Comparison of wheelchair cushion calibration by users with spinal cord injury and by occupational therapists, using a pressure mapping system

Differences in cushion calibration by the user and occupational therapist

Paulo VB Mendes¹, Débora C Paulisso¹, Camila C Caro¹ and Daniel MC Cruz².

¹ Postgraduate Program in Occupational Therapy, Federal University of São Carlos, São Paulo, Brazil.
² Occupational Therapy Department and Postgraduate Program in Occupational Therapy, Federal University of São Carlos, São Paulo, Brazil.

Corresponding author
Daniel M. C. da Cruz
Universidade Federal de São Carlos,
Departamento de Terapia Ocupacional,
Rodovia Washington Luiz, Km 235.
Bairro: Monjolinho. CEP: 13565-905,
São Carlos, São Paulo, Brasil
Email: paulomendes3@hotmail.com / cruzmc@gmail.com

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Abstract

Introduction: Pressure ulcers are frequent complications in patients with spinal cord injury. Air cushions have been identified as the most indicated device to relieve interface pressure and prevent pressure ulcers. The objective of this study was to identify if there are differences in the manual calibration of cushions by the user compared to the use of a pressure mapping system by an occupational therapist. Method: This was a case study with a sample of five subjects with spinal cord injury. Two experiments were performed: 1) interface pressure assessment, with the volume of air in the cushion calibrated by the user and 2) evaluation of the interface pressure after calibration by an occupational therapist. The mean pressure, peak pressure, and the contact area between the buttocks and cushion were assessed in the two experiments. The data were analysed using Student's t-test. Results: After the volume of air in the cushion was calibrated by an occupational therapist, there were significant improvements in the mean pressure (p = 0.01) and contact area (p = 0.02). Conclusion: This study provides evidence for the importance of regular calibration of air cushions by specialised professionals using a pressure mapping system.

Keywords: Cushion, occupational therapy, assistive technology.

Introduction

The development of pressure ulcers (PUs) may significantly interfere with a person’s ability to participate in activities of daily life, leisure, and work. Identifying the cause of a PU requires evaluation of occupational performance in each person’s contextual environment (Giesbrecht, 2006). Individuals who have had spinal cord injury have anatomopathological and pathophysiological alterations that put them at risk of developing PUs, and assessment of the contact surface of the buttocks while sitting, routine skin care procedures, the prescription of support surfaces, and the distribution of interface pressure are constant challenges faced by occupational therapists working with this population (Rose and Mackenzie, 2010).

Literature Review

Pressure Ulcer and Spinal Cord Injury

People who spend long periods lying in bed or sitting for many hours in a wheelchair and those who have difficulties in actively repositioning themselves are at risk of developing PUs (Cook and Polgar, 2015).

PUs are characterised by injury to the skin and/or the underlying tissue, usually on a bony protuberance, as a result of pressure or a combination of friction and skin shear (Gefen, 2014). After a period of poor blood flow, nutrients can no longer be supplied to the tissues, the degradation products accumulate, and ischemia occurs followed by hyperaemia, oedema, and tissue necrosis, eventually progressing to cell death (National Pressure Ulcer Advisory Panel, 2014).

PUs are frequent complications in patients with spinal cord injury (Trewartha and Stiller, 2011). The sacral region is more affected when the lesion is in the acute phase, while the ischiatic region is more commonly affected in patients with chronic lesions (National Pressure Ulcer Advisory Panel, 2014; Stinson et al, 2013; Costa and Oliveira, 2005; Burns and Betz, 1999).

After a spinal cord injury, anatomopathological and pathophysiological alterations occur in the buttocks, such as the adaptation of the tissues to the prolonged sitting and muscular downtime. These modifications include an increase in body weight and fat mass, which alters the size of the buttocks. Demineralisation of the epiphyses, thinning of the walls of the cortical bone diaphysis below the injury level, flattening of the ischiatic tuberosities due to continuous bone loss, and fractures when performing transfers due to the fragility of the bones, muscle atrophy, and sometimes, even spasms can occur. These phenomena increase the risk of PU in these individuals (Levy, Kopplin and Gefen, 2014, Gefen, 2014).
Bad posture in wheelchair-bound individuals can affect the distribution of pressure on the surface of the seat and contribute to the development of skin lesions. In particular, sitting with an oblique pelvic orientation and sitting on the sacrum are potential causes of PUs (Cook and Polgar, 2015). Such factors, together with limitations relating to spinal cord injury, have significant impacts on functionality and limit the process of rehabilitation and the social reintegration of patients (Stinson et al, 2013).

Individuals with spinal cord injury need special provisions of resources to facilitate an ergonomic sitting posture, because in addition to preventing damage to the skin, these interventions will influence the functionality of the upper limbs and head (Gefen, 2014). Health professionals use assistive technology resources to allow greater wheelchair functionality (Cook and Polgar, 2015).

In order to reduce the risk of PUs and increase tolerance to long periods in the sitting position, assistive technology resources for postural control such as wheelchair cushions are prescribed to individuals with spinal cord injury. These devices are intended to enable a greater support area, provide stability, accommodate deformities, and provide comfort and/or reduce the pressure peaks next to the ischiatic tuberosities and coccyx (Cook and Polgar, 2015; Levy, Kopplin and Gefen, 2014; Sonenblum et al, 2014; Brienza et al, 2001).

Health professionals generally agree that the use of appropriate cushions is critical for people with spinal cord injury in protecting them from PUs and deep tissue injuries. Currently, different types of cushions are marketed for distributing pressure, with the purpose of helping to prevent and control PUs. These include smooth foams, segmented foams, contoured foams, air cushions, and gels (Gefen, 2014). Air cushions are made with air-filled chambers and provide a number of benefits, including improved pressure distribution, the maintenance of body temperature, and light weight (Stockton et al, 2009).

Choosing the resource that best fits an individual’s needs is the role of occupational therapists aiming to improve functionality and prevent of ulcers. Studies carried out by these professionals have analysed the effectiveness of different types of cushions on minimizing the risk of the development of PUs (Yuen and Garrett 2001; Trewartha and Stiller 2011).

Occupational Therapy and Pressure Ulcers

Occupational therapists are involved in the prevention and assessment of risk factors for PUs in accordance with their knowledge related to posture and the prescription of wheelchairs and beds, and these professionals are considered essential resources in the rehabilitation team and play an important role in the evaluation and prescription of resources for postural adequacy and positioning (Giesbrecht, 2006; Rose and Mackenzie, 2010).

A Canadian study of conducted occupational therapists concluded these professionals play a role in the prevention of PUs through the prescription of pressure-relieving equipment and the development of positioning guidelines. Occupational therapists were found to primarily provide guidance to patients and prescribe equipment (Giesbrecht, 2006).

Keeping in mind that air cushions must be inspected periodically to check if the volume of air is suitable for distributing the pressure between the patient’s buttocks and the seat of the wheelchair, this study aimed to identify if there are differences in the manual calibration of air cushions by the user compared to those achieved by an occupational therapist using a pressure mapping system.

Method

Study Design
This was a case study with a design based that used by Yuen and Garrett (2001), in which participants tried different cushions in static positions.
Setting and timelines
Data were collected in the Laboratory of Functional Analysis and Technical Aids- LAFATec of the Department of Occupational Therapy, Federal University of São Carlos - UFSCar, São Carlos City, São Paulo Province, Brazil. The research participants were recruited from a non-governmental organisation, and included people with disabilities in the municipality of São Carlos.

Participants
Inclusion criteria:
Subjects older than 18 years with spinal cord lesions were selected from both sexes. Only those with lesions classified as A or B according to the American Spinal Injury Association scale were recruited. Individuals who used the Roho® Quadtrro Select High Profile™ cushion were selected, as this cushion has been identified by the literature as having a good ability to distribute pressure and prevent PUs (Trewartha and Stiller, 2011).

Exclusion criteria:
Subjects with hip deformities, the presence of PUs, and suspected deep tissue lesion and unclassifiable ulcers according to the classification of the National Pressure Ulcer Advisory Panel (2014) were excluded.

Instruments
1) Characterisation questionnaire
A characterisation questionnaire was applied to each participant, and queried information regarding the spinal cord injury, length of wheelchair-bound period, pressure relief manoeuvres, and air cushion use. In the latter metric, the questions examined the manner in which the resource was acquired (if a healthcare professional prescribed the cushion) and the form and frequency of calibrations.

2) X-Sensor
Pressure distribution was measured using the mark X-Sensor, model PX100:36.36.02, which is a digital and three-dimensional pressure mapping system composed of a rectangular surface and a series of electronic sensors distributed in a network coated with an impermeable fabric. When placed between the body and the cushion, the system measures pressure at different point, processing them with software and presenting the weight distribution of the cushion used by the patient as a computerised image (X-sensor, 2015).

Data Collection
Interface pressure evaluation involved measuring mean pressure, peak pressure, and area of contact on the air cushion used by the participant in two experiments:
1) Pre-calibration: pressure evaluation of the interface on the cushion with the air volume used by the participant.
2) Post Calibration: evaluation of the interface in the cushion pressure after performing a calibration of air volume by an occupational therapist. The calibration of the air volume of the cushion was performed according to the manufacturer’s manual.

In each of the experiments, after participant was transferred onto the cushion, a period of 5 minutes was allowed to pass in order for the tissues in contact with the cushion to settle, because Yuen and Garret (2001) stated that this is the time necessary for the pressure between the buttocks and the cushion to stabilise. During this period, the participants were requested to keep their hands on their thighs, and to maintain 90° flexion of the hips, knees, and ankles.
The evaluation of pressure in each experiment was performed by recording 10 frames per second over 5 minutes. In this period, the participants were also requested to keep their hands on their thighs, and to maintain 90° flexion of the hips, knees, and ankles. This procedure was followed for both experiments.

**Data Analysis**

We assessed the mean pressure, peak pressure, and contact area between the buttocks and the cushion using the Xsensor® Pressure Mapping System and used the pressure analysis software X3 Medical, version 6.0 to interpret the data.

In this study, a sensitivity of 100 mmHg was used for X-sensor pressure mapping. The pressure cells were divided into two categories: measurements between 60 and 99 mmHg and measurements ≥ 100 mmHg. These two categories were used according to the methodology of Yuen and Garrett (2001), who demonstrated that the levels of pressure on the ischial region between 60 and 99 mmHg could affect tissue health among individuals with spinal cord injury and that pressure levels of ≥ 100 mmHg significantly increase the risk of compromised tissue health. Pressure readings < 60 mmHg were discarded as they represented areas at low risk for the development of PUs.

Student's *t*-test was used to compare the effect of factors on the results. This statistical analysis was performed using R, version 3.1.3 (Alcatel-Lucent, São Paulo, SP, Brazil).

**Results**

The study population was composed of five subjects with spinal cord injuries, four of whom were men. The mean duration of sitting on the wheelchair was 9 ± 3 hours. The characteristics of the study participants are summarised in Table 1.

<table>
<thead>
<tr>
<th>Participant</th>
<th>Sex</th>
<th>Lesion Level</th>
<th>Time in the wheelchair*</th>
<th>Pressure relief manoeuvres</th>
<th>Frequency of the manoeuvres</th>
<th>Prescription**</th>
<th>Form of acquisition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M</td>
<td>C6/C7</td>
<td>10</td>
<td>None</td>
<td>-</td>
<td>None</td>
<td>Own resource</td>
</tr>
<tr>
<td>2</td>
<td>M</td>
<td>T11</td>
<td>6</td>
<td>Push ups</td>
<td>Every 40 minutes</td>
<td>None</td>
<td>Own resource</td>
</tr>
<tr>
<td>3</td>
<td>M</td>
<td>T8/T10</td>
<td>12</td>
<td>None</td>
<td>-</td>
<td>None</td>
<td>Own resource</td>
</tr>
<tr>
<td>4</td>
<td>M</td>
<td>C5</td>
<td>12</td>
<td>Mobilises the body</td>
<td>Whenever needed</td>
<td>None</td>
<td>Own resource</td>
</tr>
<tr>
<td>5</td>
<td>F</td>
<td>C5</td>
<td>5</td>
<td>Front tilt of the torso</td>
<td>Every 2 hours</td>
<td>None</td>
<td>Own resource</td>
</tr>
</tbody>
</table>

*Measured in hours, **Only relevant if the cushion was prescribed by a healthcare professional.

Three of the participants were given advice by the shop from which they purchased the cushion regarding the calibration of the cushion. They were told that calibration should be performed by inflating the cushion with air while keeping the valve open so that the internal pressure of the cushion stabilized with the external pressure before closing the air valve. Two participants (n = 2) were instructed that the cushion should be inflated while sitting on it with the valve open, before closing the valve once the air has flowed out.
Four participants reported never having calibrated the cushion after purchase and only participant No. 4 reported inflating the cushion when it felt unstable on the seat.

The data collected with the pressure mapping system are presented in Table 2, in which information on mean pressure, peak pressure, and contact area on the cushion are presented for each of the data collection steps.

Table 2. Pressure interface data

<table>
<thead>
<tr>
<th>Participant</th>
<th>Mean pressure (mmHg) Pre</th>
<th>Mean pressure (mmHg) Post-Calibration</th>
<th>Peak pressure (mmHg) Pre</th>
<th>Peak pressure (mmHg) Post-Calibration</th>
<th>Contact Area (cm²) Pre</th>
<th>Contact Area (cm²) Post-Calibration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>41.3</td>
<td>29.4</td>
<td>102</td>
<td>132.2</td>
<td>743.5</td>
<td>1054.8</td>
</tr>
<tr>
<td>2</td>
<td>49.9</td>
<td>36.5</td>
<td>161</td>
<td>227.6</td>
<td>838.7</td>
<td>1103.2</td>
</tr>
<tr>
<td>3</td>
<td>72</td>
<td>53.1</td>
<td>255</td>
<td>226.8</td>
<td>1017.7</td>
<td>1191.9</td>
</tr>
<tr>
<td>4</td>
<td>63.3</td>
<td>44.4</td>
<td>255.7</td>
<td>197</td>
<td>1158</td>
<td>1414.5</td>
</tr>
<tr>
<td>5</td>
<td>37.3</td>
<td>34.8</td>
<td>132</td>
<td>108.9</td>
<td>1256.4</td>
<td>1374.1</td>
</tr>
</tbody>
</table>

Analysis of the data obtained using the X-sensor® indicated that there was a significant improvement (p < 0.05) of mean and peak pressure indices after calibration of the cushions (Figures 1 and 2).

The mean post-calibration pressure values were significantly lower than the mean pressure values recorded before calibration (p = 0.01). The post-calibration pressure values of the cushions were significantly higher in the contact area (p = 0.02).

Discussion

In this study, the appropriate calibration of cushions provided lower mean pressure and a larger contact area for the buttocks and thighs. The analysis of the data in this study points to a wheelchair-bound period of 9 hours, and that over this period, pressure relief manoeuvres are carried out only when patients have discomfort or at intervals greater than 40 minutes. Published data indicate that for adequate pressure relief, repositioning/pressure relief manoeuvres should be performed every 20 minutes, with a duration of 1.5 to 4 minutes being required for the full recovery of oxygen in the tissues. However, several factors may limit the implementation of such regimes (Gefen, 2014; Makhsous et al, 2007; Sonenblum et al, 2014).

With respect to the muscular flaccidity caused by spinal cord injury, studies suggest that returning to the seat after pushups should be performed slowly to avoid mechanical impacts to tissues and consequent deformation (Gefen, 2014; Makhsous et al, 2007; Sonenblum et al, 2014). These factors, together with the
loss of skin resistance, atrophy, and the loss of muscle mass and increase of intramuscular fat tissue, elevate the risk of the participants of the patients included in this study developing PUs due to long periods sitting with prolonged maintenance of pressure in the ischial region (Gefen, 2014). These factors are compatible with the theories for the occurrence of PUs put forward by the National Pressure Ulcer Advisory Panel (2014).

The fact that the participants did not perform appropriate calibration of their cushions according to information available in the manual demonstrates how little attention is directed to this procedure. The importance of correct calibration according to each user’s needs has already been reported as one of the fundamental aspects of ensuring efficient relief of pressure for wheelchair users (Hamanami, Tokusiro and Inoue, 2004). In both experiments, the mean pressures levels < 60–99 mmHg interval, and therefore did not have the potential to jeopardise tissue health. However, the mean peak pressure values were > 100 mmHg in both experiments, representing a risk of compromising tissue health in people with spinal cord injuries (Yuen and Garrett, 2001).

Our statistical analysis indicated that there was a significant difference in the mean pressure and the contact area between the two experiments, as appropriate calibration of the cushion provided lower mean pressure indices and a larger contact area for the buttocks and thighs, pointing to the need to follow the manufacturer’s instructions when calibrating the cushions in order to provide a better distribution of pressure and to reduce the risks the development of PUs. This suggests the need for educational instruction for patients, especially as the calibration of the cushions was found to be inadequate in our case series.

The Roho® cushion offers superior quality compared to other cushions in terms of the distribution of pressure and the accommodation of patients with high risk of developing PUs (Trewartha and Stiller, 2011). Thus, the descriptive analysis of the data obtained by the X-sensor indicated that there was an inverse relationship between mean pressure and contact area, because upon increasing the contact area after calibrating the cushions, it was possible to observe a decrease in the mean pressure at the buttock/cushion interface (Gefen, 2014).

The pressure indices measured in this study indicated the need to appropriately calibrate cushions according to the needs of each user following the manufacturer’s instructions, since the efficiency of pressure relief may vary according to the air pressure inside the cushion, thus altering the distribution of pressure at the interface between the buttocks and the cushion (Hamanami, Tokusho and Inoue, 2004). Thus, it is necessary to instruct and educate users on the correct use of the cushion, taking into account the following: skin temperature, relative humidity at the buttock-cushion interface, the cost of the equipment, the patient’s ability to perform transfers, the perception of comfort by the patient, and the ability of the patient to look after the cushion (Yuen and Garrett, 2001).

Even with the use of an adequate pressure interface with proper calibration, it is necessary to use pressure relief manoeuvres including pushups or mobilisation of the torso in the wheelchair (National Pressure Ulcer Advisory Panel, 2014).

Study Limitations
The limitations of this study include the small sample of patients who underwent a single evaluation in a short period of time. In order to further investigate the role of cushion calibration, a study using longer periods of time and revaluations of buttock/cushion interface pressure levels is recommended so that recalibrations of the cushions are undertaken. The occurrence of skin redness in the long term should be investigated, as it may indicate the efficacy of the cushions in preventing injuries.

Future studies should include: a) longitudinal evaluations of subjects with their cushions, to assess the effectiveness of the devices in the prevention of PUs; (b) analysis of the effect of educational
strategies of regular calibration of the cushions in maximising the effect of pressure distribution afforded by cushions and the prevention of PUs.

**What is the recommendation for possible interventions to occupational therapy?**
Occupational therapists are involved in the prevention and assessment of risk factors for PU based on their specific knowledge of seating and positioning. They are also knowledgeable about assistive technology, and play an important role in the rehabilitation team and in the evaluation and prescription of these resources (Giesbrecht, 2006; Rose and Mackenzie, 2010).

Hence, it is necessary that these professionals perform interventions to guide and educate users about the correct calibration of cushions as well as to monitor and revaluate their use by checking that the cushion is successfully preventing damage to tissues.

**Conclusion**
For the adequate distribution of pressure and the accommodation of the buttocks and thighs, it is necessary to guide and educate the user on the correct calibration of air cushions so that they maintain the ability to distribute the pressure along the surface of the seat and prevent PU. The monitoring and periodic review of the cushion is also necessary in order to determine if it is being used correctly and if the user is not developing skin lesions.

**Key Messages:**
- Calibration by an occupational therapist using a pressure mapping system provided the best indices of mean pressure and contact area.
- All users acquired their cushions without the prescription of a professional.

**What the study has added**
This study contributed evidence of the importance of properly calibrating air cushions in preventing PUs in the sitting position.

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