Comparing Wheelchair Cushions for Effectiveness of Pressure Relief: A Pilot Study

Orit Shechtman, Carolyn S. Hanson, Donna Garrett, Pam Dunn

The prescription of wheelchair cushions to increase comfort and decrease decubiti in individuals using wheelchairs is often the function of occupational therapists.

Key words: wheelchair cushions • pressure mapping system • cushion comfort

Abstract

The purpose of this study was to determine if there were differences in pressure relieving abilities among six commonly prescribed wheelchair cushions and whether differences were related to the participant's body mass. In addition, the participant's perception of cushion comfort was investigated. A convenience sample of 40 adult wheelchair users were recruited from a rehabilitation hospital. Participants sat on the following six cushions for 5 minute periods: Flexseat, Jay 2, Pindot, ROHO High, ROHO Low, and Stimulite. Pressure measurements were recorded with the Xsensor Pressure Mapping System, a new instrument available to therapists. It was discovered that ROHO High and ROHO Low cushions were more effective in relieving pressure than the other cushions. Cushion pressure relieving abilities were largely dependent on the individual's body mass. ROHO cushions were also perceived to be more comfortable than all other cushions tested regardless of body mass and pressure relief.

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Decubitus ulcers, also known as pressure ulcers and pressure sores, are a frequent and serious complication for many long-term wheelchair users that disrupt every aspect of a person's life, affecting health, employment, education, and social interaction (Springle, Faisant, & Chung, 1990). Kuhn and Coulter (1993) estimated that 1.7 million patients develop new pressure sores annually, with associated expenditures of 8.5 billion dollars. The costs of preventing pressure sores, however, are significantly less than the costs of treatment.

Decubitus ulcers develop mainly as a result of disruption to the vascular network of arteries, arterioles, and capillaries (Bridel, 1993). Although impaired metabolism, friction, and shear forces have been shown to be instrumental in the pathogenesis of decubitus ulcers, prolonged supracapillary pressure appears to play the most important role (Bridel, 1993; Dinsdale, 1974; Kosiak, 1958). In his landmark work, Kosiak (1959) demonstrated an inverse relationship between the minimal time and the minimal pressure needed to produce a decubitus ulcer. It has since been established that redness persisting for 24 hours or more is a stage I decubitus, and if pressure is not removed entirely, such an area frequently proceeds to ulceration (Delateur, Berni, Hongladarom, & Giaconi, 1976). Kosiak's studies proved what has come to be well known and accepted among the medical community—duration of pressure is actually more critical than intensity. Proportionately lower pressures produce equivalent tissue damage with increasing duration of application (Souther, Carr, & Vistnes, 1974).

Foremost in the prevention and treatment of decubitus ulcers is the prescription of pressure relieving devices such as wheelchair cushions designed to distribute the body's weight away from the areas most vulnerable to tissue erosion. The knowledge and expertise to prescribe these devices usually lies with the rehabilitation staff and includes occupational and physical therapists (Garber, 1979). A primary objective of occupational therapy is to maximize functional potential in patients with impairment and disability. Pressure sores are a major complication in the rehabilitation of these individuals (Garber, 1985b). The occupational therapy perspective or practice model that the therapist uses to organize the many aspects of this complication will influence what the therapist measures, which variables she or he chooses to treat, and what conclusions are drawn. The rehabilitative conceptual model of practice is applicable to patients with the potential complication of decubitus ulcers secondary to impaired mobility and sensation because it addresses problems at the disability and handicap levels of disablement and aims at making the person as independent as possible in spite of residual disability. The rehabilitative model is used when remediation is incomplete or impossible and focuses on teaching adaptation so that the person may become an active partner in his or her health (Trombly, 1995). Knowledge of the causes and treatment of decubitus ulcers is therefore essential for the occupational therapist, and effective methods of prevention are critical if occupational therapy is to be instrumental in bringing about rehabilitation through adaptation in persons at potential risk for decubitus ulcers.

To aid in the decision, the therapist employs various strategies to select a patient's wheelchair cushion, including the objective assessment of pressure between the patient's buttocks and the seating surface and also clinical judgment including diagnosis and analysis of lifestyle factors. Since the successful selection of the proper wheelchair cushion for a particular patient cannot be based on objective data or clinical judgment alone, it becomes obvious that individualized prescription must be a combination of objective information provided by a pressure-detecting instrument and skilled clinical assessment (Garber, 1985b). In addition to a therapist's judgment, patient preference must always be considered in the cushion selection process, especially the patient's perception of comfort of the cushion. A cushion, regardless of its ability to relieve pressure, is unlikely to be used if the patient feels that it is uncomfortable. Also, no studies have yet examined the relationship between a person's assessment of cushion comfort and the cushion's actual pressure relieving ability.

Once a pressure relieving wheelchair cushion has been carefully selected and prescribed, it is often the occupational therapist who is responsible for training the patient and family in proper, cushion use,
positioning, care, and maintenance. Many decubitus ulcers have developed when a patient has sat on a deflated air type cushion for a period of time, or has unknowingly reversed the cushion and sat on the abductor wedge. A major goal, therefore, of occupational therapy is consumer education. Consumers need to know the characteristics of the many types of cushions available and the advantages and disadvantages of each cushion being considered. Data suggest that periodic reevaluation of patients by their therapist is essential to detect changes in lifestyle, general health, and skin integrity in order to prevent the development of decubitus ulcers (Garber & Krouskop, 1982). It must be realized that cushion prescription is not a one time occurrence, and changes may be necessitated by a patient's alteration in health status, body build, mobility level, or activity pattern.

In recent years, hundreds of commercially available seating devices have been developed and marketed, creating an urgent need for therapists to better understand this technology (Garber, 1985a). Although specially designed pressure relieving wheelchair cushions have been manufactured and widely prescribed, little research (Rosenthal, Felton, Hileman, Lee, Friedman, & Navach, 1996) examining the relative effectiveness of these cushions has been conducted within the last 5 years. Earlier studies comparing the pressure relieving abilities of various cushioning technologies examined cushions that are no longer manufactured or prescribed, with the exception of ROHO and Jay products (Fisher & Patterson, 1983; Garber, 1985b; Garber, Krouskop, & Carter, 1978).

Since the 1970s, several pressure-mapping systems have been employed in clinical research studies to compare commonly prescribed pressure relieving wheelchair cushions (Rosenthal et al., 1996; Fisher & Patterson, 1983; Garber, 1985b; Garber et al., 1978). These evaluation systems, however, were impractical to mass-produce, cumbersome to operate, and not readily available for use in the clinic. The technology of both wheelchair cushions and pressure detection instrumentation has changed dramatically in recent time.

The availability of pressure detection instrumentation in the clinical setting may allow therapists to make informed decisions in choosing appropriate cushions for specific patients. Indeed, the idea for this project was conceived out of clinicians' interest in scientific inquiry of optimum patient care. This pilot study was conducted in a wheelchair clinic to investigate the capabilities of a recently purchased pressure detection system (the Xsensor Pressure Mapping System) designed to determine differences in pressure among wheelchair cushions.

The purpose of this study was to investigate whether there were differences in the pressure relieving abilities of six wheelchair cushions currently on the market. Also, we investigated whether the pressure relieving abilities of these cushions were related to the participant's body mass, and whether the participant's opinion regarding the comfort of the cushions corresponded to the objective measure of pressure relief provided by the cushions.

Methods

Sample Selection

A purposive sample of 40 wheelchair users (22 males and 18 females, average age 59 ± 18 years) who were currently inpatients or outpatients at Brooks Rehab Hospital in Jacksonville, Florida, was selected. Staff occupational therapists and physical therapists at Brooks Rehab Hospital identified potential participants from their current caseload. Once it was determined that the patients met the inclusion criteria for the study, they were invited by their therapist to join the study. Inclusion criteria included a status of decreased mobility and current use of a standard width wheelchair and a wheelchair cushion. The participants also had to be alert, cognitively intact, verbally expressive, and 18 years of age or older.
Participants who were unable to sit for approximately 5 minutes on each cushion or transfer from the testing wheelchair while cushions were being exchanged were excluded. Twenty-five participants were diagnosed with cerebral vascular accident, 4 with lower extremity trauma or amputation, 3 with spinal cord injury, and 8 with other neurological or muscular disease. All participants signed an informed consent approved by the University of Florida Institutional Review Board.

**Equipment and Materials**

**Body Mass Index**

Body mass index (BMI) is a medical reference commonly used as an indication of adult nutritional status and body mass. It is calculated by dividing a person's weight in kilograms by their height in meters squared (W/H²). Data on height, weight, and gender were collected from medical records, and BMI was calculated for each participant. The participants were divided into three groups according to BMI: light (BMI less than 20.7 kg/m² for males and 19.1 kg/m² for females; n = 4), heavy (BMI greater than 27.8 kg/m² for males and 27.3 kg/m² for females; n = 13), and average (BMI between the two previous ranges; n = 23) (Thomas, 1993). Height and weight information is found in Table 1.

**Pressure-Relieving Cushions**

Six commercially available pressure-relieving wheelchair cushions currently on the market were evaluated for each participant: Flexseat (Flofit, Boulder, CO), Jay Medical Jay 2 (Sunrise Medical, Longmont, CO), Pindot Personal Seat (InvaCare Corporation, Elyria, OH), ROHO High Profile and ROHO Low Profile (Crown Therapeutics, Belleville, IL), and Supraeor Stimulite (Supracor Systems, Inc., Sunnyvale, CA). These particular cushions were selected because they represented different cushion construction materials: air, gel/fluid, polyurethane foam, and plastic. All cushions were used for prevention or treatment of decubitus ulcers.

<table>
<thead>
<tr>
<th>Variable</th>
<th>H</th>
<th>Mean ± SD</th>
<th>Range</th>
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<tbody>
<tr>
<td>Height (m)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All subjects</td>
<td>40</td>
<td>1.70 ±0.10</td>
<td>1.55- 1.93</td>
</tr>
<tr>
<td>Average group</td>
<td>27 (68%)</td>
<td>1.70 ±0.13</td>
<td>1.55- 1.93</td>
</tr>
<tr>
<td>Heavy group</td>
<td>13 (32%)</td>
<td>1.68 ±0.08</td>
<td>1.55- 1.83</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All subjects</td>
<td>40</td>
<td>74.9 ± 16.8</td>
<td>45.9- 117.7</td>
</tr>
<tr>
<td>Average group</td>
<td>27 (68%)</td>
<td>59.5 ± 7.3</td>
<td>45.9- 100.0</td>
</tr>
<tr>
<td>Heavy group</td>
<td>13 (32%)</td>
<td>90.1 ± 3.6</td>
<td>66.8- 117.7</td>
</tr>
</tbody>
</table>

Based on the premise that distribution of body weight away from high risk pelvic areas to a greater surface area will reduce focal pressures and thereby decrease the risk of ischemia and eventual tissue breakdown. The pressure relieving abilities of the six cushions were measured on 40 participants, while that of the sling seat was measured on only 38 participants since computer data were mistakenly deleted for two of the sling seat measurements.
The cushions were all currently in stock in the wheelchair clinic at Brooks Rehab Hospital. They were approximately the same age (2 to 6 months) and exhibited similar degrees of wear. They were removed from general use during the study period. All cushions were covered during the study with the standard cushion cover provided by the manufacturer at the time of purchase with the exception of the Jay 2 cushion. Jay Medical Company explicitly requested that their cushion be tested with the cover removed because of concern about the "hammock effect." It is noted that the "hammock effect" of cushion covers has been found by several researchers to be an insignificant source of interference with the pressure distribution properties of wheelchair cushions (Denne, 1981; Fisher & Kosiak, 1979). Therefore, a black, standard cushion cover was used during the testing period (except for the Jay 2 cushion) so that participants were blinded to which cushion was being tested.

The Pressure-Measuring System

The Xsensor Pressure Mapping System (Crown Therapeutics, 100 Florida Ave., Belleville, IL 62221) was used to measure and map the pressures occurring at the participant-cushion interface of the sling seat and the six wheelchair cushions. The Xsensor system was linked to a 486 DX/33 laptop computer. The software provided with the Xsensor system calculated pressure within specific pressure ranges spanning from 0 mm Hg to 100+ mm Hg. The ranges in the software were divided into 10 categories of 10 mm Hg each: (1) 1 to 10 mm Hg, (2) 11 to 21 mm Hg, (3) 22 to 32 mm Hg, (4) 33 to 43 mm Hg, (5) 44 to 54 mm Hg, (6) 55 to 65 mm Hg, (7) 66 to 76 mm Hg, (8) 77 to 87 mm Hg, (9) 88 to 99 mm Hg, and (10) 100+ mm Hg.

The sensor pad dimensions were an area of 46 cm x 46 cm and a thickness of 0.64 mm when compressed. The sensor pad was constructed of flexible plastic and contained a total of 1,296 individual pressure sensors. The software automatically displayed the number of sensors activated by the seated patient (the contact area). The pad was capable of providing a sampling rate up to 2,000 sensors per second. The data generated were accurate to 10% or 10 mm Hg as stated by the manufacturer. The system was newly purchased and precalibrated at the factory at the onset of this study.

Perceived-Comfort Scale

A Likert type scale of perceived comfort was used to determine the participant's perception of the comfort level for each cushion tested. Use of a verbal rating scale to measure comfort as a function of pain in relation to therapeutic interventions is accepted as a reasonably valid tool (McQuire, 1984). The scale that was used in this study was created by the researchers and was composed of five corresponding verbal and numerical descriptions of cushion comfort: 1 - very uncomfortable, 2 - moderately uncomfortable, 3 - comfortable, 4 - very comfortable, and 5 - extremely comfortable. The scale was printed in large, bold print on 22 cm x 28 cm (8.5 x 11 in.) white paper and laminated to increase durability throughout the study.

Data Collection Procedure

Pressures were measured on 40 participants using one designated test wheelchair; a lightweight, manual, folding style chair with tubular armrests manufactured by Action (Invacare Corporation, Elyria, OH). The chair had a standard 46 cm wide by 41 cm deep seat with 58 cm rear spoke wheels and 15 cm front castors, and a floor-to-seat height of 50 cm. During cushion testing, a birch solid seat insert was placed over the soft sling seat of the wheelchair as would normally be done in a clinical setting to give the cushion and patient a firm, solid base on which to sit, thus avoiding internal rotation of the pelvis. The footplates of the testing wheelchair were removed for this study and replaced with wooden boxes and a wedge to ensure that the hips and knees were at 90° and the thighs were horizontal and not bearing their own weight. The armrests of the testing wheelchair were placed at their lowest possible position and both towels were rolled up and put between the armrest and the participant's arms so that they rested
comfortably at approximately a 90° angle of elbow flexion. Each participant was positioned in a fully upright posture with weight equally distributed over both buttocks.

Prior to the beginning of the study, the six cushions were tested to determine the length of time required for the cushions to acclimate or adapt to the geometry of the participant's body. It was found that a 5 minute sitting period was necessary to obtain stable, reproducible pressure results. Previous studies (Rosenthal et al., 1996; Garber et al., 1978) indicated various times from 5 to 60 minutes for this process. Therefore, a 5 minute acclimation time was used for each cushion throughout the study and was accurately timed with a stopwatch beginning when the participant initially sat on a cushion.

At the beginning of the pressure measurement session, the participants were transferred from their wheelchair to the uncushioned sling seat of the testing wheelchair that was covered by only the Xsensor pressure mapping pad. The participants were properly positioned and after 5 minutes of sitting, pressure was measured, recorded, and stored in the computer. The first cushion to be tested was then put on the solid seat insert and covered with the Xsensor pressure mapping pad. The participants were again positioned as previously described, and after exactly 5 minutes, pressure was measured, recorded, and stored in the computer. After 4 minutes of sitting on each cushion, the participant was given the Scale of Perceived Comfort. This procedure was repeated until the sling seat and all six cushions were tested on each participant. Testing order of the cushions was randomized and recorded on a cushion randomization form.

Data Analysis

The terms "activated sensors" and "pressure" will be used interchangeably throughout this article since the number of activated sensors reflects and is proportional to pressure. Two ranges of pressure were analyzed: the 66 to 100 mm Hg, which will be termed the high pressure throughout this article, and the 100+ mm Hg, which will be termed the highest pressure. These ranges were chosen because the literature indicates that pressures greater than 60 mm Hg are potentially dangerous to tissue health and because the Xsensor system measures and displays a range of 55 to 65 mm Hg, with the next range being at 66 mm Hg. The highest pressure range reported by the Xsensor system (100+ mm Hg), which indicates a potentially critical level of pressure, was analyzed separately. An analysis of covariance (ANCOVA) was performed to determine if there were significant differences in pressure among the six wheelchair cushions and the sling seat, and to examine the influence of the participant's body mass on the pressure-relieving abilities of these cushions. The high and highest pressure ranges were analyzed separately.

Only 30 participants (75%) were able to give their opinion regarding the comfort level of the cushions (the perceived comfort scale) since 10 of the participants had little to no sensation. The comfort of the wheelchair sling seat (no cushion) was not assessed. A two-way ANOVA (BMI by cushion) was performed to examine whether there were comfort differences among the six cushions. An ANCOVA was performed to test whether pressure was the main predictor of comfort. All differences were considered significant at the 0.05 level of confidence.

Results

The average and light groups were combined (n = 27) because of the low number of participants in the light group (n = 4). An ANOVA was performed to confirm that there were no differences in pressure relief between the two groups (for the high pressure range: F = 0.00; p = 0.9660 and for the highest pressure range: F = 2.48; p = 0.1282). The combined light/average BMI category is hereafter referred to as "average." Mean cushion pressures as expressed by mean activated sensors for the
average BMI and heavy BMI groups at the high and highest pressure ranges are found in Figure 1 and Figure 2, respectively.

After the separation into two BMI groups (average and heavy), an ANCOVA for the high pressure range revealed a significant interaction ($F = 3.61; p < 0.0062$) and significant main effects for both cushion ($F = 15.92; p < 0.0001$) and BMI ($F = 8.30; p < 0.0065$). Similarly, for the highest pressure range, there was a significant interaction ($F = 3.64; p < 0.0060$) and significant main effects for both cushion ($F = 15.52; p < 0.0001$) and BMI ($F = 30.29; p < 0.0001$). Tukey-Kramer post hoc analyses were performed to determine which cushions were significantly different from other cushions.

![Figure 1: The number of activated pressure sensors at the high range (66 to 100 mm Hg). Each cushion is represented as mean ± standard error of the mean.](image)
Figure 2: The number of activated pressure sensors at the highest range (100+ mm Hg). Each cushion is represented as mean + standard error of the mean.

**Table 2**
Tukey-Kramer Post-Hoc Analysis of Pressure Differences between Cushions

**a. Average BMI Group at the Highest Pressure Range (100+ mm Hg)**

<table>
<thead>
<tr>
<th>Cushion 1</th>
<th>Cushion 2</th>
<th>t</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROHO High</td>
<td>Pindot</td>
<td>-5.28</td>
<td>0.0004</td>
</tr>
<tr>
<td>ROHO Low</td>
<td>Pindot</td>
<td>-4.10</td>
<td>0.0130</td>
</tr>
<tr>
<td></td>
<td>Sling seat</td>
<td>-3.88</td>
<td>0.0229</td>
</tr>
</tbody>
</table>

**b. Heavy BMI group at the Highest Pressure Range (100+ mm Hg)**

<table>
<thead>
<tr>
<th>Cushion 1</th>
<th>Cushion 2</th>
<th>t</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROHO High</td>
<td>Flexseat</td>
<td>-4.57</td>
<td>0.0034</td>
</tr>
<tr>
<td></td>
<td>Jay 2 Flexseat</td>
<td>-4.46</td>
<td>0.0047</td>
</tr>
<tr>
<td>ROHO Low</td>
<td>Flexseat</td>
<td>-5.28</td>
<td>0.0004</td>
</tr>
<tr>
<td></td>
<td>Jay 2 Flexseat</td>
<td>-5.14</td>
<td>0.0006</td>
</tr>
<tr>
<td>Pindot</td>
<td>Flexseat</td>
<td>-4.04</td>
<td>0.0153</td>
</tr>
<tr>
<td></td>
<td>Jay 2 Flexseat</td>
<td>-3.95</td>
<td>0.0191</td>
</tr>
</tbody>
</table>

**c. Heavy BMI Group at the High Pressure Range (66 to 100 mm Hg)**
For the average BMI group, at the highest pressure range, the ROHO High cushion had significantly lower pressure than the Pindot cushion, and the ROHO Low cushion had significantly lower pressure than both the Pindot cushion and the sling seat (see Table 2a). There were no significant pressure differences between the cushions in the high pressure range for the average group. For the heavy group at the highest pressure range, the ROHO High, ROHO Low, and Pindot cushions had significantly lower pressures than did the Flexseat and Jay 2 cushions (see Table 2b). At the high pressure range, both ROHO High and ROHO Low cushions had significantly lower pressures than the Flexseat and Jay 2 cushions. Also, the Stimulite had lower pressures than the Jay 2 cushion (see Table 2c).

Table 3

<table>
<thead>
<tr>
<th>Cushion 1</th>
<th>Cushion 2</th>
<th>t</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROHO High</td>
<td>Flexseat</td>
<td>-4.71</td>
<td>0.0023</td>
</tr>
<tr>
<td>ROHO Low</td>
<td>Flexseat</td>
<td>-5.15</td>
<td>0.0006</td>
</tr>
<tr>
<td>ROHO Low</td>
<td>Jay 2</td>
<td>-4.18</td>
<td>0.0102</td>
</tr>
<tr>
<td>Stimulite</td>
<td>Jay 2</td>
<td>-4.19</td>
<td>0.0100</td>
</tr>
</tbody>
</table>

For the average BMI group, at the highest pressure range, all cushions (except the sling seat of the wheelchair) showed significantly greater pressures for the heavy group than for the average group (see Table 3). On the other hand, at the highest pressure range, only the Flexseat cushion exhibited significantly lower pressures for the average group than the heavy group (t = -3.81; p = 0.0281). Power analysis of the effect and sample size showed that at the present sample size of 13 participants in the heavy BMI group and 27 participants in the average BMI group, a power of 0.90 and 0.99 respectively was present to detect a 0.50 effect size.

A Tukey-Kramer post hoc analysis revealed that at the high pressure range, all cushions (except the sling seat of the wheelchair) showed significantly greater pressures for the heavy group than for the average group (see Table 3). On the other hand, at the highest pressure range, only the Flexseat cushion exhibited significantly lower pressures for the average group than the heavy group (t = -3.81; p = 0.0281). Power analysis of the effect and sample size showed that at the present sample size of 13 participants in the heavy BMI group and 27 participants in the average BMI group, a power of 0.90 and 0.99 respectively was present to detect a 0.50 effect size.

A 2-way ANOVA (BMI by cushion) was performed to examine whether there were comfort differences among the cushions. While the interaction term and the BMI main effect were not significant, the cushion main effect was significant (F = 8.68; p < 0.0001), indicating that there were significant differences in comfort among the cushions regardless of BMI. A Tukey-Kramer post hoc analysis revealed that both ROHO High and ROHO Low cushions had significantly greater comfort scores than all the other cushions tested (see Figure 3). To test whether pressure was the main predictor of comfort, an ANCOVA was performed in which pressure was adjusted. The overall ANCOVA was significant (F = 10.21, p = 0.0017) and a Tukey-Kramer post hoc analysis revealed that regardless of pressure, the ROHO High and ROHO Low cushions were perceived as being significantly more comfortable than all other cushions.
Discussion

The results of the present study showed significant differences in cushion performance in terms of pressure reduction. In general, the ROHO High and ROHO Low cushions exhibited consistently lower sensor means, and thus better pressure-relieving abilities (lower pressures), than most other cushions. On the other hand, the sling seat, Jay 2, and Flexseat cushions showed consistently higher sensor means than most other cushions. It is interesting to note that Figures 1 and 2 indicate more differences between cushions than are demonstrated by our statistical analysis. The figures may seem misleading at first glance since the ANCOVA adjusted for the BMI covariate and these graphic illustrations do not represent the adjustment. The results of the present study are in agreement with other studies (Fisher & Patterson, 1983; Garber, 1985b) that showed ROHO cushions provided lower mean pressures when compared to other cushions (most of which are no longer manufactured).

The value of the patient-surface interface pressure that best represents the threshold for tissue viability has long been debated in the literature. Ideally, pressures at the patient-seating surface should be as close to arteriole pressure as possible, that is, 32 mm Hg (Landis, 1930). However, alt but one (Rosenthal et al., 1996) study on wheelchair cushions conducted to date found that achieving such low pressures is impossible. Various studies considered 60 mm Hg to be an acceptable limit for patients who can self-relieve pressure (Rothery, 1989; Ferguson-Pell, 1991; Bar, 1991; Tali, Hershler, Daechese, Peel, & Pearson, 1994). In the present study, however, the pressures at the patient-seating surface were more than 60 mm Hg for all but one participant. The controversy in the literature concerning which cushion is the most effective in relieving pressure may stem from a lack of uniformity in methods. Different pressure-measurement devices and different cushions were used in the various studies, making conclusive comparisons difficult. In general, cushions that were evaluated in older studies are no longer being manufactured (Garber & Dyerly, 1991). Also, many of the studies had inadequate sample size and failed to control the many potential intervening variables (Crenshaw & Vistnes, 1989).

While a study using one pressure-measuring system (an Entran transducer) found average pressures
to be significantly lower with the ROHO cushion than with a foam cushion (Fisher & Patterson, 1983), another study (Rosenthal et al., 1996) that used an air pressure pad and a contact circuit to evaluate four cushions (including Jay and ROHO) found the ROHO cushion to produce significantly higher pressures than the Jay. Even studies using the same pressure system (the Pressure Evaluation Pad) to compare pressure-relieving capabilities of wheelchair cushions showed wide variations in the performance of the tested cushions (Garber, 1985b; Garber et al., 1978). While one study found that the ROHO cushion exhibited substantially higher pressures under bony areas than four other cushions tested (Garber et al., 1978), a follow-up study by the same author found the ROHO cushion to provide the greatest pressure reduction when compared to six other tested cushions (Garber, 1985b). These variations prompted researchers to conclude that despite the clinical similarity of the patients tested, a universally effective pressure relieving cushion could not be clearly identified (Garber, 1985b; Garber et al., 1978).

The results of the present study, however, contradict those of a study comparing four cushions that found a Jay cushion had significantly lower ischial pressures than the ROHO High cushion, but slightly higher thigh pressures (Rosenthal et al., 1996). Methodological differences may explain these contradicting results: the present study examined overall pressure and did not analyze pressure by body part. A different pressure-measuring device was used in the two studies and the model of the Jay cushion tested was not specified by Rosenthal et al. (1996).

It is evident from the present and other studies that cushion performance varies widely from person to person and there is no one universal cushion that can reduce pressure equally for all participants. The results of the present study show that the ROHO cushions consistently exhibited lower pressures than other cushions for both average and heavy groups. Thus, indicating that the ROHO cushion design and material (interconnected air cells) may be superior to other cushion designs and materials (contoured foam, gel, and plastic) for minimizing pressure at the patient-seating surface and providing pressure relief for the majority of wheelchair users. This may be because the unique ability of air to provide an individualized custom fit that is not shape or weight sensitive, nor dependent on body mass, to be effective in distributing and reducing focal pressures. Since no significant pressure differences were found to exist between the ROHO High and ROHO Low cushions, it appears that air cell height or cushion thickness does not influence the pressure-relieving abilities of this type of cushion.

The present study found that the pressure-relieving capabilities of the cushions were related to the participant's body mass. Overall, higher BMI was shown to produce significantly higher cushion pressures. This was expected since pressure is a function of force per unit area. The significant interaction (cushion x BMI) term, however, suggested that a cushion's pressure reduction ability is different for average and heavy participants. Indeed, significant differences were found to exist in the pressure-relieving abilities of the cushions in relation to BMI, which indicated that cushion effectiveness in relieving pressure depends on the participant's body mass category. While both ROHO cushions showed the lowest pressures in both average and heavy participants, the Pindot cushion and sling seat had the highest pressure in the average participants and the Jay 2 and the Flexseat had the highest pressures in the heavy participants.

The results of the present study also indicated that different cushions may be better suited for different body mass categories, which is demonstrated by the performance of the Pindot cushion. In the average BMI group, the Pindot cushion and sling seat were the worst performers; in the heavy group, however, the Pindot cushion had significantly lower pressures (i.e., better pressure relieving performance) than both the Jay 2 and the Flexseat cushions. Also, all cushions had lower pressures in the average than in the heavy group at the highest pressure range, while only the Flexseat relieved pressure better in the average than the heavy group at the high pressure range.

There is disagreement in the literature concerning the effect of body mass on the pressure relieving
ability of wheelchair cushions. Krouskop, Williams, Eng, Noble, and Brown (1986) found seating pressures to be the lowest for thin individuals, followed by average then heavy participants. The trend, however, was not statistically significant, which was attributed to other variables that may influence seating pressure, such as height, sitting posture, the weight and length of the lower extremities, and the prominence of the ischium. On the other hand, Garber and Krouskop (1982) demonstrated a significant relationship between pressure and body mass. Dividing their participants into three groups (light, average, and heavy BMI), they found that light participants had slightly higher overall pressures than heavy participants but that average weight participants had equal pressures to those of heavy participants. Since they used a pressure-measuring system that was able to distinguish between bony prominence and soft tissue, they were able to conclude that light participants showed a greater tendency for higher pressures under bony areas than did average weight or heavy participants. This suggested that the pressure relief needs of thin patients may differ from those of heavier patients. This contradicts the findings of the present study, that there are differences in pressure-relieving abilities of wheelchair cushions between average and heavy patients. The disagreement between the studies may be attributed to different factors such as testing different pressure relieving cushions, using different pressure measuring devices, and the merging of light and average BMI participants into one group as in the present study.

Comfort is defined as "an abstract, multidimensional concept that is difficult to define and measure" (Redfern, 1976). Perception of comfort plays a crucial role in the acceptance and continued use of a cushion because no matter how efficient a cushion is in relieving pressure, patient compliance will be low if the cushion is perceived as uncomfortable. In addition to objective information (e.g., pressure), the participative information (e.g., the comfort rating by the cushion user) is informative and can provide much insight into the usability of the product (Springle et al., 1990). The present study, therefore, examined whether there were differences between the various cushions in perceived comfort. The perception of comfort has not been investigated in previous studies.

Both ROHO cushions received ratings of 4 and 5 (very comfortable and extremely comfortable) 68% of the time, in contrast to 28% of the time for the other cushions. In fact, ROHO High was the only cushion to never receive a pressure rating of "extremely uncomfortable." The statistical analysis showed that both ROHO cushions had significantly greater comfort scores than all the other cushions tested, regardless of pressure. These results indicated that factors other than pressure contribute to a person's perception of comfort. Such factors may include position, stability, pressure distribution, and individualized cushion fit. The results also indicated that body mass does not influence the perceived comfort of the cushions. Both groups of participants (average and heavy) perceived the ROHO cushions to be more comfortable than any other cushions tested.

Limitations

Since sample selection in the present study was not random and participants were selected from only one rehabilitation center, the generalizability of the results may be questioned. However, the mix of represented diagnoses may increase generalizability. An additional limitation is that this was a laboratory study that did not address the needs of individualized wheelchair users. In the clinic, modifications are typically made to both wheelchairs and cushions to maximize function and minimize pressure. A laboratory study, on the other hand, aims to keep conditions constant to reduce unexplained variability in data. Therefore, we placed every person in the same wheelchair at the same angles of measurement without modifying or adapting the wheelchair or cushion. As this contradicts standard clinical wheelchair and cushion evaluation, the results should be viewed with caution.

Since the Xsensor Pressure Mapping System had been marketed for clinical use for only one year at the
time of this study, no research apart from the manufacturer's testing and field studies has been published using this tool. Another possible limitation of this study is that bias could exist since the Xsensor Pressure Mapping System was distributed by the same company (ROHO) as two of the wheelchair cushions evaluated. However, the participants were blind at all times as to which cushion was being tested, and the researchers, while not blind, had no vested interest in the performance of one cushion over another. Also, the comfort rating segment of this study was fully independent of ROHO instrumentation.

Future research should include testing of more homogenous patient groups to determine whether some cushions are better for a certain diagnosis. Also, the distribution and localization of pressure, rather than cumulative pressure should be investigated. Another interesting question is whether dynamic pressure during functional activities differs from static pressure. Investigating other factors that may potentially influence cushion pressure, such as age, gender, muscle tone, gluteal mass, weight distribution, and diagnoses is also warranted.

**Conclusions**

The present study compared the pressures occurring at the sling seat of a wheelchair and six pressure relieving wheelchair cushions for 40 wheelchair users. We also investigated the effect of body mass on the pressure-relieving abilities of these cushions. In addition, the study evaluated the relationship between the participant's perception of cushion comfort and the objective measure of pressure relief provided by the cushions.

A primary objective of occupational therapy is to maximize functional potential in persons with physical disabilities (Garber, 1985a). Oftentimes individuals who use a wheelchair secondary to injury or illness cannot expect full recovery from their disability and must remain in their wheelchair indefinitely. Pressure ulcers are a common and potentially dangerous complication for long-term wheelchair users with impaired sensation, severely decreased ability to relieve pressure by frequently repositioning their bodies, or both. Knowledge concerning the causes, prevention, and treatment of pressure ulcers is essential if occupational therapists are to be successful in their efforts to maximize functional potential in patients with residual disability. Many occupational therapists are directly involved in the prescription of wheelchair systems, which often includes the recommendation of pressure relieving wheelchair cushions for patients at risk for decubitus ulcers.

The present study demonstrated significant differences to exist between several cushioning products. Namely, ROHO High and ROHO Low cushions were found to be more frequently effective at relieving pressure than Pindot, Flexseat, and Jay 2 cushions, while the Stimulite cushion was a moderate performer. We also found that cushion pressure-relieving abilities were largely dependent on the individual's body mass. However, regardless of BMI and pressure relief, both ROHO High and Low cushions were perceived to be more comfortable than all other cushions tested. Therefore, factors other than pressure may also play a role in perceived cushion comfort.

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**References**


