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MACERATION PART 1: WHAT IS SKIN MACERATION

19 September 2015

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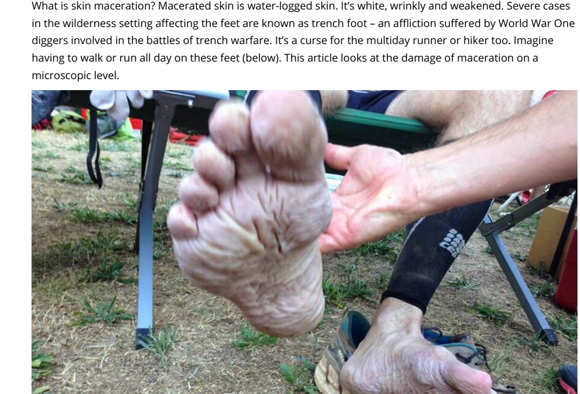
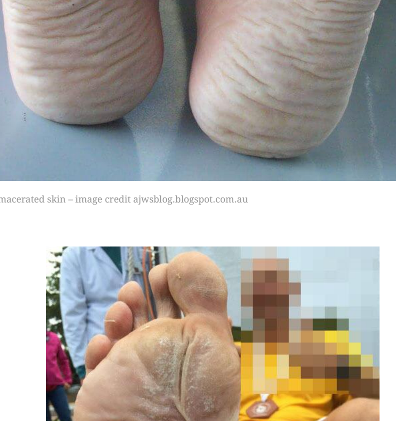
What is skin maceration? Macerated skin is water-logged skin. It's white, wrinkly and weakened. Severe cases in the wilderness setting affecting the feet are known as trench foot – an affliction suffered by World War One diggers involved in the battles of trench warfare. It's a curse for the multiday runner or hiker too. Imagine having to walk or run all day on these feet (below). This article looks at the damage of maceration on a microscopic level.



White wrinkly macerated feet – Image credit Christopher Himmel

Peeling macerated skin – image credit ajwsblog.blogspot.com.au



Deeper macerated skin – Image credit John Vonhof

WHAT CAUSES SKIN MACERATION?

Macerated skin is a curse for the multiday ultramarathon runner and hiker. Imagine getting up on day three and having to run or walk all day on these feet!

Skin maceration can occur in wet *or* dry weather:

- Rain, puddles, dew, snow
- Excessive sweating
- Pouring water over the head, only for it to dribble down into your shoes
- Wearing a saturated blister dressing for too long
- River-crossings

The condition is better known to some by various other names. But as Farafoot discusses nicely in this article, none of them are quite applicable to the condition experienced by ultrarunners and other endurance athletes:

- Trench foot
- Moon boot syndrome
- Cold water immersion foot
- Warm water immersion foot

Maceration is a tricky situation for the medic and runner/hiker alike

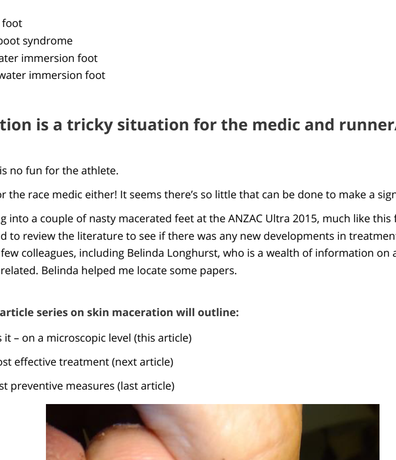
Maceration is no fun for the athlete.

It's no fun for the race medic either! It seems there's so little that can be done to make a significant difference.

After running into a couple of nasty macerated feet at the ANZAC Ultra 2015, much like this foot (below), I decided I had to review the literature to see if there was any new developments in treatment; or prevention. I contacted a few colleagues, including Belinda Longhurst, who is a wealth of information on all things feet and dermatolgy-related. Belinda helped me locate some papers.

This 3-part article series on skin maceration will outline:

1. What is it – on a microscopic level (this article)
2. The most effective treatment (next article)
3. The best preventive measures (last article)

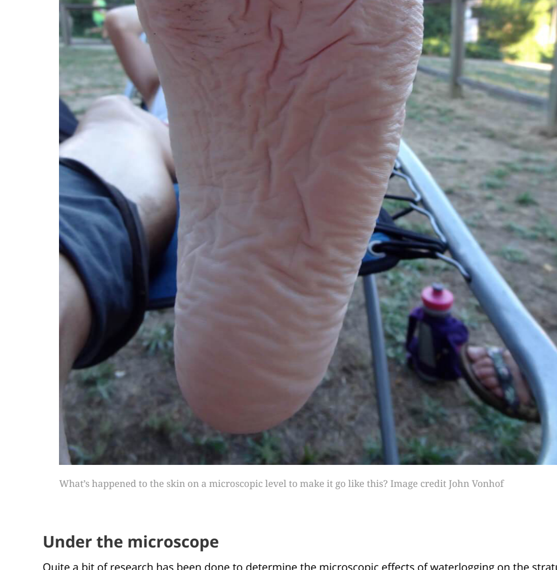


Torn macerated skin. Have a look at the little toe too – Image credit John Vonhof

THE DAMAGE OF SKIN MACERATION ON A MICROSCOPIC LEVEL

Barrier function of the skin

The skin is the organ that keeps what's inside the body, in. And what's outside the body, out. On the inside, the contents of our body are 80% water. On the outside is our environment which is very dry. Managing this water gradient is a prime function. To keep the skin in a healthy state, it has become good at absorbing what moisture it can from the atmosphere. But it's not designed for being exposed to water or other solutions for long durations.



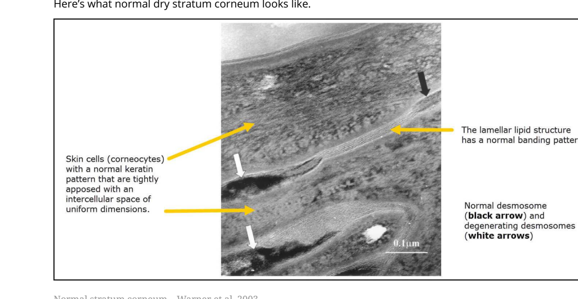
What's happened to the skin on a microscopic level to make it go like this? Image credit John Vonhof

Under the microscope

Quite a bit of research has been done to determine the microscopic effects of waterlogging on the stratum corneum (stratum means layer, corneum means horny). Remember, the corneum is the outer layer of the epidermis and unmistakably, the business end of the skin's barrier function. The skin cells (corneocytes) in the corneum are dead, dry and readying themselves to be shed. Skin cells (corneocytes) are attached to one another (by desmosomes) and they're embedded in a mortar of fat (lamellar lipid layer). The skin cells are hydrophilic (water-attracting). The lipid layer is hydrophobic (water-repelling).

a. Normal stratum corneum

Here's what normal dry stratum corneum looks like.



Normal stratum corneum – Warner et al, 2003

b. After *one hour* of water exposure

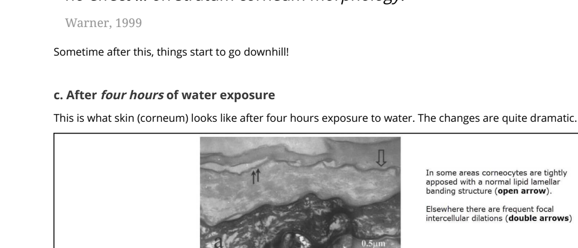
As it turns out, the skin can handle quite a bit of water exposure. At one hour, it is relatively undamaged.

> *"When water exposure is for one hour of less, even with repetitive applications during a day or over many days, water appears to have no effect … on stratum corneum morphology."*
>
> Warner, 1999

Sometime after this, things start to go downhill!

c. After *four hours* of water exposure

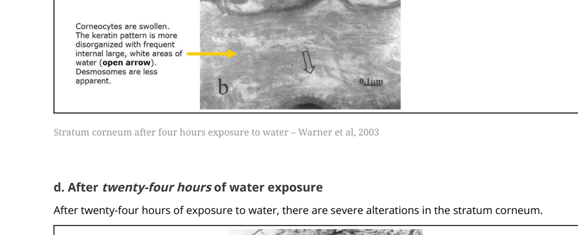
This is what skin (corneum) looks like after four hours exposure to water. The changes are quite dramatic.



Stratum corneum after four hours exposure to water – Warner et al, 2003

d. After *twenty-four hours* of water exposure

After twenty-four hours of exposure to water, there are severe alterations in the stratum corneum.

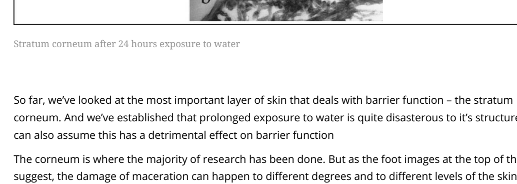


Stratum corneum after 24 hours exposure to water

So far, we've looked at the most important layer of skin that deals with barrier function – the stratum corneum. And we've established that prolonged exposure to water is quite disastrous to it's structure. We can also assume this has a detrimental effect on barrier function

The corneum is where the majority of research has been done. But as the foot images at the top of this article suggest, the damage of maceration can happen to different degrees and to different levels of the skin. Of particular interest to me is whether maceration extends into the stratum spinosum – where blisters occur*? Or deeper?

*Note: Maceration and blisters are very separate injuries of the skin.



Skin layers of the epidermis (and dermis)

DOES MACERATION GO DEEPER THAN THE STRATUM CORNEUM?

There has been one study that investigated this. Below is a quote from this paper, with a reference to "mechanical stimulation". This pertains directly to the types of forces that walking and running imparts to the skin.

> *Several studies have revealed structural changes in the stratum corneum. However, these results cannot explain the decreased skin tolerance to mechanical stimulation because skin strength is supported by intercellular junctions in the stratum spinosum and basale of the epidermis and extracellular matrix of the dermis.*
>
> Minematsu et al, 2011

These researchers discovered "ultrastructural changes in all skin layers" of the epidermis. Water penetrated all epidermal layers, right down to the stratum basale. Not only that, chemical irritants and macro-molecules penetrated into the dermis and:

> *… should be considered direct evidence for the development of maceration-induced skin lesions.*

More recently

More recently (2014), Ichikawa-Shigeta et al confirmed dermal changes due to skin maceration.

It should be noted that most research studying maceration do not use skin from the feet; or the palms, which is the closest match to plantar skin [the Minematsu study above *did* use human and rat foot skin] . This could be important for at least one reason, outlined by Dr Cynthia Bailey (personal communication, 2015).

> *On the palms and soles there is a layer between the granular layer and the horney layer called the stratum lucidum which appears under the microscope as a clear space. On other skin areas this clear layer will develop if there is a lot of rubbing/friction.*
>
> Dr Cynthia Bailey

I wonder whether this "clear space" has any effect on maceration? Does it limit the damage or does it exacerbate it? With this in mind, some caution must be taken when applying this information directly to the feet; and directly to the endurance athletic population. And that's to mention nothing of the fact there's no research that looks at maceration and the repetitive and ongoing forces involved in long distance walking or running.

Conclusion

Maceration:

- Has a catastrophic effect on the stratum corneum
- Is a full epidermal injury that effects all epidermal structures
- Involves the dermis also
- Weakens the mechanical strength of the skin

We live in a dry atmosphere. Skin is designed to absorb moisture from the atmosphere so it doesn't dry out. This design is not suited to being submerged in water for a long time [Skin that is exposed to water and liquids for long periods (oral mucosa, swimming mammals) has a very different skin structure]. Our skin can tolerate water exposure for about an hour without structural damage. After that, the damage begins. This has implications for the general barrier function. But for runners, it also has implications for the skin's overall strength. With reduced structural integrity comes a reduced ability to remain intact when subjected to the shear forces of walking and running.

I dare say the substance of this article merely backs up what most have seen or experienced first hand at various races and events. The skin folds over on itself and tears much more easily as it becomes more water-logged. While it's good to define the problem, of more use would be some substantiated information on treatment (and prevention) of this condition.

READ NOW – PART 2: HOW TO TREAT MACERATION

READ NOW – PART 3: HOW TO PREVENT MACERATION

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