The Use of Thermal Imaging in Sport Medicine Research: A Short Report:

Running Title: Thermal Imaging in Sports Medicine

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ABSTRACT

The assessment of skin temperature (T_{sk}) in athletic therapy and sports medicine research is an extremely important physiological outcome measure. Various methods of recording T_{sk}, including thermistors, thermocouples and thermocrons are currently being used for research purposes. These techniques are constrained by their wires limiting the freedom of the subject, slow response times, and/or sensors falling off. Furthermore, as these products typically are directly attached to the skin and cover the measurement site, their validity may be questionable. This manuscript addresses the use and potential benefits of using thermal imaging (TI) in sport medicine research. Non-contact infrared TI offers a quick, non-invasive, portable and athlete friendly method of assessing T_{sk}. TI is a useful T_{sk} diagnostic tool that has potential to be an integral part of sport medicine research in the future. Furthermore, as the technique is non-contact it has several advantages over existing methods of recording skin temperature.

Key Words: Infrared Thermal Imaging, Skin Temperature, Sports Medicine Research, Core Temperature, Physiological Assessment

INTRODUCTION

Non-contact infrared Thermal Imaging (TI) is becoming one of the most popular methods of assessing skin temperature (T_{sk}) in sports medicine. A specialised infrared TI camera allows an individual to record a thermogram of a region of skin. This thermogram, is a still picture image which allows for the calculation of skin temperature in the chosen region of interest (see figure 1). Infrared TI has been employed in a clinical setting since the mid 1900's[1] and utilises the phenomenon that living and non-living objects all emit infrared radiation to some extent. This rapidly developing technology can be utilised to detect, locate and monitor thermal changes or abnormalities characterized by an increase or decrease in T_{sk}[2] and consequently it is a valuable tool in sport medicine and research.

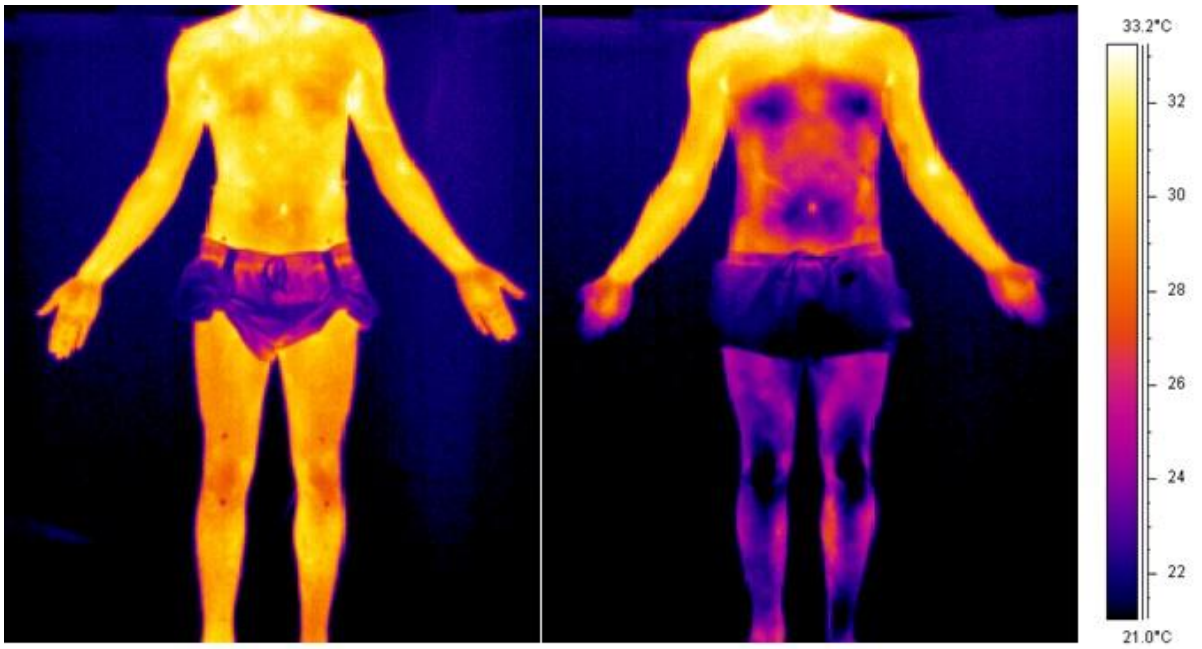

Figure 1. An example of an anterior and posterior image of a subject in the anatomical position. The thermogram on the left is before immersion in cold water to the level of the sternum and the one on the right is after immersion.

The assessment of T_{sk} in athletic therapy and sports medicine research is an extremely important physiological outcome measure and consequently an abundance of literature exists in the area. A search of PubMed, Google Scholar, Medline, and Science Direct using the phrase "skin temperature" returned ~25,000 articles in the year 2011 alone. In sports medicine academics and researchers investigating the effects of inflammation, oedema, Raynauds phenomenon, circadian rhythm, frost

nip, frost bite, heat strain, heat stress, hypothermia and hyperthermia following exposure to various environmental/climatic conditions regularly report T_{sk}. Furthermore, as it is regarded as a basic physiological measure reporting temperature (skin, muscle and/or core) following the application or exposure to any therapeutic thermal agent appears to be essential for peer reviewed journal publication. If academics assessing the effects of hot or cold environmental conditions (included the therapeutic use of cooling and heating) on heat stress,[3] muscle soreness recovery,[4] aerobic performance in hot and humid conditions,[5] electromyography activity,[6] functional performance[7] or rehabilitation[8] do not report skin temperature in the manuscript it is likely to be regarded as a 'limitation' of the study.

Brief history of the technique and current status

Since the 1980's infrared imaging has been recognized by the American Medical Council as a feasible diagnostic and analytical tool. More recently the American Academy of Medical Infrared Imaging, and various other groups and associations, have acknowledged its use and promote it as a means of assessing skin temperature. Although the technique of infrared TI is now well accepted, the earlier work with this technique was often discredited primarily because the technology at the time was inadequate.[2] However, the development of digital technology in the last couple of decades has revolutionised the field of infrared TI. The improvement in the quality of camera and the post process analysis technology over the years has led to the increasing use and efficiency of thermal imaging as a tool for diagnostic imaging procedure that records and produces images of skin temperature.[9]

Mean skin temperature has been determined, since the 1930s,[10] using formulas that weight a number of measurement sites to calculate a mean skin temperature. Thermistors, thermocouples and thermocrons all have the capability of measuring skin temperature but are constrained by their wires limiting the freedom of the subject, slow response times, and/or sensors falling off due to sweat production. The number of measurement sites and the thermal properties of the adhesive tape securing the sensor to the skin are also major limiting factors in their application. Furthermore, the obvious advantages of using a non-contact method of assessing T_{sk} following a change in the environmental conditions has previously been established.[11] Other methods of assessing T_{sk} that are

currently being used in sport medicine research, including ibuttons and skin thermistors, involves attaching a small thermistor to the skin and this creates the potential of insulting the area of skin where the temperature is being recorded.[11] Consequently, by using TI the investigator can be confident that they are reporting the actual temperature of the particular region of interest.

TI also allows one to record and report the minimum, maximum and average temperature of a "region of interest" and is not confined to the "spot" measurements like other techniques. Analysing a region of interest, created with pre-determined anatomical landmarks or inert markers as reference points, also allows an investigator to study a number of different (and larger) skin temperature sites. Although limited standardised frameworks have been established[12] for using TI, we have previously highlighted the effectiveness and the reliability of the use of TI to measure.[11,13,14,15]

Although TI has been described as a "low cost detection tool"[2] it is reasonably to suggest that acquiring a TI system would stretch the budget of many researchers, especially if T_{sk} is not a primary outcome measure. Furthermore, as access to a power source is typically required TI is often limited to laboratory based research.

The use of TI to Diagnose Sports Injuries

Using the same technique that allowed the quantification of skin temperature and subsequently screening of people with fever like symptoms;[16] infrared thermography could be used to diagnose injuries.[2] It is well established that overuse injuries, and several other pathophysiological injuries that affect athletes, cause inflammation and a subsequent localised increase in skin temperature around the affected region. As TI has the capabilities to detect any disturbances in the normal symmetry[2] it may assist athletic training and sport physicians to start early intervention programme or indeed prehabilitation sessions. Furthermore, TI has recently been described as a useful tool in the objective assessment of whiplash injuries caused by sudden sharp whipping movement of the head and neck.[17] Consequently, TI may provide a sports physician with some additional information regarding the type and severity of an injury.

Thermal Imaging in Hot & Humid Environmental Conditions

The measurement of skin temperature and mean skin temperature is of paramount importance in evaluating the physiological effects of heat strain/stress. Environmental and/or metabolic heat loads produce compensatory changes within physiological systems to mitigate any significant change in core temperature. When heat loads become excessive, the overall physiological change that occurs in response to heat stress is termed heat strain. The primary heat strain parameters that are monitored include heart rate, sweat loss, core and skin body temperatures. Infrared thermal imaging has been successfully validated in exercising humans in thermoneutral, hot and cold environments.[18] International standards for the evaluation of thermal strain[19] have also identified the use of infrared thermal transducers as being preferable to contact transducers.

Unrestrained prolonged heat strain can result in heat illness. Heat illness has traditionally been defined as specific ailments that range from minor complaints of miliaria rubra (heat rash) to the potentially fatal heat stroke. The National Athletic Trainers' Association, in the United States, Position Statement on Exertional Heat Illnesses states that 'the primary goal of athlete safety is addressed through the prevention and recognition of heat-related illnesses...to alleviate symptoms and minimize morbidity and mortality'.[20] In practice, cooling modalities such as cold water or ice, applied to the skin, are common used to treat heat stroke.[21] However, knowledge regarding the safe limits of both skin and core temperature during the treatment of heat stroke are essential and TI may provide a means to study these variables.

Scientific advancements and applications to Sport Medicine

Perhaps the most promising advancement in the use of TI is the recent work of Bourlai[22] and colleagues. This research demonstrated how the technique can be used to accurately estimate core body temperature in the heat. By capturing a high-resolution thermal image of the face, concomitant with measures of core (compared to an ingestible core temperature capsule) and skin temperature, before, during, and after treadmill exercise, the authors were able to accurately estimate core body temperature during exertion in a heated room. It has been suggested that this scientific advancement

could be deployed in the near future to monitor participants at mass-gathering athletic events such as marathons or ultra-endurance races.[21] Other applications for this technology could include screening multiple subjects to identify those with suspected hyperthermia after an endurance competition and the military where personnel are exposed to extreme environmental conditions.

Conclusion

TI offers a quick, non-invasive, portable and patient/athlete friendly method of assessing T_{sk} and potentially estimating core temperature. TI also allows one to record and report the minimum, maximum and average skin temperature of a "region of interest" and is not confined to the "spot" measurements like other techniques. Furthermore, other methods of assessing T_{sk} that are currently being used in sport medicine research involves attaching a thermistor to the skin and this creates the potential of insulting the area of skin where the temperature is being recorded. Although further research is required, TI may soon be considered the gold standard of assessing skin temperature in sports medicine.

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