Objective. Previous studies have suggested that no single wheelchair pressure-relieving cushion material was optimal for all persons with spinal cord injury (SCI). The purpose of this study was to compare the effectiveness of the short-term pressure-relieving ability of the three most commonly prescribed wheelchair cushions (Roho, Jay, Pindot) for a person with SCI.

Method. The number of pressure sensors registering at the buttock–cushion interface during wheelchair sitting was measured by the Xsensor Pressure Mapping System after 5 min of sitting. An alternating treatments research design, with an initial baseline and a final treatment phase ending with the most effective cushion for relieving pressure, was used for the clinical evaluation. Measurements were compared using visual inspection and a Wilcoxon signed ranks test.

Results. Data analyses indicated that the number of pressure sensors that registered potential harmful levels of pressure at the buttock–cushion interface for the Roho cushion was significantly less than those of the Jay and Pindot cushions.

Conclusion. The Roho cushion was more effective in relieving pressure at the seating surface than the Jay and Pindot cushions.


Based on the analysis of the National Spinal Cord Injury Statistical Center database (Richards, Go, Rutt, & Lazarus, 1995), Chen, Apple, Hudson, and Bode (1999) found that pressure ulcers developed in almost one quarter of patients during rehabilitation. About half of the pressure ulcers were located in the buttock areas (i.e., sacrum, ischium). Using the same database, McKinley, Jackson, Cardenas, and DeVivo (1999) discovered that pressure ulcers were the most common long-term secondary medical complications in persons with spinal cord injury (SCI). Pressure ulcers were more common in persons with complete lesions than in those with incomplete lesions, regardless of the levels of injury. The incidence of pressure ulcers increased steadily as the years postinjury increased (McKinley et al., 1999).

Research on the relationship between the presence of pressure ulcers and the peak pressure beneath the ischial tuberosities during sitting revealed that the two were highly correlated (r = .95; Ferguson-Pell, Wilkie, Reswick, & Barbenel, 1980). One prevention strategy to reduce the risk of pressure ulcers in persons with SCI is to provide a pressure-relieving wheelchair cushion. Designs of the pressure-relieving cushions are based on the premise that sitting...
interface pressure should be distributed evenly over the whole contact area to reduce high focal pressure underneath bony prominences.

Occupational therapists often are directly involved in the prescription of wheelchair systems, including pressure-relieving cushions for persons with SCI. Because a wide assortment of pressure-relieving cushions are available on the market and all are promoted as being the best for the reduction of peak pressure at the buttock–cushion interface, selection of the most effective cushion for a particular patient often is a difficult decision. Objective information about the pressure-relieving capability of the cushions assists the therapist in making this important clinical decision. Several controlled clinical trials have been conducted in the past 25 years to compare the relative effectiveness of a variety of pressure-relieving wheelchair cushions for persons with SCI. The results of these studies varied greatly.

Some studies (Burns & Betz, 1999; Koo, Mak, & Lee, 1996; Pellow, 1999; Takechi & Tokuhiro, 1998) indicated that Roho cushions were superior to Jay or gel cushions, and Jay or gel cushions, in turn, were superior to polyurethane foam cushions in relieving pressure. Alternatively, Garber, Krouskop, and Carter (1978) demonstrated that polyurethane foam cushions were 30% better than the Roho cushions in this aspect. Differences in devices used to measure interface pressure, the focus of measurement (overall buttock pressure distribution vs. single-point pressure at the ischial tuberosity), and cushion models being evaluated may explain these inconsistencies in results. Ferguson-Pell and Cardi (1993) compared several different pressure-measuring devices and found wide variations in interface pressure registered for each participant on a given cushion. Even cushions made of the same type of material but with different brand names, models, or designs have shown differences in pressure-relieving capability (Ferguson-Pell & Cardi, 1993; Garber et al., 1978; Takechi & Tokuhiro, 1998). Findings from other studies (Bar, 1991; Takechi & Tokuhiro, 1998) have indicated that cushion performance varies widely from person to person and that intersubject variation may affect the validity of the results. The literature repeatedly suggests that no single wheelchair pressure-relieving cushion material was optimal for all persons with SCI (Bar, 1991; Garber & Dyerly, 1991).

Future researchers must develop alternative, clinically practical methods to evaluate pressure-relieving cushions for individual patients. The single-subject research design is one scientific method used to evaluate wheelchair cushions objectively for a particular patient. This method provides a valid and scientific clinical evaluation through strict control of the majority of threats to internal validity, which is imperative for clinical research (Ottenbacher, 1986). The purpose of the present study was to use an alternating treatments design, with an initial baseline and a final treatment phase ending with the most effective wheelchair cushion, to compare the pressure-relieving capabilities of the three most commonly prescribed cushions for a person with SCI.

The independent variable was the three pressure-relieving wheelchair cushions: (a) the Enhancer by Roho Cushion Corporation1, (b) the Extreme by Jay Medical Company2, and (c) the Ulti-Mate by Pindot3. These cushions were selected because they were the ones most frequently prescribed to persons with SCI for reducing the risk of pressure ulcer development during rehabilitation (Garber & Dyerly, 1991). They also represented the three major categories of cushion construction materials: air (Roho), gel (Jay), and polyurethane foam (Pindot). The cushions were currently in stock in the wheelchair clinic at the rehabilitation hospital, were approximately the same age (2–6 months), and had approximately the same degree of wear. They were removed from general use during the study period. At the time of this study, the retail prices in U.S. currency were $419 for the Roho, $287 for the Jay, and $385 for the Pindot.

The dependent variable was the number of pressure sensors registering (a) between 66 mmHg and 99 mmHg of pressure and (b) ≥ 100 mmHg of pressure at the buttock–cushion interface as measured by the Xsensor Pressure Mapping System4. The 66 mmHg to 99 mmHg range was chosen because Henderson, Price, Brandstater, and Mandac (1994) found that pressures greater than 60 mmHg are potentially dangerous to tissue health in persons with SCI.

Xsensor is a computerized pressure-mapping pad used to measure the magnitude of pressure and to map the overall pressures occurring at the buttock–cushion interface. The pad is constructed of flexible plastic, measures 46 cm x 46 cm (18 in. x 18 in.), and is composed of 1,296 individual capacitive sensors. The pad is .64 mm (.025 in.) thick when compressed and is durable, pliable, and detachable from the electronics. It is capable of a sampling rate up to 2,000 sensors per second, and the data generated are accurate to 10%, or 10 mmHg, as stated by the manufacturer (www.crownthera.com/pressuremeasurement.html). The system was newly purchased and precalibrated at the factory at the onset of this study. The Xsensor system displays pressure ranges spanning from 0 mmHg to 100 mmHg and above in 10 mmHg increments. Each increment of 10 mmHg is color-coded for mapping. Pressure images are displayed in real time, with options to save a static “snapshot” measurement or to record a “movie.” This study used a snapshot measurement taken after 5 min of sitting. Images for buttock–cushion interface are displayed

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1Crown Therapeutics, 100 North Florida Avenue, Belleville, Illinois 62221.
2Sunrise Medical, 7477 East Dry Creek Parkway, Longmont, Colorado 80503.
3Invacare Corporation, One Invacare Way, PO Box 4028, Elyria, Ohio 44035-2125.
4Crown Therapeutics, 100 North Florida Avenue, Belleville, Illinois 62221.
in color-coded two dimensional pressure maps. The pressure map indicates the total contact area and the number and distribution of the pressure sensors activated.

Based on the latest literature on cushion evaluation (Burns & Betz, 1999; Koo et al., 1996; Pellow, 1999; Takechi & Tokuhiro, 1998), the present study’s hypothesis was that the Roho cushion would provide the most pressure relief as indicated by the least number of pressure sensors registering > 60 mmHg at the buttock–cushion interface.

Method

Participant

P. J. was a 19-year-old man with a 1-month history of paraplegia after a motor vehicle accident that resulted in a complete spinal cord lesion at the T8 level. He was admitted as an inpatient to a rehabilitation hospital where he received training in transfers and activities of daily living. P. J. retained no voluntary movement below the waist and exhibited total paralysis with complete loss of sensation in his lower extremities. He had fair to good trunk stability and endurance, and normal function of his upper extremities. P. J. was totally wheelchair dependent for ambulation and required a chest strap for safety. He accomplished bed-to-chair transfers with minimal to moderate physical assistance using a transfer sliding board. P. J. was 6 ft 1 in. (1.85 m) tall and weighed 220 lb (99.8 kg) at the time of the study.

Procedure

Before beginning the study, a trial was conducted on the three cushions to determine the length of time required to allow the cushions to acclimate to the topography of P. J.’s body. To accomplish this trial, pressure readings were taken at the buttock–cushion interface of the three cushions (i.e., Roho, Jay, Pindot) at 2-, 5-, 10-, and 15-min intervals and noted at what time interval the pressure readings stabilized for all cushions. It was found that a 5-min sitting period was sufficient to obtain stable, reproducible pressure results.

This 5-min acclimation period was used for each cushion throughout the study. During the acclimation period for each cushion, P. J. was positioned in a fully upright sitting posture with his feet supported by a footrest and his hips at 90°. His thighs were horizontal to the floor, and his arms were positioned comfortably on the armrests at approximately a 90° angle of elbow flexion. This standard testing position has been used widely in the evaluation of wheelchair cushions (e.g., Cochran & Palmieri, 1980). P. J. was asked to maintain this sitting posture for 5 min, which was timed with a stopwatch for accuracy, beginning when P. J. initially positioned on a cushion to ensure consistency across all three cushions.

All data were collected in a testing room at a rehabilitation hospital over approximately a 3-week period by the second author and a staff occupational therapist. The occupational therapist had 6 years of experience in seating, positioning, and wheelchair prescription. P. J. participated in this research study for 13 days, Mondays through Fridays, three times per day for a total of 39 separate testing sessions. The three daily sessions were scheduled at fixed time intervals at least 2.5 hours apart throughout the study. Before beginning data collection, P. J. was asked to inspect his skin for signs of redness or irritation after each day of testing and to report any problems to the second author or the staff occupational therapist.

During the baseline phase of the study, P. J. came to the testing room three times per day for 3 consecutive days (i.e., nine sessions). For each session, he was assisted to transfer from his wheelchair into a testing wheelchair manufactured by Action5 in which a Jay Extreme cushion of the same dimensions as the one he was currently using was placed. On top of this cushion was the Xsensor pressure-mapping pad. After the 5-min acclimation period, the pressure distribution present at the buttock–cushion interface was recorded. P. J. was then assisted to transfer back to his regular wheelchair and resumed his normal activities at the facility until the next session. The baseline performance of the Jay cushion was used for later comparison with the performance of the other two cushions.

The alternating treatments phase of the study began on the 4th testing day when the two additional pressure-relieving cushions, the Roho Enhancer and the Pindot Ulti-Mate, were introduced. Each cushion was evaluated once per day for the next 7 testing days. To control for the order effect of the sequence of evaluation in this phase, each of the three cushions was presented in a counterbalanced, random fashion. P. J. was unaware of which cushion was being tested because each trial cushion was covered by the Xsensor pressure-mapping pad. During the alternating treatments phase, P. J. was positioned in the wheelchair as during the baseline phase. After the 5-min acclimation period, the pressure distribution occurring at the buttock–cushion interface was measured.

During days 11 through 13, the final treatment phase of the study was conducted. The cushion that had performed the best during the alternating treatments phase (i.e., the Roho Enhancer) was reevaluated three times per day for 3 consecutive days. The purpose of this final phase was to eliminate potential interference of the multiple-treatment effect of the other two cushions (Neuman, 1995). P. J. again came to the testing room each day at the three scheduled times (i.e., nine sessions) and repeated the evaluation procedure exactly the same as in the previous phases.

Data Analysis

The results were analyzed by visual inspection of the graphic presentation of the data. To assist visual analysis, mean and distribution of the pressure sensors activated.
lines were added to the graphs. Statistical analysis supplementing the visual analysis was used to detect subtle differences. Edgerton (1982) recommended using nonparametric statistics for analyzing data in studies using alternating treatments design, especially when the number of treatment sessions is relatively small. A Wilcoxon signed ranks test was used to assess whether the median number of pressure sensors registering for the Roho cushion was lower than that of the other two cushions. To accommodate increased Type I error for multiple testings, the critical alpha value was adjusted to .025, one-tailed. Before using the Wilcoxon signed ranks test, the data were evaluated to check for autocorrelation, which is the correlation of two different scores of the same variable at different points in a series (Ottenbacher, 1986). Data exhibiting autocorrelation lead to inflated Type I error rates when using a statistical analysis (Ottenbacher, 1986).

Results

A lag-1 autocorrelation performed on the data for each cushion in the alternative treatments phase revealed no significant autocorrelation (i.e., not sequentially correlated). The mean number of pressure sensors registering between 60 mmHg to 99 mmHg for the Jay cushion during the baseline was 314.78. In the alternating treatments phase, the mean number of pressure sensors registering was 319.00 for the Jay cushion, 316.86 for the Pindot cushion, and 204.14 for the Roho cushion. In the final phase, 241.33 pressure sensors registered for the Roho cushion (see Figure 1). The results of the Wilcoxon signed ranks test indicated that the median number of pressure sensors registering for the Roho (median = 197) cushion during the alternating treatments phase was significantly lower than that of the Jay (median = 320) and Pindot (median = 290), $z = -2.366$, $p = .009$, one-tailed.

The mean number of pressure sensors registering $\geq 100$ mmHg for the Jay cushion during the baseline was 78.44. In the alternating treatments phase, the mean number of pressure sensors registering was 101.14 for the Jay cushion, 61.43 for the Pindot cushion, and 42.71 for the Roho cushion. In the final phase, 45.00 pressure sensors registered for the Roho cushion (see Figure 2). The results of the Wilcoxon signed ranks test indicated that the median number of pressure sensors registering for the Roho cushion (median = 39) during the alternating treatments phase was significantly lower than that of the Jay cushion only (median = 102), $z = -2.366$, $p = .009$, one-tailed.

During the 13-day study period, P. J. never experienced redness or irritation of the skin at the sitting surface. On the basis of the results of this clinical evaluation and P. J.’s motoric assessments, P. J. was prescribed a Roho cushion. At 6 months follow-up, P. J. continued to use the Roho cushion and expressed no dissatisfaction about it.

Discussion

The results indicate that the Roho cushion was more effective in relieving pressure on the seating surface for P. J. than the Jay and Pindot cushions. Results of the present study
agree with the findings of previous studies (Burns & Betz, 1999; Takechi & Tokuhiro, 1998) that used a similar pressure-measuring device (Tekscan® system) to evaluate a Roho cushion, a Jay or gel cushion, and a foam cushion. The design and results of the present study give therapists a prototype using a sound scientific research method for selecting an appropriate wheelchair cushion for their patients.

In addition to the objective pressure assessment between P. J.’s buttocks and the seating surface, other factors regarding wheelchair cushion selection should be examined before making a final prescription, such as skin temperature and relative humidity at the buttock–cushion interface, cost, ease of transfer, the patient’s perception of the comfort, and the patient’s ability to care for the cushion. Because no commercial cushion has ever been proved to reduce sitting pressures below 32 mmHg, which is the level of arteriole pressure, a comprehensive program of regular pressure-relief activities, such as push-ups, and daily skin hygiene and inspection should be performed as part of the complete prevention picture.

Two limitations were noted in this study. One was the fact that the cushions used in the study were not brand new. This factor may affect the validity of the study because the extent of previous wear was not standardized. However, the aim of the study was to illustrate the use of a single-subject, alternative treatments design to evaluate the performance of pressure-relieving cushions. In the clinic, it would not be feasible to test patients with brand new cushions each time an evaluation was needed. Additionally, the performance of the cushions is not likely affected substantially by less than 6 months of intermittent use. The second limitation was related to the reliability of the pressure-recording procedure, which could be improved by taking the mean of several pressure readings, such as averaging the six pressure readings taken in every 10-sec period from the 5th min to the 6th min of sitting duration.

**Conclusion**

This single-subject study illustrates a research design used for the comparison of the short-term pressure-relieving performance of three different wheelchair cushions. A more ecologically valid study would be designed to investigate the long-term performance of each cushion for at least 3 hr to 4 hr (with 5 sec of push-ups for every 15 min of sitting) in a controlled clinical situation. Long-term performance of the cushions may differ from the short-term performance, as cushion performance may be compounded by the physical property of the cushion material, which can affect the buttock–cushion interface pressure.

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**References**


