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# Microenvironment temperature prediction between body and seat interface using autoregressive data-driven model

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Temperature prediction;
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**Abstract** There is a need to develop a greater understanding of temperature at the skin—seat interface during prolonged seating from the perspectives of both industrial design (comfort/discomfort) and medical care (skin ulcer formation). Here we test the concept of predicting temperature at the seat surface and skin interface during prolonged sitting (such as required from wheelchair users). As caregivers are usually busy, such a method would give them warning ahead of a problem. This paper describes a data-driven model capable of predicting thermal changes and thus having the potential to provide an early warning (15- to 25-min ahead prediction) of an impending temperature that may increase the risk for potential skin damages for those subject to enforced sitting and who have little or no sensory feedback from this area.

Initially, the oscillations of the original signal are suppressed using the reconstruction strategy of empirical mode decomposition (EMD). Consequentially, the autoregressive data-driven model can be used to predict future thermal trends based on a shorter period of acquisition, which reduces the possibility of introducing human errors and artefacts associated with longer duration "enforced" sitting by volunteers. In this study, the method had a maximum predictive error of $<0.4\,^{\circ}$C when used to predict the temperature at the seat and skin interface 15 min ahead, but required

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45 min data prior to give this accuracy. Although the 45 min front loading of data appears large (in proportion to the 15 min prediction), a relative strength derives from the fact that the same algorithm could be used on the other 4 sitting datasets created by the same individual, suggesting that the period of 45 min required to train the algorithm is transferable to other data from the same individual. This approach might be developed (along with incorporation of other measures such as movement and humidity) into a system that can give caregivers prior warning to help avoid exacerbating the skin disorders of patients who suffer from low body insensitivity and disability requiring them to be immobile in seats for prolonged periods.


## 1. Introduction

Research interest in seat design and comfort evaluation has seen continued growth owing to the considerable amount of time being spent on sitting, both at home and in the office [1]. Nowhere is this more important than in relation to those people who have lost access to their natural feedback mechanisms which would warn them of impending skin damage due to hypoxia (compressed blood flow), hyper-humidity and high temperature. Currently, however there seems to be little consistency in the methodologies employed to investigate this area. Most research effort appears to be spent on design of the seat rather than on developing an understanding of the physiological issues related to patients with sensory deficits or using sensor-based systems as a replacement for neurological deficit. Hampering this further, the relationship between objectively measured parameters and the qualitative domain of comfort/discomfort are still unclear.

It is obvious that the thermal properties (heat absorption and dissipation) of a cushion can play a vital role in the evaluation of sitting comfort [1–4]. However, thermal characteristics might also have a bearing on tissue viability and as a consequence the likelihood of skin ulcer formation [5]. Interestingly, the effect of increased temperature due to sitting does not just affect skin viability; lesser changes in temperature can also cause more subtle changes. What might otherwise be considered as insignificant changes in temperature might contribute to the decrease in both semen quality and quantity; indeed increases in scrotal temperature of up to 3 °C have been reported following a 20-min period of sitting on commonly used chairs [6], however those with spinal cord injury in wheelchairs tend to have higher scrotal temperatures than the non-spinal cord injured [7]. When scrotal skin temperature increases and normal thermoregulation mechanism is impaired, the local increase in temperature negatively impacts on semen quality (sperm concentration, motility and morphology) as well as sperm chromatin structure. From this perspective, it is important to recognise the need to limit the temperature change at the seat–skin interface during prolonged periods of sitting. This paper aimed to determine whether it was possible to derive a method which can offer advanced warnings of temperature change reaching an undesired level; changes which if left unaddressed might put the immobile person at risk of skin or other tissue damage.

According to the authors' knowledge [8,9], direct assessment of the thermal properties between the body and seat interface has been subjected to little objective experimentation. Other approaches have included a focus on the more subjective domain, using indirect assessment of thermal comfort [10,11]. The direct measurement approach has employed either infrared imaging [8], or direct measurement at the site [9]. Ferrarin and Ludwig [8] compared thermal transients of four seat materials at three test points (ischial and thighs). However, measurement was intermittent, as the subjects were required to stand up for 30 s every 5 min in order to image the seat by thermography, thus potentially adding an inconsistency to the temperature profile and increasing uncertainty that the subjects sat in a natural manner. Cengiz and Babilik [9], on the other hand, evaluated thermal change effects on comfort by placing eight measurement devices (under thigh, inner thigh, stomach, side of body, chest, waist, back, right bottom) on the skin of subjects who attended road trials of automobile seats and assessed seat comfort by questionnaires. Although mean temperatures were employed to compare thermal properties of three different seat covers, no sensors were placed at the body–seat interface to assess temperature at this site during the period of sitting.