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Variation of surface temperatures of different ground materials on hot days: Burn risk for the neuropathic foot

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ABSTRACT

The purpose of this study is to assess the relationship between ambient temperature and surface temperatures of commonly used building/ground materials, in order to estimate the risk of contact thermal injury. It is an observational study where the air ambient temperature and the surface temperatures of slate, metal, cement, sand, brick and bitumen, were measured, in shaded and unshaded conditions, on cloudy and cloudless days in summer in Adelaide, South Australia. All unshaded surfaces reached temperatures capable of causing significant sole of foot burns given requisite exposure time in both clear and overcast conditions, even with a relatively low ambient temperature. Shade imparted total protection from irreversible thermal injury for all of the ambient temperatures assessed. Although surface temperatures were reduced in overcast conditions, the temperatures recorded were still capable of causing thermal injury. Peripheral neuropathy prolongs heat exposure times, often resulting in significant and complex injury, requiring lengthy treatment and generating potentially poor functional outcomes. This study provides a reference point for the enactment of preventative measures for at risk population groups such a diabetics.

1. Introduction

Burns caused by direct contact with a hot object or surface, account for 9% of burn presentations in Australia [1,2]. Burns sustained by contact with ground surfaces, such as road bitumen or concrete, most frequently occur in patients with sensory neurological compromise due to pre-existing medical conditions, such as diabetic neuropathy or lumbosacral radiculopathy [3,4]. This study seeks to assess the relationship of ambient temperature to surface temperatures of various common materials, in order to estimate the risk of burns in people with increased risk of exposure.

In Adelaide, South Australia, ambient temperatures can be very high. In January 2014, citizens were subjected to 9 days where the air temperature exceeded 38 °C [5]. Surface temperatures of common ground materials however often exceed this, as they absorb solar radiation. The temperature of ground surfaces is determined by the balance between solar thermal radiation and air convection. The magnitude of solar radiation that reaches the surface materials is determined by the presence of cloud cover and shade, which absorb and reflect thermal radiation [6]. Thus, the ambient temperature and the presence of cloud and shade, directly modulate the surface temperature of ground materials, and the propensity for thermal injury.

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Previous studies have established that at surface temperatures at or over 44 °C, irreversible thermal injury occurs, given appropriate exposure time [7]. The exposure time required to cause this injury decreases exponentially with an increase in the temperature of the surface above 44 °C. At 55 °C for example, 20 s of contact is required to sustain irreversible thermal injury, whereas at 60 °C only 3 s is required [7]. It should be noted that both the surface temperature of ground materials and their propensity to cause thermal injury, are dependent on several other physical properties of the material, including thermal inertia, which are beyond the scope of this paper.

Foot burns are more common in diabetic patients and can cause significant morbidity [8]. These patients are predisposed to burns on the plantar aspect of the feet for a variety of reasons, however the majority of lower extremity burns result from intentional exposure to sources of heat without recognition of the burn, due to peripheral neuropathy [9] (see Fig. 1). Obtundation, caused by acute and chronic illness, pharmacological treatment or intoxication by drugs or alcohol, also places people at risk of contact burns due to loss of protective reflexes.

Diabetes mellitus is the most common cause of peripheral neuropathy in western countries [10] and it is estimated that approximately 50% of patients over 60 with diabetes have sensory loss in the extremities [11]. There is an estimated 4.2% prevalence of diabetes mellitus in Australia, which is increasing annually [12]. Diabetics are subsequently well represented amongst burn patients, with studies showing that as high as thirty-two percent of burn patients over 55 years have diabetes mellitus [13,14]. Diabetic patients also present later after injury, suffer higher rates of infection, prolonged hospital stay, and increased mortality for an equivalent total body surface area of burn compared to non-diabetics [15]. Burns to the lower limbs and feet are challenging injuries to manage in both diabetic and non-diabetic patients and often require complex healthcare plans and a prolonged recovery time [9].

There is little evidence-based research available for clinicians to direct the counselling of their diabetic patients about thermal injury to the soles of their feet pertaining to surface/ground materials and ambient temperature. The first step to preventing foot burns is to ascertain the temperature of various ground surfaces during the day and determine whether a substantial risk of skin injury exists and, if so, what severity of injury might be expected.

Temperature assessments have been conducted in the past, which have proven useful for patient education and burn prevention, including a study in Hong Kong which utilised satellite thermal imaging to reduce hazards in city planning [16] and another investigating differing hot beverages to advise caregivers about the handling of drinks to avoid scalds to vulnerable individuals [17]. Although one study examined the temperature of different surfaces over the course of 24 h [3] and another examined peak asphalt temperatures in Arizona [18], no study has investigated the effect of shade on surface temperatures throughout a range of different ambient temperature.

The data generated by this study has been made available to Diabetes treatment and advice groups and hopefully can assist in education and in the development of prevention strategies.

Fig. 1 – A 55-year old diabetic with deep dermal burns on the plantar foot sustained from standing/walking on hot concrete.

2. Materials and methods

All measurements of the surface temperatures of selected ground surfaces (slate, metal, cement, sand, brick and bitumen) were obtained daily between the hours of 14:00 and 15:00 in Adelaide, Australia in January 2014. The measurements were taken in conditions of direct sunlight and shade and on cloudy and cloudless days. A Testo 830-T1 Infrared Thermometer was used. Ambient temperatures were recorded from observations made by the Bureau of Meteorology of Australia [19]. The authors determined the presence of cloud cover subjectively and the measurements of surface temperature were performed by one investigator to limit variability.

3. Results

Table 1 demonstrates the temperature of the various surfaces in shaded and unshaded conditions, as well as in cloudless and overcast conditions. Of the surfaces assessed, unshaded metal consistently demonstrated the highest surface temperature compared to other materials on all four days with differing ambient temperatures. On the hottest day recorded with an ambient temperature of 43.9 °C, metal recorded an unshaded temperature of 71.5 °C. This was followed by unshaded sand (69.5 °C), unshaded slate (68.5 °C), unshaded brick (68.5 °C), unshaded bitumen (68.5 °C) and unshaded cement (64 °C). The shaded surface temperatures were considerably cooler than unshaded, at any given ambient temperature. Sand recorded the highest shaded temperature (42.5 °C) followed by metal (42 °C) slate (41.5 °C) bitumen (39 °C) cement (38.5 °C) and brick (38.5 °C). Clouds had a moderating effect on surface temperature, with consistently lower temperatures recorded in overcast conditions for a similar given ambient temperature. The surface temperature of unshaded metal decreased from 65.5 °C to 59 °C, sand from