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An evaluation of fluid immersion therapy for the prevention of pressure ulcers☆

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ABSTRACT

Background: Individuals with impaired mobility can spend prolonged periods on support surfaces, increasing their risk of developing pressure ulcers. Manufacturers have developed mattresses to maximise contact area. The present study evaluated both the biomechanical and physiological responses to lying postures on a Fluid Immersion Simulation mattress.

Methods: Seventeen healthy participants were recruited to evaluate the mattress during three prescribed settings of immersion (high, medium and low). Parameters reflecting biomechanical and physiological responses, and the microclimate were monitored during three postures (supine, lateral and high-sitting) over a 90 minute test session. Transcutaneous oxygen and carbon dioxide gas responses were categorised according to three criteria and data were compared between each condition.

Findings: Results indicated that interface pressures remained consistent, with peak sacral values ranging from 21 to 27 mmHg across all immersion settings and postures. The majority of participants (82%) exhibited minimal changes in gas tensions at the sacrum during all test conditions. By contrast, three participants exhibited decreased oxygen with increased carbon dioxide tensions for all three immersion settings. Supine and high sitting sacral microclimate values ranged between 30.1–30.6 °C and 42.3–44.5% for temperature and relative humidity respectively. During lateral tilt there was a reduction of 1.7–2.5 °C and 3.3–5.3% in these values. The majority of participants reported high comfort scores, although a few experienced bottoming out during the high-sitting posture at the high immersion setting.

Interpretation: Fluid Immersion Simulation provides an intelligent approach to increase the support area. Further research is required to provide evidence based guidance on the use of personalised support surfaces.

1. Introduction

Pressure ulcers (PUs) are caused by sustained pressure, or pressure in combination with shear, and commonly occur adjacent to body prominences (European Pressure Ulcer Advisory Panel, 2014). Several risk factors have been recently identified in the development of PUs, in particular reduced mobility/activity, a history of pressure ulcers and perfusion (Coleman et al., 2013). In the last few years the condition has been recognised as both a Patient Safety and Quality of Care indicator for health care providers in both the acute and community settings (Department of Health, 2010). Although there is a strong focus on prevention within health services, the incidence of PUs remains unexceptably high with associated treatment costs estimated at £4 billion annually in the United Kingdom (National Patient Safety Agency, 2010).

In order to reduce the risk of developing PUs, frequent repositioning is advised in international guidelines (European Pressure Ulcer Advisory Panel, 2014). In practice, this involves the periodic redistribution of pressure through postural change, which enables relief of previously loaded tissue areas. In individuals with impaired mobility this process often requires the assistance of a clinician which can be time-consuming and expensive for the healthcare provider (Moore et al., 2013). Hence, with limited healthcare resources, this may not be strictly adhered to, particularly in busy hospital or community settings (Defloor et al., 2005). As an alternative to manual repositioning, advanced air mattress systems have been introduced to periodically relieve support pressures. However, their benefits over more economical foam or static hybrid systems have not been fully demonstrated (McInnes et al., 2015).

A number of measurements have been used to examine the performance of support surfaces. As an example, interface pressure measurements between the individual and the support surface have been extensively used in both lab-based and clinical studies (Stinson and Crawford, 2009). These studies have demonstrated how postural

Abbreviations: FIS, Fluid Immersion Simulation; PUs, Pressure Ulcers; $TcPO_2$, transcutaneous oxygen; $TcPCO_2$, transcutaneous carbon dioxide.

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change can have a significant effect on interface pressures (Defloor and Grypdonck, 1999). However, interface pressure values alone do not provide clinicians with indications of when and where pressure ulcers are likely to develop (Reenalda et al., 2009). This has motivated a number of recent studies which have examined the temporal effects of applied pressures on a range of measures indicative of physiological tissue status (Chai and Bader, 2013; Kim et al., 2012). These have indicated that changes in transcutaneous gas tensions ($TcPO_2$ and $TcPCO_2$) can reflect the physiological response of skin tissues to altering posture (Woodhouse et al., 2015). In addition, there is increasing evidence that thermodynamic conditions in skin tissues strongly influence the susceptibility to PUs. This has led to an interest in the control of the microclimate, namely temperature and humidity, at the loaded-skin support interface (Clark et al., 2010).

An alternative recommended means of managing the support surface conditions involves immersion and envelopment of the individual, thereby maximising the contact area. One such system, the Fluid Immersion Simulation (FIS) has been reported to provide benefits in a small clinical study (Fletcher et al., 2014). However, its performance in terms of its management of the biomechanics and microclimate at the interface has not been evaluated. This motivated the present study which is designed to evaluate a range of FIS settings and postures, in a cohort of participants employing a biomechanical and physiological measurement approaches at critical tissue locations (Woodhouse et al., 2015).

2. Material and methods

The present study adopted a prospective randomised cross-over design in a cohort of healthy participants.

2.1. Description of support surface and immersion settings

The Fluid Immersion Simulation (FIS) mattress (Joerns, Texas, USA) was employed in the present study. The reactive therapy system is designed to displace the patient's weight throughout a simulated fluid medium. The system has a series of user defined settings, which change the immersion characteristics of the mattress. The present study applied three settings to assess the effects of these immersion properties, namely; low, medium and high. The lower the immersion setting, the less the individual was displaced into the support surface and the higher the internal pressure of the mattress. The mattress was placed on a standard bed frame (VersaCare, Hill-Rom, USA) and was evaluated in both the horizontal position and at a head of bed angle of 40°.

2.2. Participants

Participants were recruited from the local community if they had no history of skin-related conditions, no history of neurological or vascular pathologies which could affect tissue health and were able to lie or sit for a period of 90 min. Institutional ethics was granted for the study (ERGO-FOHS-17598) and informed consent was obtained from each participant prior to testing.

2.3. Test equipment

Physiological measures of transcutaneous oxygen and carbon dioxide tensions ($TcPO_2$, $TcPCO_2$) were monitored at the sacrum using a transcutaneous gas tension electrode (Model 841, Radiometer A/S, Denmark) heated to 43.5 °C to ensure maximum vasodilation (Bogie et al., 1995) and attached to a separate monitor (TCM4, Radiometer, Denmark). Interface pressures were recorded via a thin sheet incorporating a total of 96 sensors placed on top surface of the mattress and attached to an interface pressure monitoring system (Talley Pressure Monitoring TPM Mk III, UK). The total included one separate 12-sensor array, located under the sacrum, at a corresponding spatial resolution of 30 mm in both directions. The remaining 84 sensors were positioned along the body with a spatial resolution of 50 mm across the body width and 120 mm along the body length.

Two digital temperature and humidity sensors (SHT7x, Sensirion, Switzerland) were positioned externally (one at each end of the bed) and two were positioned at the interface between the participant and the mattress (under the sacrum and thorax). A manometer (Digitron, UK) was used to measure the internal pressure of the immersion mattress and the angle at which each participant was tilted during the high-sitting and lateral postures was measured by a hand held inclinometer (SOAR, Digital Level meter 1700). In addition, comfort scores were recorded for each participant using a 5 point verbal rating scale, with 0 representing the lowest score and 5 representing the highest score.

2.4. Test protocol

All test procedures were performed in a laboratory where room temperature was maintained at 20 °C. Participants who wore loose fitting clothing during data collection, were asked to lie in a prone position for a 15 minute period to establish baseline unloaded $TcPO_2$ and $TcPCO_2$ levels. Each participant was then carefully positioned in a supine posture on the immersion mattress. The mattress was then configured to one of three randomly assigned immersion settings and maintained for three randomly allocated postures (supine, high sitting and lateral tilt), each of which lasted 10 min. Supine and high sitting postures were established using the bed frame controls. During the lateral tilt, postures were maintained with pillow support at the back and lengthways under the legs using a standard protocol (Moore, 2012) (Fig. 1). The process was then repeated for the other two immersion settings, with a total of nine test conditions lasting a period of 90 min. Transcutaneous blood gas measurements were continuously recorded at the sacrum throughout the test period. Three cycles of interface pressures were recorded at the mid-point of each test condition and single measures of internal mattress pressures, postural tilt angles and comfort scores were also recorded.

Fig. 1. Participant lying in the 30° tilt position support by pillows under the back and legs.