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Monitoring the biomechanical and physiological effects of postural changes during leisure chair sitting

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ABSTRACT

Background: Individuals with limited mobility can spend prolonged periods in leisure chairs, increasing their risk of developing a seated acquired pressure ulcer. The present study aims to use objective measures of posture and tissue viability to identify the associated risks of leisure chair related pressure ulcers.

Methods: Healthy participants ($n = 13$) were recruited to sit on a leisure chair with either a viscoelastic foam or air cushion. Participants were asked to adopt four different postures for a period of 10 min followed by a 10 min refractory period. Measurements at the leisure chair-participant interface included interface pressure, transcutaneous tissue gas tensions at the ischial tuberosities, accelerometer data collected from the sternum and subjective comfort levels.

Results: Results indicated that interface pressures remained consistent, with peak pressure index values of less than 60 mmHg across all conditions. A proportion of participants exhibited decreased oxygen tensions associated with increased carbon dioxide tensions during one or more test condition. This was particularly prevalent during the right lean posture on the air cushion (46%). In all cases, normal tissue viability was restored during standing. The accelerometer was able to detect significant changes ($p < 0.05$) in relative trunk angles during slump and right lean when compared to optimal sitting posture.

Conclusion: Commercially available leisure chairs have little evidence to support their pressure relieving properties. This study revealed that a proportion of healthy individuals demonstrated a compromised tissue viability in specific postures. Further research is required to assess the impact of these sitting conditions in vulnerable individuals.

1. Background

In the seated position a high proportion of body weight is supported by the ischial tuberosities and buttocks, the sacrum and upper thighs. Further body weight may by supported by the arms, via arm-rests, and the feet via footrests or the floor [1]. Prolonged sitting in association with high mechanical loads exerted over relatively small body support areas gives rise to mechanically-induced soft tissue damage in vulnerable individuals, typically those who are immobile and/or present with neurological impairment. This condition, commonly termed Sitting-Acquired Pressure Ulcers (SAPUs), has major implication on an individual's quality of life and the financial burden on health services [2].

Recent European and UK prevalence studies have highlighted an obvious disparity in the management of high risk patients when seated, in comparison with how they are cared for in bed [3,4]. Most specifically, it was found that over 50% of at risk patients did not receive specialist chair equipment when seated and were repositioned at irregular time intervals [3]. In addition, recent cross-sectional studies in Europe have revealed that only a very small proportion of patients are given care plans to prevent pressure ulcers in the seated environment [5]. This represents a patient safety issue given that the correlation between prolonged sitting and the presence of pressure ulcers has frequently been reported [2]. While these correlations have often been reported in cross-sectional studies, direct causal association between sitting and the development of pressure ulcers has also been reported [6]. Additionally, those who are wheelchair dependent often experience pressure ulcers at a relatively young age.

The literature reveals a significant number of papers examining the effects of prolonged sitting in wheelchair bound individuals,

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typically focused on the Spinal Cord Injured [7–10], who are known to be at high risk of developing pressure ulcers throughout their lifetime. By contrast, there are only a few studies which have examined the effects of sitting in static chairs, involving specific subject groups with vulnerable skin [6,11,12]. This is surprising given the fact that many hospitalized patients e.g. trauma and post-surgical, who have reduced mobility are regularly transferred into a chair where they may remain for 8 h and longer [13]. In addition, there are many situations in the community, both in residential and private homes, where vulnerable individuals spend most of their daily lives sat in their “preferred” leisure chairs, often choosing to sleep in them overnight. In each case, the lack of mobility and monitoring of posture can lead to the development of SAPUs. Indeed, a recent review found that the majority of individuals at risk of developing pressure ulcers do not adhere with the pressure relieving frequency or magnitude of movements currently recommended [14,15]. Studies have combined interface pressure measures with accelerometers to assess the efficacy of pressure relieving behaviours. The study revealed that the magnitude of movement required to offload vulnerable tissues was substantive and typically not achieved with traditional repositioning activities [16].

The literature review also highlighted the need for further research investigating the effect of recommended pressure relieving movements on the pressures around the ischial tuberosities [14]. The authors have recently adopted an approach where combined measures of biomechanics and the physiological response of tissues are investigated to assess the performance of support surfaces and postures in the lying environment. This approach will now be translated into the seating environment to assess the effects of seat cushion type and posture on the ischial tubersoities of young able-bodied volunteers supported on a commercial leisure chair. The aim of the study is to provide a robust means of identifying postures and support surfaces which put the tissues at risk of pressure ulcers and determine how tissue recover during periods of offloading.

2. Methods

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

2.1. Description of the leisure chair and cushion properties

A standard Rise and Recline leisure chair (Configura®, Accora, United Kingdom), also known as a lounge chair or easy chair, was maintained in a neutral position, without tilt or recline, throughout the test protocols for each participant. Two cushions specifically designed for the leisure chair were used, namely, a static visco-elastic foam cushion and a dynamic air cushion (CushionAir). The chair and each of the cushions were set-up and fitted in accordance with the manufacturer's guidelines [17]. The inflation pressure of the air cushion was maintained at a mid-setting for all subjects and postures. The CushionAir device is a seat pad that consisted of an array of 64 individual air cells contained within a 4-way stretch, vapour-permeable cover. The air-cell array is constructed such that side-to-side rows of interlinked cells fill and empty in a 1-in-2 alternating sequence. The leisure chair was designed with a hollow insert for cushions. Both the foam and air cushions were the same thickness (4″) resulting in the same height for chair for both conditions, which was standardised for all participants.

2.2. Participants

Participants were recruited from the local community at the University of Southampton 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 sit for a period of 90 min. Institutional ethics was granted for the study (ERGO-FOHS-4972) and informed consent was obtained from each participant prior to testing.

2.3. Test equipment

Physiological measures of transcutaneous oxygen and carbon dioxide tensions (T_cPO_2, T_cPCO_2) were monitored at the right and left ischial tuberosities using a transcutaneous gas electrodes (Model 841, Radiometer A/S, Denmark) heated to 43.5 °C to ensure maximum vasodilation [9]. Each electrode was attached to a separate monitor (TCM4, Radiometer, Denmark), recording at a frequency of 0.5 Hz. Interface pressure measurements were recorded using a Pressure Measurement System (Tekscan CONFORMat®, Boston, MA). The mat incorporates a flexible grid based array of 1024 pressure measuring sensors, with a spatial resolution of 10 mm. Each sensor was set to operate within the range of 5–250 mmHg (accuracy ± 10%) with a data acquisition rate of 1 Hz. An accelerometer (Shimmer Platform, Realtime Technologies Ltd, Dublin, Ireland) was used to measure trunk movement. The tri-axial accelerometer was attached to the sternum with a Velcro strap. This device represents a small wireless sensor (53 mm × 32 mm x 25 mm) that recorded real-time kinematic data at 51 Hz. In addition, subjective 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 ± 2 °C. Participants, who wore loose fitting clothing during data collection, were asked to lie on their side with their hips flexed to 90° for a 15 min period to establish baseline unloaded $TcPO_2$ and $TcPCO_2$ levels at each ischial tuberosity. Each participant was then carefully positioned in a stable posture on the leisure chair, incorporating either the visco-elastic foam or the air cushion, as randomly selected. Participants were then asked to adopt four randomly allocated postures; optimal sitting (hips positioned 90° relative to trunk), slump (hips positioned 135° relative to trunk), right lean (trunk leaned over to the right 15°) and feet up (hips positioned 80° relative to trunk with feet raised). Subjects sat with their forearms resting on their laps and were instructed not to re-adjust their posture once seated (Fig. 1). The feet of participants were supported by the floor or a standard box for each posture. The pelvis was kept in a neutral tilt angle and the trunk was supported by the back of the leisure chair. The knees were bent to 90° for all postures apart from the raised feet. Each posture was checked with a hand held goniometer, measuring at the trunk, hip and knees by two researchers.

Each posture was assessed by two researchers to check hip and trunk angles and then maintained for a 10 min period. After each test condition, participants were asked to stand for a 10 min refractory period to allow reperfusion of the soft tissues, with the aim of restoring basal levels of transcutaneous gas tensions prior to the next test condition. The process was then repeated for the second cushion (air or viscoelastic foam), with a total of eight test conditions lasting a period of 160 min (Fig. 2). Transcutaneous gas measurements were continuously monitored at the ischial tuberosities throughout the test period. Accelerometer data was also captured continuously at the sternum. After 5 min of each posture, interface pressures were recorded for a 60 s period. Single measures of subjective comfort scores were also noted at the end of

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