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Microclimate evaluation of strap-based wheelchair seating systems for persons with spinal cord injury: A pilot study

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ABSTRACT

Study purpose: The purpose of this pilot study was to assess microclimate characteristics of two versions of a strap-based wheelchair seating system (perforated and solid straps) and to conduct preliminary microclimate comparisons of subjects' current wheelchair seating systems.

Materials and methods: In this pilot study, the microclimate properties of two variations (solid and perforated) of a strap-based seating system were compared with two commonly used seating systems. Six subjects sat on three different seating systems each for 100-min test periods, while temperature and relative humidity were measured with a single sensor adjacent to the skin-seat interface. Additionally, thermal images of the seat interface were collected before and after each test period.

Results: The thermal images revealed that the maximum surface temperature of the solid-strap-based seating system was significantly lower than the other seating systems, −1.21 °C. (95% CI -2.11 to −0.30, p = 0.02), immediately following transfer out of the seat. Five minutes after transferring out of the seat, the perforated-strap seat was significantly cooler than the other seats −0.94 °C. (95% CI -1.59 to −0.30), p = 0.01, as was the solid-strap-based seat, −1.66 °C. (95% CI -2.69 to −0.63), p = 0.01. There were no significant differences in interface temperature or relative humidity measured with the single sensor near the skin-seat interface.

Conclusion: This pilot study offers preliminary evidence regarding the microclimate of the strap-based seating systems compared with other common seating systems. Clinically, the strap-based seating system may offer another option for those who struggle with microclimate management.

1. Introduction

Persons with spinal cord injury (SCI) spend about 10 h a day seated in their wheelchairs on average, putting them at high risk for pressure injury [1,2]. Pressure injury to the seated area is primarily attributed to one or more risk factors occurring at the interface between the skin and seating system: mechanical pressure, shear, and microclimate [3]. In his review of the literature, which included human and animal studies, Gefen (2008) found evidence suggesting that presure injuries can occur in less than 1 h, not specifically considering moisture and temperature [4]. The National Pressure Ulcer Advisory Panel defines microclimate as "the local tissue temperature and moisture (relative humidity) level at the body/support surface interface" [5]. Both factors are known to affect the physiological resilience of skin and underlying tissue [6], thus, we believe it is most likely, an increase in either or both microclimate factors can lead to a decreased time to pressure injury occurrence and possibly increased incidence. Further, for persons with a higher-level SCI (T6 or above), the normal autonomic feedback loop for internal temperature control can be compromised [7], thus their response to environmental, e.g. microclimate of seating system, heating and cooling is different from that of a neurologically intact person's response. A well-fitted wheelchair seating system can provide protection against incurring a pressure injury [8,9] by: 1) off-loading the seated area's bony prominences of the ischial tuberosity and the sacral-coccyx-trochanter region; 2) preventing shear; and 3) maintaining desirable microclimate (temperature and moisture) of the seated area.

There are numerous wheelchair seating systems on the market comprised of components such as air-cells, gels, foam beads, and combinations thereof, primarily focused on off-loading the bony prominences of the seated area. Unfortunately, pressure injuries continue to occur, implying a continued need for innovative seating design, materials and fabrication methods to manage load and other risk factors

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Abbreviations

C	Celsius
C-5-7	Cervical spine, 5th through 7th vertebrae level
RH	Relative humidity
S	Subject
SCI	Spinal cord injury
SCI/D	Spinal cord injuries and disorders
T-5	Thoracic spine at 5th vertebrae level

[10]. Minimal knowledge exists regarding existing wheelchair seating microclimate properties and management of those properties. Clinically, seating specialists are challenged to match a specific seating system to a patient when it is known that persons who sit for extended periods of time experience increased risk for pressure injury [11] due to temperature and moisture factors of the seated area [12,13].

A tabby-weave strap-based seating system (Tamarack Habilitation Technologies Inc., Blaine, Minnesota) has been designed to address risk factors associated with pressure injury development, including microclimate management. The strap-based seating system uses 11 to 14 horizontal straps and 13 longitudinal straps (depending on frame size) that are interwoven and connected to a perimeter frame contoured to accommodate the skeletal anatomy. The length of these straps can be adjusted to obtain a clinically acceptable fit [14]. A seat cover is used on top of the straps and is made of a polyester spacer fabric and a nylon/spandex fabric layer with low-friction zones located under the pelvis. Because no additional fabrics or cushioning is used on the seating surface, the strap-based seating system may allow for increased airflow, which may potentially reduce heat and moisture buildup in the seated area.

The purpose of this pilot study was to gather preliminary data regarding the microclimate characteristics of two versions of the strap-based wheelchair seating system (perforated and solid straps). These microclimate characteristics were also measured in the subjects' current wheelchair seating systems for comparison.

2. Materials and Methods

2.1. Materials

The strap-based seating system has been previously described in detail [14]. The interwoven straps have spaces between them designed to allow airflow around the wheelchair user's seated area (Fig. 1). Both strap systems are made of 100% polyester. The difference between the two strap-based seating systems is that the perforated version has an array of small holes throughout the strap length, whereas the other is a solid woven strap.

Quantitative measures included thermal images of the seating systems, as well as temperature and moisture measured at one site near the skin-seat interface. An infrared thermal imaging camera (T450sc, FLIR Systems Inc., Wilsonville, Oregon) was used to capture each seating system's heating and cooling characteristics at three times: Pre-seating (at room temperature), immediately after the subject transferred out of the seat after sitting for 100 min, and 5 min after transfer. A sensor was placed adjacent to the skin-seat interface to continuously measure temperature (°C) and moisture (measured as relative humidity [RH]) (MSR Electronics GmbH, Seuzach, Switzerland, FH2). This small, capsule-shaped sensor (approximately 6 mm in diameter and 21 mm long) was connected to a digital data logger (MSR Electronics GmbH, Seuzach, Switzerland, MSR145WD) with a thin cable (approximately 1 mm in diameter). The accuracy of temperature measurements is ± 0.5 °C for measurements between 10 °C and 65 °C, and the accuracy of RH measurements is ± 2% for measurements between 10% and 85% and ± 4% for measurements above 85%, as stated by the sensor manufacturer. Although other studies have used multiple sensors [15–17] preliminary testing verified that a single sensor, placed on the medial thigh, forward of the ischial tuberosity and adjacent to the skin-seat interface, provided consistent reliable data to test between seat variability, without causing tissue injury during the prolonged testing periods. We also found in preliminary testing that using multiple sensors and their wires were difficult to manage when transferring the subject from bed to seat, interfering with data integrity.

This study was approved by the Minneapolis VA Health Care System's Institutional Review Board (a research review and ethics board) and was conducted at the Minneapolis VA Spinal Cord Injuries and Disorders (SCI/D) Center. The study rooms had environmental controls to regulate air flow, ambient temperature, and humidity, to help ensure these factors had minimal effects upon the seat comparisons.

2.2. Recruitment

For this pilot study, our goal was to recruit at least six subjects currently using a customized foam based seating systems (RIDE, Aspen Seating, Littleton, Colorado) to gain a sense of the strap-based seating system's relative micro-climate characteristics. At the time the study was conducted, only three users of that type of seating system met the study's inclusion criterion. Therefore, we added three subjects who were sitting on an often-used seating system for Veterans with troublesome pressure issues (ROHO®, Permobil, Lebanon, Tennessee). Again, the foam-based and air-cell-based seating systems were used *to gain a sense of the strap-based seating system's microclimate characteristics* compared to other commercially available seating systems.

2.3. Study visits

We included Veterans between 18 and 71 years of age with SCI at C5 or below who could operate a manual wheelchair and were currently using either air-cell-based or foam-based seating systems. We excluded persons with lower limb amputation or active pressure injury. We conducted skin checks of the seated area at enrollment, at each visit, and during the testing of each seating system to catch any threats to tissue integrity.

Three study visits for each subject were required to complete the microclimate testing. At the first visit, after informed consent was

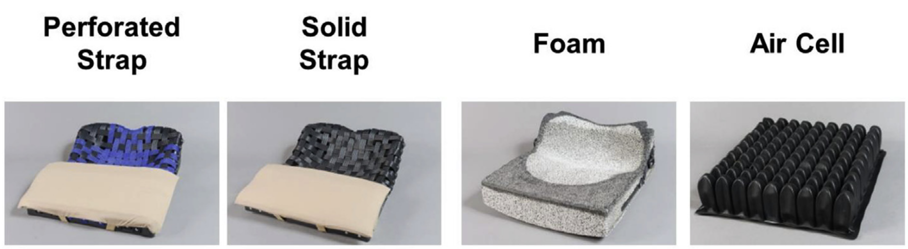

Fig. 1. Images of the four seating systems tested for microclimate characteristics including two strap-based seating systems, a foam-based and an air cell-based seating system.