic one – to the point of being incorrect. Misinformation is widespread and it is holding the state of mainstream blister prevention at a standstill. There is a desperate need for this to change.

TAKE ME TO CHAPTER 2 >

CHAPTER 3: WHY WE GET BLISTERS ON OUR FEET

The type of skin, the microclimate and the forces encountered by your feet are unique compared to all other areas of your body. These factors combine and contribute to blister formation. Find out what these factors mean for your blister prevention.

TAKE ME TO CHAPTER 3 >

CHAPTER 4: BLISTER RISK FACTORS

Research has identified a number of risk factors for foot blisters. Some are very easy to explain – they are directly involved in the cause of blisters. Others are less intuitive and might surprise you.

TAKE ME TO CHAPTER 4 >
PART 2 - BLISTER PREVENTION STRATEGIES

Blister prevention fails for a reason. Part 2 of this guide is all about why it fails and how to make the most of what each strategy can offer.

TAKE ME TO PART 2 >

CHAPTER 5: YOUR SHOES & SOCKS

Blister prevention starts with optimal shoe fit. Then there are things you can do with your choice of socks to prevent blisters (moisture-wicking socks, double-sock systems and even toe-socks). And see how insoles, orthotics and special patches applied to the shoe or insole work. We’ll look at some simple things you can do yourself and some others that a sports medicine professional can help you with.

TAKE ME TO CHAPTER 5 >

CHAPTER 6: YOUR SKIN

Training your skin to adapt to blister-causing forces is a blister prevention consideration not to be ignored – it’s a rookie mistake to overlook this one. And discover the truths about how applying certain products to the skin can reduce blister incidence - drying preparations, lubricants and taping. This chapter is a must-read!

TAKE ME TO CHAPTER 6 >

CHAPTER 7: YOUR ACTIVITY

Blister-causing forces on the skin can be reduced by modifying aspects of your running form and training regime. If you’re a trail runner or play a court sport (tennis, netball, basketball etc) watch the video in this chapter.

TAKE ME TO CHAPTER 7 >
CHAPTER 8: COMPARISONS

We’ll wrap it all up with a comparison chart that outlines the pros & cons and a 3-star rating of the strategies discussed. So you can see at a glance how one strategy compares to another.

ABOUT THE AUTHOR

Learn more about author Rebecca Rushton and why she is driven to improve the state of blister prevention world-wide.

REFERENCES

As you read through this guide, you’ll see little numbers above the writing. You can click on these links to find the source of the information quoted – they’re all on the reference page.
PART 1: FOOT BLISTER CAUSES

Chapter 1 - The Problem of Foot Blisters

In this chapter
- Blister incidence
- Blister prone
- What is needed from here

BLISTER INCIDENCE

Blisters are one of the most common injuries in running, sport and everyday life. Their incidence has been measured in runners, hikers and the military.
- 2% of male marine recruits during initial training\(^5^2\)
- 16% of runners during a 10 mile race\(^1^1^8\)
- 20% of marine recruits over 32 weeks of training\(^1^0^6\)
- 22% after a 5-day 21km cross-country hike\(^4^9\)
- 29% of long distance hikers in Vermont\(^5^7\)
- 33% of soldiers during Operation Iraqi Freedom\(^1^0^0\)
- Up to 39% of marathon runners\(^7^1\)
- 42% of military cadets during initial training\(^3^3\)
- 48% during a 21km cross-country hike\(^4^5\)
- 57% during 6 weeks of basic military training\(^8^5\)
- 77% of military recruits during training\(^9^9\)
- 95% of college students on a 580km road hike\(^1^1^1\)

Blisters are not just a common injury – they often rank as the number one injury. Research into distance running, hiking and military injuries regularly find foot blisters are more common than musculoskeletal injuries of the knee, back, ankle and foot.\(^2^8\ \(^4^9\ \(^5^1\ \(^7^1\ \(^1^1^8\)

In fact blisters are so common we tend to not take them seriously, even when they’re exceptionally painful and limiting. What happens next is blister treatment becomes the focus – not prevention. This is not acceptable. As an athlete, you should not be satisfied with this. And as a sports medicine professional, you should be even less satisfied with this approach.
It’s not that blisters are an insignificant injury. But it seems that because they’re an injury of the skin rather than the musculoskeletal system, they tend to be relegated to an injury of lesser importance. “With such a high incidence and potential for disability, one would think that the prevention of friction blisters would be better understood… many myths continue to be propagated regarding the prevention and treatment of friction blisters.”

BLISTER PRONE

Research has shown that there is such a thing as being blister prone. Blisters form quicker in some people compared to others when the same rubbing force is applied to the skin. Just look at the results of the three pieces of research below from Naylor² Sulzberger³ and Hashmi.¹⁰⁹

<table>
<thead>
<tr>
<th>Year of research</th>
<th>Time to blister range</th>
<th>Subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>1955</td>
<td>27-138 rubs</td>
<td>19 British medical students and doctors</td>
</tr>
<tr>
<td>1966</td>
<td>3-50 minutes</td>
<td>54 American army personnel</td>
</tr>
<tr>
<td>2013</td>
<td>4-32 minutes</td>
<td>30 university volunteers</td>
</tr>
</tbody>
</table>

FIGURE 1: FOOT Blisters ARE A COMMON PROBLEM AND DO NOT RECEIVE THE ATTENTION THEY DESERVE.

FIGURE 2: THE LARGE INDIVIDUAL VARIATION IN TIME TO BLISTER (REFS 2, 3, 109)
WHAT IS NEEDED FROM HERE

With foot blisters being so common, there needs to be a better understanding of:

- what causes blisters
- where opportunities for blister prevention exist
- how each blister prevention strategy works ... and doesn’t work!
- where there are gaps in our knowledge

There is an alarming amount of bad information available about blisters. It results in poor management practices. The right information is available: there’s a lot of good material that has come from military research; there’s some really good information in diabetic foot and prosthetic limb skin management literature; and there’s a lot of research from the field of tribology (the study of friction). But there’s nothing that has taken information from all of these sources, applied it specifically to foot blisters and made it easy to understand and freely available.

This guide bridges that gap. It is the easy-to-understand and freely available resource you can use to improve your blister prevention outcomes, whether you’re an athlete or a sports medicine professional. And it comes from someone who knows about feet and foot function and who is blister prone herself.

Please feel free to share this with your friends and colleagues.

SUMMARY

1. Blisters are one of the most common injuries in running sport and everyday life.
2. There is a large individual variation in blister susceptibility.
3. You should not be satisfied with relying on blister treatment.
Chapter 2: The Injury Mechanism

In this chapter:
- What causes blisters – the blister injury
- Influencing factors
- Good friction / bad friction

WHAT CAUSES BLISTERS – THE BLISTER INJURY

**Step 1** Place the tip of your right index finger on the back of your left hand.

**Step 2** Wobble it back and forth but keep it stuck to the same bit of skin. Notice how your skin stretches? *This is shear and this is what causes blisters.* Keep wobbling as you read:

Shear might look like rubbing but it’s not. Notice how your finger tip has not moved relative to the skin of the back of your hand? But the skin on the back of your hand has moved relative to the underlying bone. Shear is the sliding of tissue layers over one another and it happens internally, below the skin’s surface (whereas rubbing happens on the outer skin surface). It’s that last little bit of shear that is damaging, when there is maximum skin stretch. When shear is excessive and repetitive, blisters form.

Here’s the significance of friction – friction is what keeps the tip of your finger stuck to the back of your hand! Shear needs high friction to be able to approach blister-causing levels. The video below shows you what shear looks like at the back of the heel, a common site for blisters. The foot remains stationary in the shoe as the heel bone moves up and down. This causes the soft tissues (skin, fatty tissue, fascia, muscle, ligaments etc) between the skin surface and bone to shear (stretch).

FIGURE 3: SOFT TISSUE SHEAR CAUSING HEEL BLISTERS VIDEO HTTP://YOUTU.BE/TDJ51WZZB3G
Contrary to popular belief, you don’t need rubbing to cause blisters. This is one of the main misconceptions of blister formation. The “rub” doesn’t cause the blister. Shear is the blister injury. Rubbing (in the presence of high friction) causes further abrasive skin damage. Rubbing (in the presence of low friction) can in fact save you from blisters and forms the basis of many blister prevention strategies.

“The injurious effects of friction on the skin and the underlying tissues can be divided into two classes, those without slip [no rubbing] and those with slip [rubbing]. The former may rupture the epidermis and occlude blood and interstitial fluid-flows by stretching or compressing the skin [blisters]. The latter adds an abrasion to this damage [deroofed blisters].”

![Figure 4: Intact Heel Blisters](imagecredit)

![Figure 5: Deroofed Heel Blisters](imagecredit)
INFLUENCING FACTORS

The four requirements for blister-causing shear are:
1. A certain type of skin
2. High friction and pressure (the coefficient of friction)
3. Moving bone
4. Repetition

Friction is the force that resists movement of one object over another. Skin friction is different to other types of friction because skin is a living and compressible tissue and so skin friction has two components: surface adhesion and tissue deformation. The degree to which one predominates over the other depends on the characteristics of the two surfaces and is the subject of debate amongst tribologists.¹

The common expression for frictional behaviour is the coefficient of friction (COF).¹¹ It is a dimensionless number (a ratio) that represents the ‘slipperiness’ or ‘stickiness’ between two surfaces and is defined by the equation: COefficient of friction = Friction force / Force of contact. The table below give you an idea of the coefficient of friction of several pairs of materials. There are two different COF values because the friction coefficient will be different when the surfaces are in stationary contact (static) and when they are moving relative to each other (dynamic - think rubbing). Apart from Teflon on Teflon, see how friction is higher when there is no movement!

<table>
<thead>
<tr>
<th>SURFACES</th>
<th>COEFFICIENT OF FRICTION (static)</th>
<th>COEFFICIENT OF FRICTION (dynamic)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel on steel</td>
<td>0.74</td>
<td>0.57</td>
</tr>
<tr>
<td>Glass on glass</td>
<td>0.94</td>
<td>0.40</td>
</tr>
<tr>
<td>Metal on metal (lubricated)</td>
<td>0.15</td>
<td>0.06</td>
</tr>
<tr>
<td>Ice on ice</td>
<td>0.10</td>
<td>0.03</td>
</tr>
<tr>
<td>Teflon on Teflon</td>
<td>0.04</td>
<td>0.04</td>
</tr>
<tr>
<td>Tyre on concrete</td>
<td>1.00</td>
<td>0.80</td>
</tr>
<tr>
<td>Tyre on wet road</td>
<td>0.50</td>
<td>0.40</td>
</tr>
<tr>
<td>Tyre on snow</td>
<td>0.30</td>
<td>0.20</td>
</tr>
</tbody>
</table>

FIGURE 6: COEFFICIENT OF FRICTION DATA. THE STATIC COF IS HIGHER, EXCEPT FOR TEFLEX ON TEFLEX - ADAPTED FROM TOWNSEND (REF 59)
GOOD FRICTION / BAD FRICTION

Without friction, your foot would slide around too much in your shoe causing injuries to your feet (eg: black toenails, toenails falling off) and making your muscles work harder for balance, propulsion and overall functional efficiency. Your foot requires traction within the shoe and it gets it from friction. This concept of 'not all friction is bad' is a very important one. By design, socks, insoles and shoe linings provide high friction – this is good. Friction only becomes bad when it’s high enough to cause skin injury (and the threshold for injury will be different for each person). And it usually exists in small localized areas, not the whole foot.

"A certain amount of frictional force is necessary on the plantar surface of the foot (sole) in order to develop traction and stability for propulsion."

Friction is a force parallel to the skin surface. It works in the opposite direction to the movement force from the bone. While the bone acts to pull the skin and soft tissue one way, the force of friction resists it, kind of pulling them the other way. Then there are compressive forces that are perpendicular to the skin surface - one from above (body weight) and one from the ground below - that cause pressure. These forces combine to define the shear load borne by the skin and soft tissue (shown below).
“Shear forces are applied to the human foot during walking and running because of the mechanics of foot alignment during contact and propulsion. The foot approaches the ground at a tangential angle (not a purely vertical angle) and then pushes off in a similar tangential direction. The foot [bones] must skid to a stop and then push into the ground to propel forward. The skidding will occur in both an anterior-posterior and medial-lateral direction, depending on the activity and demands of the sport.”

SUMMARY
1. Blisters are an injury of shear.
2. Shear is the internal parallel stretching of soft tissue between skin and bone.
3. Friction is necessary for shear to reach blister-causing levels.
Chapter 3: Why we get blisters on our feet

In this chapter

- Skin anatomy
- Blister formation
- Why do we get blisters on our feet?
- The blister threshold
- A hypothetical scenario

SKIN ANATOMY

Skin is the barrier between the internal and external world. It has three layers: the epidermis, the dermis and the subcutis. A layer of fascia under that connects the skin to underlying tissues including the bones. Here are a few interesting things to know:

- Blisters occur in the outer skin layer called the epidermis
- The epidermis is made up of several layers itself and blisters occur within the stratum spinosum (prickle layer)² ³ ⁶ ¹¹
- The soles and palms are made of skin with no hair and a higher proportion of sweat glands (glabrous skin). Other areas of skin contain hair and less sweat glands¹⁴
- Bones are indirectly connected to the skin surface and therefore bone movement has an impact on the tension in more superficial skin and soft tissue⁹⁴

FIGURE 8: THE LAYERS OF SKIN; THE LAYERS OF THE EPIDERMIS. BLISTERS OCCUR WITHIN THE PRICKLE LAYER.
BLISTER FORMATION

The earliest blister research by Naylor\textsuperscript{2} and Sulzberger and colleagues\textsuperscript{3} found blister formation to have two stages. These findings still hold true today:

1. the formation of an intra-epidermal split
2. the filling of this split with fluid

Blisters form when the shear stress exceeds the shear strength of the skin, resulting in a separation within the prickle layer of the epidermis.\textsuperscript{12} Presumably this is the layer of cells with the least resistance to shear. As shear becomes excessive, the structural connections between these cells stretch too far, they fatigue and fail. These microscopic tears are the initial blister injury. The higher the shear magnitude, the less repetitions required to cause a blister.\textsuperscript{2} Knapik\textsuperscript{11} summarises the observable changes of rubbing the skin (below). Most recently, Hashmi\textsuperscript{109} found the same changes in their experimental blister study on the back of the heels.

“A relatively uniform series of events are involved in blister formation. At first there is a slight exfoliation of the stratum corneum, and erythroderma [redness] 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.”\textsuperscript{119}

A blister does not fill with fluid immediately after the epidermal split but it is fully filled within 2 hours.\textsuperscript{3} 6\textsuperscript{11}

FIGURE 9: SHEAR CAN BECOME EXCESSIVE (IMAGE CREDIT)
WHY DO WE GET BLISTERS ON OUR FEET?

In Chapter 2 you saw what shear looks and feels like on the back of your hand. Here’s an extension to that which shows you why the skin of the feet are susceptible.

**Step 1:** Place the tip of your right index finger on the back of your left hand.

**Step 2:** Wobble it back and forth but keep it stuck to the same bit of skin. Notice how far your skin can stretch (shear) back and forth.

**Step 3:** Now do the same thing on the palm of your left hand. Notice how your skin doesn’t move as much? The skin on the back of the hand is thinner – you can pinch it and move it around easily. Most skin on your body is like this. On the palm it feels thicker and less mobile. It’s just like this on the sole of the foot, even more-so because of weight-bearing. This is the type of skin that blisters form on most readily, as explained below.

- The skin is relatively immobile as it is adhered firmly to underlying structures. This is a functional requirement of the foot. But it means shear reaches a peak sooner.\(^3\)\(^7\) Thankfully, the soft tissues of our feet are able to deal with a lot of shear ... to a point.

- The very outer layer of skin (the stratum corneum) is very thick on the feet, particularly on the soles. A thick corneum makes the skin surface able to withstand shear and rubbing without abrading, and able to withstand the underlying pressure of a fluid-filled lesion (blister). Conversely, the thinner the skin, the quicker it tends to abrade (either before or as soon as the skin blisters).\(^3\)\(^10\)\(^37\)\(^48\)

There are other reasons why blisters are common on the feet. And these have to do with the in-shoe microclimate.\(^83\)\(^89\) Conditions within the shoe are hot and humid at the best of times\(^83\) and consider the unique structure and function of the foot:

- There are more sweat glands on the sole of the foot compared to other areas of the body. These sweat glands secrete a certain amount of perspiration all the time, and even more-so when you exercise and when the outside temperature is hot (and some people perspire more than others). Blister and skin friction studies consistently show higher friction levels on moist sweaty skin (compared to very dry or very wet skin) and on the soles and palms compared to other parts of the body.\(^3\)\(^11\)\(^17\)\(^25\)\(^79\)\(^82\)\(^86\)\(^89\)
• Few other parts of the body are wrapped up like the feet are in socks and shoes. Air circulation is poor so cooling and evaporation are compromised.⁸³
• No other body part sustains weight-bearing pressures like the feet do
• The nature of gait is repetitive and force repetitions are a requisite for blister formation.

THE BLISTER THRESHOLD
Shear is a normal consequence of transferring weight from one foot to the other and it happens with every step you take. It is present at well-tolerated levels most of the time as we walk, run and play sport. But shear can become excessive. Excessive shear is the last little bit of shear – where it reaches its maximum. We call this the shear peak. To put it simply, when the shear peak exceeds a certain limit blisters will form. You can think of this limit as your blister threshold and it’s represented by the dotted line. In essence, the position of the blister threshold (the height along the y axis) defines where an individual sits on the continuum between 'blister prone' and 'blister resistant'.
Blister prevention and shear peaks

The aim of blister prevention is to get this shear peak below the blister threshold. So let’s look at how reducing the horizontal forces (friction and bone movement) can get the shear peak to somewhere below the blister threshold so blisters are avoided.

![Figure 11: Shear Peak](image)

**FIGURE 11: SHEAR PEAK – ADAPTED FROM TOWNSEND (59)**

![Figure 12: Reducing Friction to Lower the Shear Peak](image)

**FIGURE 12: REDUCING FRICTION TO LOWER THE SHEAR PEAK ADAPTED FROM TOWNSEND (REF 59)**

By reducing friction, you make the environment (an area large or small) more slippery. An earlier slide, of the skin relative to the shoe, means the skin moves more in sync with the bone, with less shear the result. This slide can be between the skin and sock, the shoe and sock, or both!

Examples of friction-reducing blister prevention strategies include lubricants like Vaseline, ENGO Patches, moisture-wicking socks, powders and antiperspirants.

![Figure 13: Reducing Bone Movement to Lower the Shear Peak](image)

**FIGURE 13: REDUCING BONE MOVEMENT TO LOWER THE SHEAR PEAK ADAPTED FROM TOWNSEND (REF 59)**

Rather than dealing with friction, if bone movement is reduced, quite simply, the shear peak will be lower, even in the presence of high friction. Skeletal movement can be reduced by altering biomechanics or form, or by altering the intensity, duration or frequency of the activity.

But these strategies can only be taken so far before they impact negatively on sporting performance.
A HYPOTHETICAL SCENARIO

Let’s apply our knowledge of friction and shear peaks to a hypothetical blister scenario.

Let’s say you’re a runner and you’re having a bad time with blisters, which is unusual for you. It’s a hot summer, you’ve been running a bit later in the mornings and you think the heat might have something to do with it. Let’s say we could measure your blister threshold and we knew your blister-causing coefficient of friction (COF) was 0.6. You wear good runners, cheap socks from the sport shop and you run three times a week for between 5-8kms on a mainly flat terrain. Your form and biomechanics are good and your feet are in good condition otherwise. So it seems you can’t do much about bone movement, but you can definitely have an impact on friction, because you think the extra sweat is causing higher friction levels. If we measured the COF between your foot and the sock at the end of a run, we might get a value of 0.8 (which is above your blister threshold). So your aim would be to make your skin stay drier for longer (let’s say you used an antiperspirant and moisture-wicking socks) so you got the COF down to 0.5. At this level, you’ll have a successful blister prevention strategy.

If you still got blisters but they only developed on your 8km runs, it’s an indication the antiperspirant and socks keep the COF below 0.6 for longer, but not long enough. Presumably the antiperspirant loses effect and the moisture-wicking socks exceed their absorptive and wicking capacity. The next step could be to reduce the repetitions by keeping your running distance to 5kms. But you’re understandably not happy with that. So you try an ENGO Patch on your insole in an effort to reduce friction between it and the sock. Thankfully, even on your big runs you remain blister-free. This is an indication the COF remained below 0.6 for the duration of the run, in spite of the environmental and in-shoe conditions.

Notice how we’ve just addressed the four influencing factors of blister-causing shear?

1. Thick and immobile skin – actually not much you could do about this one
2. A high coefficient of friction – minimised with antiperspirant, moisture-wicking socks and ENGO patch
3. Moving bone – we know your mechanics and shoes are good and the terrain is flat
4. Repetition – you could have stuck to 5km runs but it would have been as a last resort

**SUMMARY**

1. The thickness and stiffness of the skin on the feet (particularly the soles) is most likely to form blisters.
2. The in-shoe microclimate is suited to blister formation.
3. The blister threshold explains why some people are more blister-prone than others.
4. The blister threshold helps explain the aim of blister prevention strategies.
Chapter 4: Blister Risk Factors

In this chapter:

- Risk factors for friction blisters on the feet
- Blisters and temperature

RISK FACTORS FOR FRICTION BLISTERS ON THE FEET

The four requirements for blister-causing shear are listed below. Factors contributing to these conditions are quite obvious risk factors for blister development.

1. Thick and immobile skin
2. A high coefficient of friction (friction and pressure)
3. Moving bone
4. Repetition

And research has identified other factors that seem to correlate to blister development too - factors that from the outside, seem unlikely to have any bearing. Factors like gender, ethnicity, tobacco use and fitness. There are conflicting results with some and the research base is not exactly substantial for many. So it’s not clear how relevant some are as risk factors.

Please note: A risk factor does not necessarily imply causation. “Risk factors or determinants are correlational and not necessarily causal, because correlation does not prove causation.”¹²² “A famous slogan in statistics is that correlation does not imply causation. We know that there is a statistical correlation between eating ice cream and drowning incidents, for instance, but ice cream consumption does not cause drowning. Where any two factors A and B are correlated, there are four possibilities:

- A is a cause of B
- B is a cause of A
- the correlation is pure coincidence
- as in the ice cream case, A and B are connected by a common cause. Increased ice cream consumption and drowning rates both have a common cause in warm summer weather.”¹¹⁰
<table>
<thead>
<tr>
<th>RISK FACTOR</th>
<th>INCREASED BLISTER INCIDENCE</th>
<th>REDUCED BLISTER INCIDENCE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FRICATION</strong> (parallel force)</td>
<td>Higher friction</td>
<td>Lower friction</td>
</tr>
<tr>
<td><strong>PRESSURE</strong> (perpendicular force)</td>
<td>Higher force</td>
<td>Lower force</td>
</tr>
<tr>
<td><strong>NUMBER OF SHEAR CYCLES</strong></td>
<td>More cycles</td>
<td>Fewer cycles</td>
</tr>
</tbody>
</table>

Friction, pressure and number of shear cycles: The magnitude of frictional forces and the number of times a material or object cycles over the skin determines the probability of blister development. The higher the COF the fewer the cycles necessary to produce a blister (Naylor E.F.B., 1995; Comalish, 1973; Akers, 1985; Knapik et al, 1995). And heavy carried loads (higher pressure) have been shown to increase blister incidence (Reynolds et al, 1999; Knapik, 2000).

<table>
<thead>
<tr>
<th>SKIN CHARACTERISTICS</th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td><strong>Thick and stiff</strong></td>
<td></td>
<td><strong>Thin and mobile</strong></td>
</tr>
</tbody>
</table>

Skin characteristics and skin moisture: Every experimental blister study has shown that blisters form most easily on thick and stiff skin of the feet, especially the soles (Akers and Sulzberger, 1972; Sulzberger et al, 1986). And research shows skin friction increases in the presence of moisture, compared to very dry or very wet skin (Naylor, 1995 A&B; Sulzberger et al, 1966; Akers and Sulzberger, 1972; Highly, 1977; Nacht et al, 1981; Sivamani et al, 2003a).

<table>
<thead>
<tr>
<th>SKIN MOISTURE</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>‘Moist’</strong></td>
<td></td>
<td><strong>Very dry or very wet</strong></td>
</tr>
</tbody>
</table>

In almost every discussion you'll read on blisters, heat is always mentioned as a causative factor. To the point that some believe friction blisters to be a burn. Research shows this not to be the case. Higher ambient or skin temperatures increase perspiration which increases skin friction. Blisters form and fill quicker in higher temperatures, but heat is not required for blister development. The temperature-blister association is multifactorial and is discussed in more detail below this table.

<table>
<thead>
<tr>
<th>TEMPERATURE</th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td><strong>Higher temperature</strong></td>
<td></td>
<td><strong>Colder temperature</strong></td>
</tr>
</tbody>
</table>

There is conflicting research evidence here ... Some studies found women to be more susceptible: Patterson et al (1994) found women were 1.6 times more likely to blister. Brennan et al (2012) found women were more likely – 47% vs 30%. And Veljen et al (2013 A) found that women were more likely to have a higher skin coefficient of friction compared to men ... Other studies have found no correlation between blisters and gender: Twombly and Schussman (1995) showed an equal blister incidence of 46% for males and females. Boulware (2004) showed similar blistering results for men (65%) and women (63%). Chol et al (2013) found blister incidence to be equal between male and female. And Knapik et al (1999) found no differences. Skin friction studies by Cua et al (1990 and 1995), Savescu et al (2008), Van Tiggelen et al (2009) and Sivamani et al (2003C) found no skin friction differences between men and women.

<table>
<thead>
<tr>
<th>GENDER</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Female?</strong></td>
<td></td>
<td><strong>Male?</strong></td>
</tr>
</tbody>
</table>

There is conflicting evidence on blister incidence and age. Reynolds et al (1999) found a younger age to be a risk factor for blisters on a 5-day 161km cross country march of 218 light infantry males. Brennan et al (2012) found 26-34 year olds were more likely to get blisters than younger and older troops. Yavuz and Davis (2010) found that plantar shear is not dependent on age, comparing adult and pediatric subjects. Veljen et al (2013 C) found COF values highest in the over 50 years of age group compared to younger subjects. And Cua et al (1990 and 1995) and Sivamani et al (2003 C) found no COF differences in skin friction between young and old subjects.

<table>
<thead>
<tr>
<th>AGE</th>
<th></th>
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</thead>
<tbody>
<tr>
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</table>

ETHNICITY

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Caucasian</strong></td>
<td></td>
<td><strong>African-American</strong></td>
</tr>
</tbody>
</table>

Patterson et al (1994), Reynolds et al (1999) and Van Tiggelen et al (2009) found Caucasian ethnicity to be a risk factor for blisters compared to African-American. Knapik et al (1999) found "individuals of black ethnicity were at significantly lower risk than those of white, Asian, Hispanic or ‘other’ ethnicities. There were no differences between white, Asian, Hispanic or ‘other’ ethnic groups". But as far as skin friction research goes, Sivamani et al (2003C) found no skin COF measurement differences between Caucasian, African-American, Hispanic or Asian ethnicities.
Despite popular belief, blisters are not a burn. Here’s why:

- Thermal burns that produce blisters are second degree burns, and second degree burns go deeper - into the dermis. Friction blisters are more superficial.
existing within the epidermis. And friction blisters do not resemble thermal burns either clinically or histologically.² ⁶ ³ ⁷

- Research has found that rubbing causes only moderate increases in skin temperatures, to between 41 degrees and 50 degrees Celsius which are insufficient to cause a burn.¹ ⁷ ¹¹ ¹² ³ ⁷ ¹⁰² ¹⁰⁹ ¹¹⁹

**The relevance of heat to blister development:** In almost every discussion you’ll read on blisters, heat is always mentioned as a causative factor. Although not directly a cause (not a burn), the involvement of temperature is multi-factorial.¹ ⁷ ¹¹ ¹² ³ ⁷

**a) The act of rubbing produces heat** – The act of rubbing any two surfaces together causes the production of heat and it’s no different for the skin.¹⁷ ¹² ³ ⁷ Li¹² demonstrated that rubbing causes a moderate increase in skin temperature, and that this warmer area of skin increases sweat production, which increases skin friction. This perspiration/friction mechanism [rubbing - heat - more sweat - higher friction - blister] is in contrast to the burn mechanism [rubbing - heat - burn - blister] and this distinction should be recognised.² ⁷ ¹¹ ¹² ³ ⁷ ¹⁰² Besides, if heat transfer from the skin surface to the stratum spinosum is a major factor in blister development, one would expect the thicker corneum of the soles and palms to afford a level of blister protection. But a thick corneum is one of the requisites for blister formation.² ¹¹

**b) Ambient and skin temperature** – Higher ambient temperatures cause more perspiration.¹ And as you’d expect, increased walking speed causes higher in-shoe temperatures⁶¹ ⁶⁸ which results in increased sweating.⁸³ This perspiration provides a ‘moist’ environment, and a moist environment (neither very wet nor very dry) is known to increase friction coefficients¹ ¹¹ ²⁰ which increases blister incidence³ ²⁴ by way of shear.¹² Although blisters occur more readily in hot temperatures, blisters still occur in cold climates.⁶ ²⁸ Griffin⁷ produced experimental blisters on chilled, warmed and “normal” temperature skin and noted:

- blisters formed quicker when initial skin temperature was higher
- blisters took longer to form on chilled skin (14 degrees) compared to normal (30 degrees) and warmed skin (46 degrees)
- when the initial skin temperature was low, the skin temperature at the time of blistering was also lower
c) The inflammatory process – Hashmi¹⁰⁹ measured temperature changes during and after blister formation. They specifically aimed to minimise heat from rubbing, instead focusing on temperatures after blister formation. They demonstrated temperature increases due to inflammation, indicating heat is a result of the injury.³⁷ ¹⁰⁹

Overall, heat causes sweating which increases skin friction, leading to a higher likelihood of blisters. And heat is a result of the blister injury.

FIGURE 15: HASHMI DEMONSTRATED AN INCREASE IN TEMPERATURE FOR SEVERAL HOURS AFTER BLISTER FORMATION INDICATING THE INFLAMMATORY RESPONSE (REF 109)
SUMMARY

1. Risk factors for foot blisters that have been identified in the literature are presented.
2. Among others, there is conflicting evidence regarding gender, age, body-mass index and fitness as risk factors for blisters.
3. Blisters are not a burn. But heat increases perspiration which increases skin friction and makes blister more likely to form.
Part 2: Blister Prevention Strategies

THE CURRENT REALITY OF BLISTER PREVENTION

The frustrating reality of blister prevention is it often fails. It can be difficult to find a strategy (or combination of strategies) that works, is long-lasting and is quick and easy to use. Several factors are at play here including the extreme forces encountered by the weight-bearing foot and the hot and humid in-shoe microclimate. But also:

- there are inherent limitations in each strategy that must be understood
- the misunderstandings of what really causes blisters can lead to an unsuitable prevention strategy being chosen

Chapters 5-7 will look at all of your blister prevention options. One by one, we’ll look at how the strategy works, its pros and cons and what research can tell us about its effectiveness.

LET’S TAKE A CLOSER LOOK AT FRICTION

But first, there’s one concept that’s generally missing from the mainstream discussion of blisters. We’ve touched on it, but you may not have realised its importance. If you can understand this concept, you will expand your repertoire of blister prevention options. The concept is that of interfaces.

Friction is present between any two surfaces. We call a pair of surfaces an interface. The in-shoe interfaces are the skin-sock (black) interface and the shoe-sock (blue) interface, depicted below. When looking for blister prevention opportunities to do with friction, you need to get specific about which interface you’re looking at because it makes a difference!
Consider the black interface. By making it more slippery here, movement of the sock against the skin is encouraged. This rubbing in not necessarily going to be a problem to the skin - unless friction increases to a level that is abrasive. Strategies that work at this interface, like lubricants, powders and moisture-wicking socks will be explained in the following chapters.

Now consider the blue interface. By making it more slippery here, movement is encouraged between the shoe and sock. The rubbing can't cause abrasive skin damage because nothing is rubbing against the skin - the sock is protecting it. The sock is protecting the skin because the two are stuck together and remain in stationary contact (thanks to friction) while movement occurs on the other side of the sock. The following chapters will explain how this works - particularly polytetrafluoroethylene patches (ENG0 Patches).

**BLISTER PREVENTION STRATEGIES**

Next we’ll look at individual blister prevention strategies that you can employ, focusing at either your:

- Shoes and socks – including insoles, orthotics & patches applied to your shoes
- Skin – including moisture management techniques & tapes applied to your skin
- Activity – including your technique and the intensity with which you perform
SUMMARY
1. Blister prevention fails when the wrong strategy is chosen for the activity; and when the inherent limitations of the strategy are not understood.
2. Friction exists between any two surfaces (called an interface). Friction may be high or low.
3. There are two interfaces in the shoe that are commonly used to apply blister prevention: the skin-sock interface and the shoe-sock interface.
4. Friction reduction at the shoe-sock interface allows the sock to protect the skin from abrasion.
Chapter 5: Your Shoes & Socks

In this chapter:
- Shoe-fit & lacing
- Socks: Moisture-wicking socks and double-sock systems
- Insoles
- Orthotics
- Polytetrafluoroethylene Patches (ENGO Patches)

1) SHOE-FIT & LACING

Shoe-fit should be your first and most basic blister prevention consideration. Too small and the extra pressure causes shear to become excessive with less repetitions. Too big and your foot slides around too much in the shoe, increasing the probability of blisters, deroofing of blisters, abrasions, bruises, black toenails, blisters under the toenails and even losing your toenails. Keep these problems to a minimum with a shoe that fits perfectly. Optimal shoe-fit revolves around length, width and adjustability.

a) Length: The ‘rule of thumb’ is to have the width of your thumb between the end of your longest toe (usually the 2nd toe – but not always) and the end of the shoe upper. Measure this while you’re standing (because your foot will elongate a bit) and make sure your heel is right at the back of the shoe.

b) Width: You don’t want the side of your foot overhanging (bulging over) the side of your shoe. By the same token, you don’t want too much width and have your foot moving around too much. When you are trying on shoes, if they fit perfectly but the facings (the material the laces go through) are touching one another, the shoe is as tight as you can get it. You’ve got nowhere to go if your shoe stretches, it’s going to get too loose. Again, check this while you’re standing.

c) Adjustability: It’s not just about the length and width. You could have a perfectly sized shoe but if your laces are too tight or too loose, you’ve wasted your time. You might as well not have bothered getting the perfect sized shoes! The whole reason we have laces is to optimise shoe-fit at all times. Because it’s only when the foot fits snugly in the shoe that the shoe provides the support it’s designed to.
Consider the fact that shoe-fit changes during the course of your activity - foot volume will increase with longer duration walking and running, even in the exceptionally fit athlete. Over-hydration, topical in recent years following the work of Noakes\textsuperscript{133} may contribute. So be prepared to adjust your laces as you go. Conversely, if your shoes are too loose and your foot feels like its sliding forward or your heel is lifting at the back, try this:

- first make sure you’ve used the last pair of eyelets – the holes your laces go through
- next try the lace-lock lacing technique (video below http://youtu.be/LXjOLWgWq9k)
- if that doesn’t work, check Ian’s Shoelace Site for a lacing technique that suits you

However, be aware that although shoe-fit has intuitive merit, it is not always enough to ensure blister protection.\textsuperscript{31 77 87}

\textbf{SUMMARY}

1. Shoe-fit is your first blister prevention consideration.
2. Lacing allows you to optimise shoe-fit at all times.
3. Optimal shoe-fit may not be enough to ensure protection from blisters.
2) SOCKS

Socks provide relatively high friction to maintain traction for the foot inside the shoe. This is by design. But socks can be used in such a way as to lower friction, namely:

a) Moisture-wicking socks
b) Double-sock systems

a) Moisture-wicking socks – High skin moisture causes high skin friction and more likelihood of blisters. The initial goal of a sock is to absorb moisture (perspiration) to keep the skin dry. But because of the sheer volume of moisture encountered, absorption alone won’t always be adequate - the absorptive capacity of any sock can be exceeded. Some socks 'move' moisture away from the skin – from the skin side of the sock to the shoe side of a sock in a process known as wicking. The moisture can then evaporate through the shoe upper. This wicking function is achieved by sock manufacturers by using fibres in a way that sets up a moisture gradient to facilitate moisture movement in this direction.

FIGURE 18: MOISTURE-WICKING MOISTURE GRADIENT (ADAPTED FROM REF 132)
Socks have many functions and fibres are selected for their construction accordingly. Thermal insulation, cushioning, durability, quick drying and ability to maintain shape: these will demand certain fibre properties. In regard to their interaction with moisture, fibres are chosen according to their hydrophilic (absorbent or water-attracting) or hydrophobic (non-absorbent or water-repelling) nature. The former keeps moisture trapped against the skin while the latter repels it away from the skin. Richie lists sock fibres from most hydrophilic to most hydrophobic:

Cotton --- Wool --- Acrylic --- Polyester --- Polypropylene

Cotton and wool are natural fibres (yarns). The others are synthetic fibres.

- Cotton: Cotton is the most hydrophilic fibre used in sock construction. It is widely-known that cotton socks have no place in endurance activities where blisters are a common consequence. Moisture is trapped within the sock and against the skin, keeping the skin moist and clammy - just perfect for blister development.

- Wool: Wool is a common fibre used in specialist hiking sock construction for its thermal insulation properties. On its own, wool is not a great fibre for sock construction because of its hydrophilic nature. But Richie explains the premium Merino wool fibre is different: “Compared with traditional wool, Merino wool has a much finer core diameter of each fiber, giving a softer feel and more air space for moisture movement. Merino wool has fewer tendencies for skin itch, which is common with regular wool socks and apparel. The finer fiber and natural airspaces created by Merino wool have lead manufacturers to claim that this fiber is superior to any synthetic fiber for insulation and wicking.”

- Acrylic: In 1990, Richie and Herring assessed blister incidence in runners wearing either 100% acrylic socks (with padded construction) or 100% cotton socks. The padded acrylic socks out-performed cotton in regard to both blister incidence and blister size (acrylic sock wearers experienced half as many blisters and of those blisters that did occur, they were one-third the size of those of cotton socks). However, “one shortcoming of acrylic is its poor insulation. On hot surfaces in summer months, acrylic fiber socks can conduct heat and be undesirable.” (Richie)

- Polyester: A common and well-known example of a polyester fibre is Coolmax. Van Tiggelen found polyester socks to significantly reduce the incidence of blisters compared to a double-sock arrangement and compared to a standard military issue wool sock. Richie explains “The most popular synthetic fibers utilised in athletic hosiery are acrylic and polyester. Both acrylic and
Polyester fibers are hydrophobic and have superior wicking properties and reduced drying time than cotton.” And “... studies have shown that Coolmax and other polyester fibers have a 15% faster drying time compared to acrylic fibers.”

- Polypropylene: Polypropylene fibers absorb very little moisture.

If you haven’t given much thought to your sock selection (like our hypothetical runner in Chapter 3) one of the easiest changes you can make to reduce your likelihood of blisters is to make sure there is no cotton fibre content in your socks and instead choose moisture-wicking sock. “Cotton fiber retains three times the moisture of acrylic and fourteen times the moisture of CoolMax®. When exposed to ambient air, socks composed of cotton retain moisture ten times longer than acrylic.”

Here’s something you may not have given much thought to. In considering the function of moisture-wicking socks, the shoes have to be recognised as part of the shoe/sock unit (or footwear system as described by Dyck³¹). To work adequately, a shoe with a breathable upper is required to allow the evaporation of moisture into the atmosphere.³¹ ⁸⁵ ⁹⁷ Water-proofing can prevent this evaporation and not surprisingly Bogerd et al¹⁰¹ found moisture vapour transmission rates (MVTR) through 4 different boot uppers to be far below that of sweating rates. On the other hand, the mesh upper of most running shoes will intuitively allow for much better MVTR.
b) Double sock systems

Double socks add a new interface into the equation. As well as the standard skin-sock and shoe-sock interface, you now have a sock-sock interface. Double sock systems come in two forms:

- Literally wearing two pairs of socks
- Socks that have two layers at certain locations within the sock (double layer socks)

![FIGURE 22: DOUBLE SOCKS (IMAGE CREDIT)](image)

Double-sock systems are all about reducing friction. The idea is to use different materials so that the sock-sock friction coefficient is lower than that of the other two interfaces. But double-socks can also provide a moisture-wicking function by using a hydrophobic material against the skin and a hydrophilic material on the outer.\(^3^2\) \(^3^9\) \(^8^5\) And the thick nap of the outer sock can act to absorb some shear.\(^3^9\) Research\(^2^1\) \(^3^2\) \(^3^9\) has demonstrated an improved blister prevention function with double socks as opposed to single socks. Although Van Tiggelen\(^8^5\) found a single polyester sock to reduce the incidence of blisters better than a double-sock arrangement. Knapik\(^3^9\) compared 3 sock systems (summarised below):

<table>
<thead>
<tr>
<th>SOCK CONDITION</th>
<th>BLISTER INCIDENCE</th>
<th>SEVERE BLISTER INCIDENCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single sock (wool-cotton-nylon-Spandex combination)</td>
<td>69%</td>
<td>24%</td>
</tr>
<tr>
<td>Double sock arrangement 1 (Standard military boot sock plus a thin polyester inner sock)</td>
<td>77%</td>
<td>9%</td>
</tr>
<tr>
<td>Double sock arrangement 2 (Very thick, dense, prototype outer sock (wool-polyprene combination) plus the same thin polyester inner sock as group 2)</td>
<td>40%</td>
<td>11%</td>
</tr>
</tbody>
</table>

![FIGURE 21: KNAPIK’S RESEARCH ON DOUBLE SOCKS (REF 39)](image)
Van Tiggelen provides this insight: “On a theoretical base, the inner sock provided the wicking capacity whereas the outer sock absorbs the moisture. On a practical basis, the recruits reported the formation of folds in the inner sock causing unequal pressure zones on the foot. Hence although the properties of this sock system are beneficial to the wearer, the application of the system could counteract its benefit by creating hot spots on the foot.” A very close-fitting inner sock is required to prevent this. And the fibre content of each sock is paramount - it’s not as easy as throwing any two pairs of socks together. Interestingly, how often do you see two pairs of socks for sale at the sports shop, sold specifically to be worn as a double sock system? More common (but still fairly uncommon) are double socks - a single pair of socks with two layers within their construction.

Toe-socks can be thought of as double socks for interdigital areas. But this sock-sock interface is actually the same material. The crux of double-sock systems is to use different fibre content to ensure lower sock-sock friction. Alternatively, benefit may come from the increased cushioning bulk between the toes. Unfortunately, apart from some favourable results following a survey of runners after the 2012 Jungle Marathon, research is lacking when it comes to toe-socks.

![injinji](image.jpg)

**FIGURE 23: TOE-SOCKS (IMAGE CREDIT)**

**SUMMARY**

1. Moisture-wicking socks aim to minimise friction at the skin-sock interface.
2. Double-socks introduce an additional interface (sock-sock) where friction is theoretically kept lowest.
3. The absorptive capacity of the sock and breathability of the shoe upper determine the success of these measures.
3) CUSHIONED INSOLES

Insoles can reduce blister formation in 2 ways:

A) Cushioning reduces peak pressure  
b) Cushioning materials absorb shear (shear modulus)

a) Peak Pressure - Compared to other parts of our body, the pressure placed on our feet is unmatched. While mainly the weight-bearing surface, there is a high force of contact between the shoe and the heel, toes and other parts of the foot even while standing. Start running, jumping, accelerating, decelerating and changing direction and we’re looking at even higher forces. This pressure contributes to blister-causing shear by way of the coefficient of friction. Pressure is not the cause of blisters, it is a contributing factor.³⁷ You’ll see how with this experiment:

- **STEP 1:** Press the tip of your right index finger firmly on the back of your left hand.
- **STEP 2:** Wobble it back and forth but keep it stuck to the same bit of skin. Notice how your skin stretches? This is shear and this is what causes blisters.
- **STEP 3:** Wobble back and forth again but this time press softly with your finger tip. Notice how there is less shear. Low pressure allows your fingertip to slide across the skin before shear becomes excessive. High pressure sees your fingertip remain stuck to your hand for longer which causes a lot more shear.
- **STEP 4:** Put a drop of oil on the back of your hand (reduce friction) and wobble your fingertip back and forth again - with really firm pressure. Press as hard as you can! No matter how much you compress the skin against the bones underneath, there’s only a tiny bit of shear! You really have to do this to believe it. And it’s showing you how important friction is to blister development.

Cushioning reduces pressure peak by increasing surface area – by spreading the load over a larger area. Look at the diagram below. Fixed volume gels do this best as the gel is displaced laterally to form a cradle at the edges of the bony prominence.
b) Shear Modulus - Due to its thickness and cellular composition, a cushioned insole has the ability to absorb shear. When the material itself undergoes shear, it means the skin doesn’t have to (or at least, less-so). This is called the material’s shear modulus. A low shear modulus indicates the ability of the material to absorb more shear. Silicone gel has a very low shear modulus and has the ability to absorb more shear than standard insole and cushioning materials.⁵ ⁹⁴

What The Research Shows for Cushioning and Blisters

Not all insoles have the same ability to reduce pressure and absorb shear. Two insole materials that have been tested in regard to blister prevention are Spenco (a closed-cell neoprene polymer rubber) and Poron (a cellular polyurethane).⁵ ²³ The statistics from the Smith study (reported by Knapik³⁷) showed Spenco performed better at reducing blister and callus incidence (table below). However a further study found an un-named cellular polyurethane foam slightly increased blister incidence.¹⁰⁶

<table>
<thead>
<tr>
<th>PREVENTATIVE STRATEGY</th>
<th>BLISTER / CALLUS INCIDENCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Insole</td>
<td>33%</td>
</tr>
<tr>
<td>Poron Insole</td>
<td>17%</td>
</tr>
<tr>
<td>Spenco Insole</td>
<td>5%</td>
</tr>
</tbody>
</table>

For cushioning to be effective, its properties must be a good match to the job at hand. If it’s too soft, the cushioning material will simply flatten and not reduce the peak pressure at all. And if shear modulus is excessively low, braking and propulsive mechanisms are compromised, reducing the mechanical efficiencies of gait. “Cushioning degrades control and energy efficiency. Ideally, cushioning
should be used sparingly ...”. This is one of the limitations of gels used under the sole of the foot.

One thing to be aware of is insole materials like Spenco, Poron and silicone gels tend to exhibit high friction⁴⁴ ⁴⁸ ⁵⁶ ¹²⁵ as seen in the graph below. Again, this is by design because the foot needs friction for traction. But it does provide a conundrum for blister-sufferers.

**FIGURE 26: COEFFICIENT OF FRICTION DATA IN DRY AND MOIST CONDITIONS - ADAPTED FROM PAYETTE [REF 125]**

**SUMMARY**

1. Cushioning materials reduce peak pressure by spreading load over a larger area.
2. Cushioning materials can also absorb shear via their shear modulus.
3. More cushioning is not always better as it can effect shoe fit and reduce functional efficiency.
Foot orthoses (orthotics) can be used to change the magnitude and timing of vertical and parallel forces on the foot. This means orthotics can be used to prevent blister-causing shear.

Below is a table outlining possible biomechanical factors that may contribute to blister-causing shear and the potential orthotic prescription variables, musculoskeletal therapies and other interventions that can be used to alter foot function to minimise shear. While this information is mainly for the benefit of podiatrists and sports medicine professionals, you can see there is a huge potential for us to minimise blister-causing shear with the use of orthotics and other means, where it is applicable. Athletes should not use this as specific practical advice for their blisters. If you have ongoing blister issues, consult an expert in foot function for the best biomechanical advice and treatment relevant to you!

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>EXAMPLE OF STRUCTURAL / BIOMECHANICAL ISSUE</th>
<th>CONSEQUENCE</th>
<th>INTERVENTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Posterior heel</td>
<td>▶ High ankle joint dorsiflexion stiffness</td>
<td>▶ Increased tension in Achilles tendon causes the calcaneus to elevate sooner and further</td>
<td>▶ Joint mobilisation to lower talofibular joint</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>▶ Gastrocnemius/soleus stretches</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>▶ Shoes with higher heel height differential and/or heel lifts</td>
</tr>
<tr>
<td>Plantar Metatarsal</td>
<td>▶ Ligamentous laxity</td>
<td>▶ High peak pressure at 2nd-4th metatarsal heads</td>
<td>▶ Reduce subtalar joint pronation moments with orthoses including medial heel skive</td>
</tr>
<tr>
<td>Heads 2-4</td>
<td>▶ Compliant 1st and 5th rays</td>
<td>▶ Large forward / backward movement of 2nd-4th metatarsal heads</td>
<td>▶ Prescription variables to improve windlass mechanism such as forefoot extension 2-5 MPJs and cluffy wedge</td>
</tr>
<tr>
<td></td>
<td>▶ High subtalar joint pronation moments</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plantar 5th metatarsal</td>
<td>▶ Forefoot equinus</td>
<td>▶ High peak pressure under 5th metatarsal head</td>
<td>▶ Heel lift / heel height differential</td>
</tr>
<tr>
<td>head</td>
<td>▶ Inverted foot at relaxed stance</td>
<td>▶ Large forward / backward movement of 5th metatarsal head</td>
<td>▶ Increase orthosis contouring of lateral border of foot</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plantar 1st metatarsal</td>
<td>▶ A flat pronated foot with a semi-compliant plantarflexed first ray</td>
<td>▶ High medial loading</td>
<td>▶ Orthoses with prescription variables to improve windlass mechanism: first ray wipe, forefoot extension 2-5, Cluffy wedge, heel lift, Metatarsal dome</td>
</tr>
<tr>
<td>head</td>
<td></td>
<td>▶ Large forward / backward movement of 1st metatarsal head</td>
<td></td>
</tr>
<tr>
<td>Mediotplantar</td>
<td>▶ Hallux abductovalgus (bunion) and excess subtalar joint pronation with shoe width not accommodating foot width at forefoot</td>
<td>▶ Poor shoe fit with first metatarsal head bulging over sole of shoe</td>
<td>▶ Improved footwear fit (sole width)</td>
</tr>
<tr>
<td>1st MPJ</td>
<td></td>
<td>▶ Exacerbated by high medial loading</td>
<td>▶ Minimise subtalar joint pronation forces with orthoses</td>
</tr>
</tbody>
</table>

While this information is mainly for the benefit of podiatrists and sports medicine professionals, you can see there is a huge potential for us to minimise blister-causing shear with the use of orthotics and other means, where it is applicable. Athletes should not use this as specific practical advice for their blisters. If you have ongoing blister issues, consult an expert in foot function for the best biomechanical advice and treatment relevant to you!
**FIGURE 27: AN EXAMPLE OF BIOMECHANICAL CAUSES AND TREATMENTS FOR FOOT BLISTERS ACCORDING TO ANATOMICAL LOCATION. THIS IS GENERAL ADVICE ONLY AND SHOULD NOT TO BE SEEN AS SPECIFIC ADVICE FOR YOUR BLISTERS!**

<table>
<thead>
<tr>
<th>Anatomical Location</th>
<th>Cause</th>
<th>Treatment 1</th>
<th>Treatment 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plantar hallux interphalangeal joint</td>
<td>Compliant plantarflexed first ray</td>
<td>High peak pressure under interphalangeal joint of hallux due to inadequate windlass mechanism establishment</td>
<td>Orthoses with prescription variables to improve windlass mechanism: first ray wipe, forefoot extension 2-5, Cluffy wedge, heel lift</td>
</tr>
<tr>
<td>Toe apices</td>
<td>Ligamentous laxity, Very pronated / flat foot posture (FP1 +9)</td>
<td>Prolonged toe flexor muscle action during gait</td>
<td>Orthoses to reduce subtalar joint pronation, Toe props</td>
</tr>
<tr>
<td>Dorsum of toes</td>
<td>Fixed digital clawing, Laces tied loosely</td>
<td>High peak pressure at dorsum of toes due to toe box too shallow, Foot slides forward in shoe</td>
<td>Shoes with adequate depth in toebox, Laces for adjustability and lace-lock lacing technique to enable firm fitting around midfoot to prevent forward slide, Silicone toe sleeves</td>
</tr>
<tr>
<td>Interdigital spaces</td>
<td>Adductovarus deformity of lesser toes</td>
<td>Excess interdigital pressure due to lesser toe deformity, Digital movement during gait</td>
<td>Interdigital wedging/cushioning to reduce peak pressure and relative toe movement</td>
</tr>
<tr>
<td>Plantar medial longitudinal arch 'orthosis irritation'</td>
<td>Inadequate management of arch flattening moments</td>
<td>Soft tissue of plantar medial longitudinal arch subjected to high compression and shear</td>
<td>Modify orthosis prescription variables to facilitate windlass mechanism and reduce STJ pronation moments more, Improved orthosis contouring in medial longitudinal arch, Gastrocnemius/soleus stretches</td>
</tr>
</tbody>
</table>

**SUMMARY**

1. Podiatrists have an advanced understanding of foot biomechanics to help prevent blisters.
2. Foot orthotics alter pressure and friction and therefore have a direct impact on soft tissue shear.
5) POLYTETRAFLUOROETHYLENE SHOE PATCHES (ENGO PATCHES)

Polytetrafluoroethylene (PTFE) is an ultra-low friction material. Teflon® is an example of a PTFE material. ENGO Blister Prevention Patches is another. ENGO Patches are adhesive patches that stick to your shoe or insole where high friction causes blisters. Research shows two things about the friction properties of these patches:

a) a coefficient of friction of around 0.16 which is very low compared to other in-shoe materials

b) the low coefficient of friction is maintained in the presence of moisture

FIGURE 28: ENGO'S COEFFICIENT OF FRICTION REMAINS LOW IN THE PRESENCE OF MOISTURE – ADAPTED FROM CARLSON (REF 56)

FIGURE 29: MORE COEFFICIENT OF FRICTION DATA - ADAPTED FROM PAYETTE (REF 125)
Most attempts at reducing friction are focused on the skin (the skin-sock interface) – like powders, antiperspirants, lubricants and moisture-wicking socks. But friction reduction can take place on the other side of the sock: the shoe-sock interface. The advantage is that sweat is not a constant threat to adhesion. So as long as the shoe isn’t water-logged, the patches stay in place for an extended period. In fact both the adhesive and the PTFE (blue) surface are very hardy, lasting around 500kms of wear. On a personal note, the best thing I find with ENGO patches is once they’re in the shoe, you can simply forget about blister prevention. Now please exercise a healthy degree of scepticism here as this is purely my own personal experience - and I have a commercial association with ENGO Patches. But if you’re blister prone like me and taking preventative measures on a daily basis is a necessity, you’ll understand what a bane it can be (in regard to time, cost and just having to be organised, among other things). Once these patches are in the shoe, you just get your shoes on and go - there’s no fluffing about with taping or applying products to your skin each time or soaking your feet the day before. And there’s no mess.

We’ve discussed the importance of friction - it is necessary for traction and the mechanical efficiencies of gait (propulsion, changing direction etc). So where friction is too high and causing blisters, it only needs to be minimised at that location (not the whole foot). This is called Targeted Friction Management. Unlike many other friction-reducing strategies, ENGO Patches allow the targeted management of friction: they minimise ‘bad’ friction in discrete areas to avoid blisters whilst maintaining ‘good’ friction elsewhere to maintain necessary traction - meaning biomechanical function is unchanged and functional efficiency is maintained.
Considering the very low coefficient of friction of under 0.20, it's very likely friction will be reduced (more than most other strategies considering the COF values above) to below the blister threshold of most people, regardless of how heavy perspiration or environmental moisture is. Informal blister case studies show favourable results for athletes of American football, soccer, volleyball and basketball sporting codes.\textsuperscript{127} And PTFE has been found to significantly reduce the incidence of another shear injury, diabetic foot ulcers.\textsuperscript{103}

**SUMMARY**

1. Polytetrafluoroethylene (ENG0 Patches) reduce friction at the shoe-sock interface.
2. PTFE has very low friction properties that are unaffected by moisture.
3. ENGO Patches allow the targeted management of friction.
Chapter 6: Your Skin

In this chapter:
- Adaption
- Drying strategies
- Lubricants
- Taping

1) ADAPTATION

One of the most common rookie mistakes leading to blisters is to start a new type of activity without any thought to adapting your skin. By training in the actual shoes and socks (including any carried load if applicable) and on comparable terrain, you allow the skin to adapt to the physical demands of your activity. And this provides a protective function. Research has shown that when the skin is subjected to repeated frictional forces below that which causes blistering, epidermal cell turnover is faster, cells are more resistant to frictional forces and the stratum corneum becomes thicker.¹³ ¹⁴ ²¹ ³⁶ ⁴⁰ These adaptive changes (on mouse ear skin) occur sooner than you might expect - changes after 7 days are identical to those at 14-35 days.¹³ ¹⁴ ³⁶ And it takes approximately 28 days for skin cells to move from the bottom of the epidermis to the surface.³⁶

A level of reduced blister incidence has been reported with:
- having spent more time in the particular shoes³³ ⁵⁷ ¹⁰⁰
- having previous experience in the activity⁸⁵
- with more miles trained per week by runners²¹ ⁴２

Gardner and Hill⁵⁷ found hikers that had not preconditioned their footwear were more likely to get blisters (32.1% versus 25.5%) - a mild protective effect. And in testing double sock systems against standard military issue socks, Thompson³² found reduced blister incidence was most noticeable early on in recruit training, when “recruits are adapting to the rigors of physical training.” Patterson⁴³ found 95% of blisters to occur in the first three weeks of training with the following distribution, suggesting foot skin may require 2-3 weeks for adaptive changes to occur:

- Week 1: 35%
- Week 2: 51%
The take home message here is, depending on your blister threshold, although adapting your skin to your activity does not ensure protection from blisters, it will be a step in the right direction and should not be neglected.

But you can take this too far - At its best, the adaptive thickening of the corneum is barely noticeable. At its extreme, it constitutes a callus. Some believe calluses to be protective. While there is no doubt a thicker corneum will reduce the likelihood of abrasions (just because there is more thickness to wear through before getting to raw skin), blisters are not abrasions (as discussed in Chapter 3). And clinical experience suggests that thick calluses are far from protective. In fact, the shear experienced under a thick callus is more likely to be destructive to deeper layers of the skin and make blistering and blood blisters more likely.
Skin toughening - is a phrase used to describe the effect of some preparations used in blister prevention, like Compound Benzoin Tincture, alcohol, salt water, black tea.¹¹⁻¹⁵ These preparations more appropriately fit a ‘skin drying strategy’ providing for a lower frictional force – discussed next.

**SUMMARY**

1. Skin becomes more resistant to shear when subjected to repeated shear cycles.
2. It helps to train in the gear and on the terrain to benefit from this blister protective function.
3. Calluses are not protective to blisters.
2) SKIN DRYING STRATEGIES

Moist skin has higher friction than very dry or very wet skin.¹³¹⁷¹⁸²⁰¹¹¹⁶¹¹⁹ The theory is simple: keeping your skin dry - keeps skin friction low - hopefully below your blister threshold - successful blister prevention is the result. But keeping your feet dry is a tough ask - surrounded by socks, enclosed in shoes, sweat, varying amounts of evaporation, exercise, environmental conditions! Then consider if you sweat more than average. It’s not difficult to see how a ‘very dry’ in-shoe environment might be all but impossible to achieve. Skin drying strategies include:

- Antiperspirants
- Powders
- Astringent skin treatments (often termed “skin toughening”)
- Moisture-wicking socks (discussed in Chapter 5)

Antiperspirants – Antiperspirants are chemical agents that reduce sweating (spray-on, roll-on or powder form). The most popular antiperspirants have aluminium chloride and aluminium chlorohydrate at varying strengths as the active ingredients.⁶⁹ Aluminium-based antiperspirants work by blocking the sweat ducts, thereby reducing the amount of sweat that reaches the skin’s surface. Sweat continues to be produced by the sweat gland but it isn’t able to reach the surface of the skin.⁶⁹ Based on this, there may be a risk of an intra-epidermal maceration (weakened skin). Aluminium-based antiperspirants have been tested in blister research. The table below summarises the effect on blister incidence but at the expense of skin irritation.

<table>
<thead>
<tr>
<th>RESEARCHER</th>
<th>ANTIPERSPIRANT</th>
<th>METHOD</th>
<th>RESULT</th>
<th>SIDE-EFFECT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knapik et al (1998)</td>
<td>20% solution of aluminium chloride hexahydrate in anhydrous ethyl alcohol</td>
<td>21-km hike</td>
<td>Blister incidence 21% (antiperspirant group) vs 48% (control group)</td>
<td>Skin irritation</td>
</tr>
<tr>
<td>Darrigrand et al (1992)</td>
<td>aluminium chlorohydrate and aluminium zirconium tetrachlorydroxeglycine</td>
<td>1 hour treadmill walking</td>
<td>No significant blister prevention effect</td>
<td>Irritant dermatitis</td>
</tr>
<tr>
<td>Reynolds et al (1995)</td>
<td>20% aluminium zirconium tetrachlorydroxeglycine PLUS moisturizing additives</td>
<td>3hr 20min treadmill walk</td>
<td>Skin irritation was negated with the addition of moisturizing additives</td>
<td>But the blister protective effect was lost</td>
</tr>
</tbody>
</table>

FIGURE 34: THE DISAPPOINTING RESULTS OF ANTIPERSPIRANTS FOR BLISTER PREVENTION (REF 34, 45, 130)

Another antiperspirant, Prantal Powder, works differently. Its active constituent diphemanil methylsulfate effects the parasympathetic nerves that control sweat
production, to prevent perspiration altogether. No research has been performed in relation to blister prevention.

**Powders** – Talcum powder has the ability to absorb moisture and act as a dry lubricant. But adding 13-17% hydration (ie: when your feet get a bit sweaty) causes the friction coefficient to increase. “It is self-evident that talcum does not remain dry in such areas as the foot for very long” and “the addition of talc to socks would be expected to increase frictional trauma.” Both Knapik and Richie cite three British military studies from the 1960s that tested the use of drying powders to find either no benefit or an increased blister incidence. If for whatever reason a powder is your blister prevention strategy of choice, frequent reapplication is required and is better than using too much in one application.

'Skin toughening' - Skin toughening is a phrase used to describe the effect of some ‘astringent’ preparations used in blister prevention, like Compound Benzoin Tincture, alcohol, salt water, black tea but of which there is no blister or skin friction research. An exact ‘skin toughening’ mechanism of action is not clear. Since astringents “precipitate protein, reduce permeability of the cell membrane and reduce transcapillary movement of plasma proteins” this possibly has a drying effect to the outer stratum corneum. If so, this is not so much ‘skin toughening’ but rather a skin drying strategy. More consideration for a blister prevention mechanism is required and research to demonstrate a protective effect to blisters.

**SUMMARY**

1. Moist skin exhibits higher friction than dry skin – so keeping skin dry is a method of blister prevention.
2. The in-shoe microclimate dictates that the skin is usually moist.
3. Neither antiperspirants nor powders have proven to be both safe and effective and there is no data on the use of astringent preparations. Moisture-wicking socks (discussed earlier) have proven to provide a level of blister protection.
3) LUBRICANTS

At the opposite end of the skin moisture spectrum are lubricants. Vaseline (petrolatum) is a well-known one, you apply it to your foot and friction definitely reduces. El-Shimi¹⁷ and Highley¹⁸ explain that viscous lubricants like this work by forming a film on the skin which keeps your sock and skin apart. Interestingly, the frictional properties have nothing to do with the skin-sock interface but rather, the hydrodynamic properties of the lubricant. Even more interestingly, over time, the lubricant disperses and absorbs and friction actually increases:

- As the lubricant film becomes thinner, the contact increases between the surfaces and the observed friction level is less about the hydrodynamic properties of the lubricant
- The lubricant absorbs into the skin, increasing skin hydration and therefore skin friction

![Figure 35: Lubricants are occlusive and gradually increase skin friction](image)

Landmark research by Nacht²⁰ measured skin friction for 6 hours after using moisturisers graded according to their perceived “greasiness”. The level of greasiness determined whether friction increased or decreased, as outlined in the graph below. Only the very greasy lubricants (petrolatum, heavy mineral oil and glycerin) reduced friction, and only for 60-90 minutes. Highley¹⁸ produced similar results with viscous lubricants and Sivamani et al.⁶³ found similar trends for increased skin friction with water and slightly/moderately greasy moisturisers. It should also be noted that the probe that was moved over the skin was a flat non-porous
surface. Comaish and Bottoms¹⁰ suggest a reduction in friction will be shorter-term when the skin is in contact with a fabric such as a sock. Perhaps this is why lubricants are applied very liberally.

The increase in friction found by these researchers is what Richie⁸⁸ eludes to when he states “Physicians, coaches and athletic trainers continue to advocate the use of petrolatum jelly and skin powders to prevent blisters while the scientific literature suggests these measures may actually increase the chance of blistering on the feet.” The potential limitations to the use of lubricants include:

1. Initial lack of traction - Lubricating large areas of the feet, particularly the weight-bearing sole of the foot may not be a good idea. In preventing blisters, it is not the aim to reduce friction indiscriminately. A targeted approach is the ideal approach so that traction and functional efficiency are maintained.

2. Later friction increase – This won’t be a problem with short duration exercise but for longer duration efforts, you would need to reapply the lubricant to maintain
any benefit. If not, not only has your blister protection gone, you’re actually at more risk of blistering.

3. It weakens the skin - Lubricants have an occlusive effect that traps moisture within the skin. By reducing transepidermal moisture loss, skin hydration is excessive and prolonged. In other words, the skin becomes water-logged. And water-logged skin is weaker and less able to resist trauma.³³ It’s a bit like how your skin goes when you’re in the bath for too long.

4. Attracting grit & messy - The common lubricant Vaseline (petrolatum jelly) can be a poor choice, particularly on off-road surfaces as it has a tendency to attract grit. And its potential carcinogenic properties have attracted some attention recent times as it is a product of petroleum. Viscous lubricants like Vaseline are messy too.

**SUMMARY**

1. Lubricants affect friction at the skin-sock interface.
2. Moisturisers and less greasy lubricants increase friction.
3. Viscous lubricants initially reduce friction. As the lubricant absorbs and dissipates, friction increases.
4) TAPING

Sports tape applied to blister susceptible areas is a common prevention strategy. Leukoplast, Fixomul, KinesioTex Tape and RockTape are popular choices and there are many others. And blister dressings like Compeed are also popular. These products are adhered to the skin.

By admission from athletes, sports medicine professionals and manufacturers themselves, taping provides protection from rubbing. Rubbing removes skin cells from the skin surface to progressively deeper and deeper layers causing abrasions. But this is not blister prevention - because you don’t need rubbing to cause blisters.¹² This describes abrasion prevention. So how does taping prevent blisters?

Surprisingly, there is a lack of evidence.³⁷ ⁶⁰ ⁸⁸ And a proposed mechanism of action has not attracted significant discussion in the literature either (other than is stops rubbing – which misses the crux of blister causation). Actually, rubbing will cause some shear, but not as much as when there is no rubbing¹⁰ ²⁴ ⁹⁴ (Chapter 2 figure 6). So tapes and dressings may help reduce blister formation, if the tape’s surface provides lower friction than skin friction. Understanding this, Polliack and Scheinberg⁷⁰ gathered a number of blister dressings and tested their friction properties (table below). The over-riding impression from this research is that most of these coefficient of friction values are very high, when compared to the values shown in the graphs from Carlson⁵⁶ and Payette¹² ⁵ in Chapter 5 figure 28 & 29.

<table>
<thead>
<tr>
<th>DRESSING</th>
<th>MANUFACTURER</th>
<th>COF</th>
<th>THICKNESS (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bursatek Bandage</td>
<td>Advanced Wound Systems, Newport, OR</td>
<td>0.57</td>
<td>6mm</td>
</tr>
<tr>
<td>Dr Scholl’s Moleskin Plus</td>
<td>Schering-Plough Corp, Kenilworth, NJ</td>
<td>0.69</td>
<td>31mm</td>
</tr>
<tr>
<td>Moleskin</td>
<td>PPR Inc, Brooklyn, NY</td>
<td>0.94</td>
<td>26mm</td>
</tr>
<tr>
<td>Band-Aid</td>
<td>Johnson &amp; Johnson, New Brunswick, NJ</td>
<td>1.01</td>
<td>22mm</td>
</tr>
<tr>
<td>Band-Aid Plastic</td>
<td>Johnson &amp; Johnson</td>
<td>1.03</td>
<td>18mm</td>
</tr>
<tr>
<td>2nd Skin Blister Pads</td>
<td>Spenco Medical Corp, Waco, TX</td>
<td>1.04</td>
<td>35mm</td>
</tr>
<tr>
<td>New-Skin</td>
<td>Medtech, Jackson, WY</td>
<td>1.05</td>
<td>9mm</td>
</tr>
<tr>
<td>Nexcare Comfort</td>
<td>3M Health Care, St Paul, MN</td>
<td>1.08</td>
<td>35mm</td>
</tr>
<tr>
<td>Dr Scholl’s Blister Treatment</td>
<td>Schering-Plough Corp</td>
<td>1.20</td>
<td>32mm</td>
</tr>
<tr>
<td>Blister Block (Compeed)</td>
<td>Johnson &amp; Johnson</td>
<td>1.37</td>
<td>40mm</td>
</tr>
<tr>
<td>Tegaderm</td>
<td>3M Health Care</td>
<td>1.54</td>
<td>1.5mm</td>
</tr>
</tbody>
</table>

**FIGURE 37: COEFFICIENT OF FRICTION DATA OF BLISTER DRESSINGS - ADAPTED FROM POLIACK AND SHEINBERG (REF 70)**

Unfortunately, there is no such coefficient of friction data for tape, neither from research nor their manufacturers. So we don’t know whether individual tapes reduce friction or not! Knapik³⁷ confirms plain adhesive tape can be used to prevent rubbing (ie: abrasions) “and may be effective if it reduces the coefficient of friction.
(ie: if it is ‘slick’).” Of taping, Richie⁸⁸ states “There are no published studies to show these measures actually work. Few things applied to the feet will stay intact for more than one hour of vigorous activity” highlighting the effect of perspiration and the extreme in-shoe conditions that are constant threats to adhesion.

An alternative mechanism of action – Although not described in the literature, it is plausible that tapes reduce shear at discrete locations due to the fact that they’re adhered to the skin. Just as cushioning spreads the vertical load over a larger area to reduce peak pressure, because tape is adhered to the skin, does tape spread the ‘pull’ of the horizontal load over a larger area to reduce peak shear distortion per unit area of skin? In other words, by spreading the shear load, shear per unit area of skin will be less (Carlson, 2013: personal communication).

Taping technique – Whatever the mechanism of action, the success of taping relies on keeping the tape well-adhered to the skin. Much effort is put into perfecting both the choice of tape and the application technique. Yet there is little consensus on either.

John Vonhof¹⁰⁵ ¹⁰⁸ is arguably one of the most accomplished practitioners of taping for the most extreme of ultramarathon conditions- from dry desert to tropical jungle environments. He favours the kinesiology tape called StrengthTape in wet conditions. Other taping advice from Vonhof, particularly in maximising adhesion include:

- Compound Benzoin Tincture applied to the skin before taping in order to maximise adhesion.
- Apply tape at least one hour before use (if not the night before) which allows the tape’s adhesive time to bond with the skin.
- Rub the tape for 20-30 seconds after applying it to the skin – it warms the adhesive to make it more tacky.
- When using kinesiology tapes, lay the tape on the skin and if you have to stretch the tape around a heel or toe, only apply a slight stretch. The more stretch you apply, the more likely the tape is to come loose, especially in wet conditions.
- It takes as long as it takes – a precision tape job can take more than 30 minutes. Practice makes perfect and an adequate application technique can take time.

Anna Beetham for Oxfam Trailwalker in Melbourne uses Fixomul and explains her application technique in this video: [http://youtu.be/dIHILzTQ8ek](http://youtu.be/dIHILzTQ8ek). Trent Salkovich prefers Leukoplast and uses the following technique: [http://youtu.be/hHxLjumvd0M](http://youtu.be/hHxLjumvd0M).

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**SUMMARY**

1. There has been very little research on how taping prevents blisters.
2. Tapes and dressings prevent abrasions.
3. Perspiration compromises the adhesion of tapes and dressings.
Chapter 7: Your Activity

In this chapter:
- Modify your form
- Modify your activity

Friction is a very necessary force that helps you move with speed and efficiency. And the bones within your feet must move back and forth with every step and in all directions as part of normal function. As such, soft tissue shear within the feet is a normal and unavoidable consequence of movement.

“The foot approaches the ground at a tangential angle (not a purely vertical angle) and then pushes off in a similar tangential direction. The foot [bones] must skid to a stop and then push into the ground to propel forward. The skidding will occur in both an anterior-posterior and medial-lateral direction, depending on the activity and demands of the sport.”

Most blister prevention studies focus on the friction component of this equation. And quite rightly because there is a huge potential for reducing friction alone to prevent blisters. However, you can also expect some sort of blister prevention by minimising bone movement relative to the skin surface.

MODIFY YOUR FORM

Changing the way you walk and run (commonly referred to as form) can reduce the magnitude of shear distortions per step. Here’s an example:

The underside of the heel is not a common blister site. Hikers covering steep downhill terrain are most susceptible to these debilitating blisters. You hit the ground with your heel. The heel bone slides forward relative to the planted foot, which causes a lot of shear to the tissues under the heel bone. Compared to walking over a flat surface, there is a delay in the forefoot contacting the ground – so shear under the

FIGURE 39: BLISTERS UNDER HEELS (IMAGE CREDIT)
heel bone is prolonged. Not to mention the higher magnitude of shear; the braking forces are much higher due to the slope and forward/downhill momentum of your body weight.

Changing your form to a foot-flat strike, or even if you remain heel striking but your heel strikes closer to you, you can minimise these shear distortions. You’ll achieve this by taking smaller steps and/or by bending your hip and knee more. If this change in your form is enough to bring the shear distortions under your blister threshold, you’ll avoid these blisters.

MODIFY YOUR ACTIVITY

Watch the video below. And imagine the bones as they roll over the skin when the foot is planted. This creates the shear that can become blister-causing. The longer you do this drill and the higher intensity you perform at, the more likely this will become blister-causing for you.

FIGURE 40: TENNIS PLAYERS, NETBALLERS AND OTHER COURT SPORT PLAYERS SUSTAIN A LOT OF THIS SIDE-TO-SIDE SHEAR (VIDEO) HTTP://YOUTU.BE/IUOPUL7MY4S

Tennis is a sport where blisters are very common and the shear distortions result from aggressive side-to-side movements, particularly under the ball of the foot and on the toes. Netball is another. Features of these court sports are sudden accelerations, decelerations and changes in direction. This video barely does these sports justice but you can image the magnitude of these side-to-side shear distortions when playing competitively!
If you’re just playing socially, you could ease up a bit, or sub off. If you’re a runner, you could not push yourself as hard (forget about your times) or cut back on your distance. And for the example of our downhill hiker, taking a different route to minimise the slope could be an option. These modifications revolve around:

- Reducing the intensity
- Reducing the duration
- Reducing the frequency

**These options are usually impractical – neither possible nor desired!** Hopefully you’ve found a successful blister prevention strategy before you get to this.

### SUMMARY

1. Aspects of form and technique may contribute to blister-causing shear.
2. The duration, intensity and frequency of an activity can be altered to prevent blisters.
3. Alterations to form and activity are often impractical and undesirable.
Chapter 8: Comparisons

The following table represents a summary of the pros and cons of the blister prevention strategies discussed. The star-rating with 3-stars being the best score is based on the following criteria:

- quick and easy to use
- a lack of harmful effects
- maintenance of normal function and efficiency
- demonstrated preventative effect and research evidence
# The Pros & Cons of Blister Prevention Strategies

<table>
<thead>
<tr>
<th></th>
<th>Pros</th>
<th>Cons</th>
<th>Star Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Shoe-fit &amp; Lacing</strong></td>
<td>Your first and foremost blister prevention strategy</td>
<td>May not ensure total blister protection</td>
<td>★★★</td>
</tr>
<tr>
<td><strong>Insoles &amp; Cushioning</strong></td>
<td>Proprietary insole can be replaced easily if necessary</td>
<td>More cushioning is not always better</td>
<td>★★</td>
</tr>
<tr>
<td><strong>Orthotics</strong></td>
<td>Often neglected but can provide long-term blister prevention</td>
<td>Not relevant to all blister sizes</td>
<td>★★</td>
</tr>
<tr>
<td><strong>EnGo Patches</strong></td>
<td>Extremely low COF, Long-lasting (500kms), Unaffected by moisture, Targeted friction management</td>
<td>Avoid water-logging, Can't be used for blisters between toes</td>
<td>★★★</td>
</tr>
<tr>
<td><strong>Moisture-Wicking Socks</strong></td>
<td>You need socks anyway so why not choose socks with advanced moisture management properties</td>
<td>Absorptive capacity of sock can be exceeded and long-term effect relies on evaporation through the shoe upper</td>
<td>★★★</td>
</tr>
<tr>
<td><strong>Double-Socks</strong></td>
<td>Provides an additional interface, The thin inner sock will not compromise shoe-fit</td>
<td>Optimal combination will take trial and error</td>
<td>★★</td>
</tr>
<tr>
<td><strong>Adaption</strong></td>
<td>A basic blister prevention requirement</td>
<td>Requires preparation – training in gear and on terrain before event</td>
<td>★★★</td>
</tr>
<tr>
<td><strong>Anti-Perspirants</strong></td>
<td>Easy to use, Often ineffective, Stronger preparations can cause skin irritation</td>
<td>Messy, Short term effect at best, Increases blisters at worst</td>
<td>★★</td>
</tr>
<tr>
<td><strong>Powders</strong></td>
<td>Readily available, No research exists, Theoretically only has a short term effect</td>
<td>Messy, Short term effect at best, Increases blisters at worst</td>
<td>★★</td>
</tr>
<tr>
<td><strong>Astringents</strong></td>
<td>Easy to apply</td>
<td>Initially degrades mechanical efficiency, Later friction increases above baseline, Can weaken the skin, Messy</td>
<td>★★</td>
</tr>
<tr>
<td><strong>Lubricants</strong></td>
<td>Popular</td>
<td>Time consuming, Very little research, May not reduce friction, Sweat constantly compromises adhesion</td>
<td>★★</td>
</tr>
<tr>
<td><strong>Taping &amp; Dressings</strong></td>
<td>Very popular, Good abrasion strategy</td>
<td>Changing technique may have adverse effect elsewhere</td>
<td>★★</td>
</tr>
<tr>
<td><strong>Form Alteration</strong></td>
<td>Can help if running form is at fault</td>
<td>Can help if running form is at fault</td>
<td>★★</td>
</tr>
<tr>
<td><strong>Activity Modification</strong></td>
<td>Theoretically easy to institute</td>
<td>Rarely possible or acceptable</td>
<td>★★</td>
</tr>
</tbody>
</table>
About the author

Rebecca Rushton graduated from Curtin University in 1993 in Podiatry.

Being blister prone, she has always suffered with foot blisters when playing sport. Frustrated after years of unsuccessful management of her own blister problem, she has studied the topic of foot blisters and blister prevention extensively.

After noticing many mainstream management techniques are counter to research findings; and that at its core, blister causation is poorly understood, Rebecca founded “Blister Prevention”. Aimed at helping athletes and sports medicine professionals, Blister Prevention is a website dedicated to improving the understanding of:

- what causes foot blisters
- blister prevention options
- how individual blister strategies work (and don’t work)

With over 20 years of experience as a Podiatrist, Rebecca works in private practice in Esperance, Western Australia. You can follow Rebecca on Facebook, Twitter and LinkedIn and contact her at rebecca@blisterprevention.com.au.

FIGURE 42: THE BLISTER PREVENTION WEBSITE
References


