

Cooling the Foot to Prevent Diabetic Foot Wounds

A Proof-of-Concept Trial

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The etiology of neuropathic diabetic foot wounds can be summarized by the following formula: pressure \times cycles of repetitive stress = ulceration. The final pathway to ulceration consists of an inflammatory response, leading to tissue breakdown. Mitigation of this response might reduce the risk of ulceration. This proof-of-concept trial evaluates whether simple cooling of the foot can safely reduce the time to thermal equilibrium after activity. After a 15-min brisk walk, the six nondiabetic volunteers enrolled were randomly assigned to receive either air cooling or a 10-min 55°F cool water bath followed by air cooling. The process was then repeated with the intervention reversed, allowing subjects to serve as their own controls. There was a rise in mean \pm SD skin temperature after 15 min of activity *versus* preactivity levels ($87.8^\circ \pm 3.9^\circ$ *versus* $79^\circ \pm 2.2^\circ$ F; $P = .0001$). Water cooling immediately brought the foot to a point cooler than preactivity levels for all subjects, whereas air cooling required an average of nearly 17 min to do so. Ten minutes of cooling required a mean \pm SD of 26.2 ± 5.9 min to warm to preactivity levels. No adverse effects resulted from the intervention. We conclude that cooling the foot may be a safe and effective method of reducing inflammation and may serve as a prophylactic or interventional tool to reduce skin breakdown risk. (J Am Podiatr Med Assoc 95(2): 103-107, 2005)

The prevalence of diabetes mellitus worldwide is 2.9%, with at least 16 million people affected in the United States alone. An additional 1 million people are diagnosed annually in America, with an estimat-

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ed health-care expenditure and lost productivity of approximately \$130 billion per year.¹

A major complication of this disease is lower-limb amputation, with its associated mortality and mor-

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bidity. Although people with diabetes mellitus make up only 3% of the US population, this group accounts for up to eight in ten of these procedures, making diabetes mellitus the leading cause of nontraumatic amputations.^{2, 3} Epidemiologic studies⁴⁻⁶ have identified foot ulcers as a precursor in 85% of amputation cases, and a lifetime risk as high as 15% has been estimated for ulcer development at least once during the course of the disease.

Neuropathic diabetic foot wounds are caused by pressure and repetitive stress, which frequently lead to inflammation and subsequent tissue breakdown. Theoretically, identifying areas of injury by the presence of inflammation (and the presence of dolor, rubor, and calor) would allow patients or health-care providers to take action to reduce the inflammation before a wound develops. The most consistent objective surrogate clinical measure of inflammation has been thermometry, which has been well known in the literature since the groundbreaking work of Brand⁷⁻⁹ and Manley and Darby.¹⁰ Recent pilot work conducted by our group has suggested that personal dermal thermometers, used to identify areas of increased inflammation (and temperature), may reduce the incidence of ulceration in patients with diabetes mellitus who are at high risk of ulceration and amputation.¹¹⁻¹⁵ It would stand to reason that if the wound "heats up before it breaks down," then perhaps prophylactically cooling a focal area would reduce the risk of skin breakdown.

Therapeutic hypothermia, or cryotherapy, has been used for centuries as a treatment modality for various inflammatory conditions. In acute injury, tissue swelling can occur and subsequent hypoxia can develop.^{16, 17} Ice is especially useful to reduce swelling and bleeding by causing local vasoconstriction, thereby reducing vessel permeability and fluid extravasation into tissues.¹⁷ Ice has also been shown to decrease cell metabolism, interleukin-1 β levels, neutrophil accumulation, and production of prostaglandins,¹⁸ which helps limit posthypoxia damage and confine the inflammatory response to injured tissues. Reduction of mean skin temperatures sufficiently to induce localized skin analgesia, reduce nerve conduction velocity, and reduce metabolic enzyme activity to clinically relevant levels is achieved through various means, including wet ice, dry ice, flexible frozen gel packs, and even bags of frozen peas.^{19, 20}

Although a simple cooling intervention might, on the surface, make therapeutic sense, we are unaware of any studies in the literature that have discussed this issue. The purpose of this proof-of-concept trial was to determine whether simple cooling of the foot

can safely reduce the time to thermal equilibrium after activity.

Research Design and Methods

Six healthy, ambulatory people without diabetes mellitus, neuropathy, or a history of peripheral vascular disease were enrolled in this initial proof-of-concept trial. Using a computerized random number generator (Arcus, London, England), the subjects were divided into groups that either soaked their feet in a cool water bath or rested their feet at room temperature.

Maximum skin temperature was assessed plantar to the first metatarsophalangeal joint on both feet using a noninvasive, noncontact, infrared dermal thermometer (ProScan; Salix Medical, San Antonio, Texas). Subjects were then asked to walk at a self-selected pace for 15 min in their own comfortable athletic shoes. After this 15-min walk, subjects removed their shoes and socks, and their skin temperatures were measured. Half of these subjects soaked their feet in a cool water bath (at 55°F). Skin and water temperatures were taken every minute for 10 min. Patients were then removed from the water bath, and their skin temperatures were taken each minute until they reached prewalking levels. The other half of the subjects enrolled rested their bare feet in room air until prewalking skin temperatures were reached. Air and skin temperatures were taken every minute from both groups. After this series of measurements, subjects were asked to return at the same time the following day, when the cool water and room air groups were reversed and reassessed using methods identical to those previously described.

Because subjects served as their own controls, we used a paired *t*-test to analyze differences in time to equilibrium between bath and room air treatments.²¹ For all analyses, we used an α of .05. The null hypothesis was that there would be no difference in time to equilibrium between the two groups.

Results

We enrolled six healthy, nondiabetic volunteers (4 women and 2 men; mean \pm SD age, 32.2 \pm 6.6 years). The mean \pm SD ambient room temperature was 72.1° \pm 1.0° F. There was a dramatic rise in skin temperature after 15 min of activity *versus* preactivity levels (87.8° \pm 3.9° *versus* 79° \pm 2.2° F; *P* = .0001). Water cooling immediately brought the foot to a point cooler than preactivity levels for all subjects, whereas air cooling required an average of nearly 17 min to do so (mean \pm SD, 1.0 \pm 0.0 *versus* 16.8 \pm 2.8 min; *P* = .0001). Ten minutes of cooling required a mean \pm SD of 26.2

± 5.9 min to warm to preactivity levels. There were no adverse effects from the intervention. These data are illustrated in Figures 1 and 2.

Discussion

In diabetes mellitus, as in other chronic diseases, self-care is necessary to identify early warning signs to reduce the incidence of complications and prevent morbidity. Most diabetic lower-extremity complications involve sensory neuropathy as a pivotal component of the etiologic pathway for the development of ulcers. Pain is the primary natural warning system that alerts us to take action and seek medical care. This system is faulty in people with a prolonged duration of diabetes mellitus. People with diabetes mellitus and neuropathy often sustain injuries that are not recognized until full-thickness ulcerations occur requiring surgical intervention, resulting in poor quality of life and unnecessary utilization of medical services and associated costs. The precursor to many of these injuries is inflammation. Identifying this inflammation and intervening may prove helpful in this high-risk population. The results of this preliminary study suggest that in healthy people, cooling the foot rapidly reduces focal inflammation sustained by brisk activity. This finding may be applicable to a high-risk population as well.

The physiology of total-body cooling was studied more than six decades ago²² and recently has re-

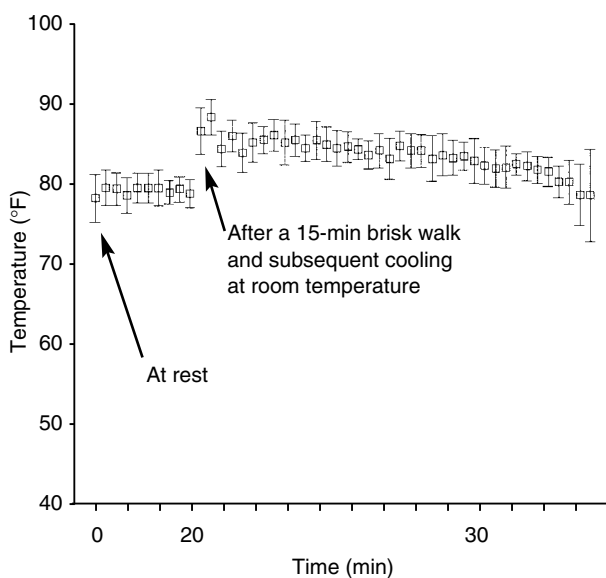


Figure 1. Effect of air cooling on mean skin temperature. Error bars represent SD.

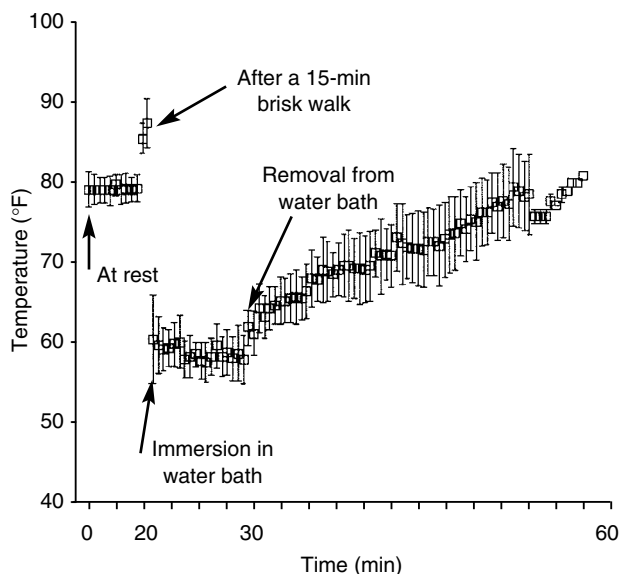


Figure 2. Effect of water cooling on mean skin temperature. Error bars represent SD.

ceived renewed interest. Several investigations have shown promising results using cryotherapy to reduce the deleterious effects of local tissue injury. Morsi,²³ in a study involving cryotherapy after total-knee arthroplasty, demonstrated a decrease in closed suction drainage volume, analgesic consumption, and wound healing. A study²⁴ of cooling the body with a liquid microclimate system during exercise heat-stress conditions revealed that cooling the arms during upper-body exercise provides no thermoregulatory advantage, although cooling the thigh surfaces during lower-body exercise does provide an advantage. Sawada et al²⁵ suggested that in a cool work environment where the body core temperature is likely to decrease, repeated finger cooling may weaken cold-induced vasodilatation reactivity and delay the recovery of finger temperature during rest periods after immersion. An entire field of study seems to be emerging in the area of therapeutic hypothermia for stroke^{18, 26-32} and in potentially limiting infarct size after acute myocardial infarction.^{29, 33-35}

The use of hypothermia in the diabetic population may prove useful in the prevention of common injuries. Most wounds in the neuropathic foot are incited by minor, preventable initiating events. Moderate repetitive stress has been reported as a frequent cause of wounds in the insensate foot.³⁶⁻⁴⁰ Trivial actions, such as walking, can cause breakdown of tissues and subsequent ulceration. Many preventive

treatments have been proposed to reduce stress and shear forces. Padding and accommodative devices are considered appropriate modalities. However, there has been little investigation of the use of therapeutic cooling as a preventive tool in the neuropathic foot. A regular regimen of cooling may be a prophylactic for the well-perfused patient against imminent activities; alternatively, it may prove useful as immediate aftercare following activity.

Today, therapeutic hypothermia is recognized as an invaluable modality in the medical professional's armamentarium. It seems that simple local application of a cool water bath effectively cools healthy patients after a period of repetitive stress to the lower extremities. This treatment modality may have relevance in the prevention of diabetic foot ulcers by reducing mechanical stresses and friction known to be a major factor in tissue damage and ulceration.

Conclusion

The results of this proof-of-concept trial show that therapeutic cooling of the foot may be a safe and effective method of reducing inflammation. In particular, it may serve as a prophylactic or interventional tool to reduce the risk of skin breakdown in high-risk patients with diabetes mellitus. We look forward to further trials in progressively higher-risk patients to determine the practicality and efficacy of this simple intervention.

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