Australian Occupational Therapy Journal

Australian Occupational Therapy Journal (2011) **58**, 287–292 doi: 10.1111/j.1440-1630.2011.00932.x

Research Article

Comparison of the pressure redistribution qualities of two air-filled wheelchair cushions for people with spinal cord injuries

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***Background/aim*:** *People with spinal cord injuries are at high risk of developing pressure ulcers. Wheelchair cushions that redistribute pressure are one prevention strategy to reduce the risk of pressure ulcers in this population. Currently, therapists have only limited evidence concerning the pressure redistribution qualities of wheelchair cushions to guide their cushion selection in clinical practice. The aim of this study was to compare the pressure redistribution qualities of two air-filled cushions currently recommended for people with spinal cord injuries.*

***Methods*:** *A series of single case studies, based on the methodology used in a previous study, was undertaken on three inpatients with complete spinal cord injury. Interface pressure readings were compared between a Roho® and Vicair® cushion using the Xsensor® Pressure Mapping System. The Roho® cushion is comprised of a series of soft, flexible, inter-connected air cells, and the Vicair® cushion contains separate, sealed cells of air.*

***Results*:** *The Roho® cushion recorded significantly fewer cells with pressures ≥100 mmHg than the Vicair® cushion for the three participants.*

***Conclusion*:** *This study has provided evidence that the Roho® cushion has superior pressure redistribution qualities than the Vicair® cushion for a small sample of patients with complete spinal cord injury.*

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Accepted for publication 19 December 2010.

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KEY WORDS *evidence based practice, seating, spinal cord injuries, wheelchairs.*

Introduction

In Australia, 300–400 new cases of spinal cord injury (SCI) occur every year, adding to an estimated SCI population of approximately 9000 (Cripps, 2008). Pressure ulcers are one of the most common medical complications experienced by people with an SCI, and critical factors contributing to their development include pressure, shearing forces, friction and moisture (Edlich *et al*., 2004; Regan *et al*., 2009). Important risk factors for the development of pressure ulcers include prolonged immobilisation, poor skin hygiene, vascular compromise, sensory impairment, incontinence and poor nutritional status (Edlich *et al*., 2004; Garber & Rintala, 2003; Gelis *et al*., 2009; McKinley, Jackson, Cardenas & DeVivo, 1999; New, Rawiki & Bailey, 2004; Regan *et al*., 2009). Risk management strategies include daily skin examination to enable early detection of problems, good skin hygiene, frequent postural changes/repositioning to redistribute pressure, adequate nutrition, incontinence management, avoidance of shearing or frictional forces on the skin, preventing moisture accumulation and temperature elevation at the support surface-skin interface and wheelchair cushions to redistribute pressure (Consortium for Spinal Cord Medicine Clinical Practice Guidelines, 2001; Regan *et al*., 2009).

To prevent and reduce the incidence of pressure ulcers, wheelchair cushion technology has become a primary focus for allied health clinicians. There are many wheelchair cushions available for use with the SCI population and these can be categorised as being air-filled, gel/fluid or foam. Factors that need to be taken into consideration when comparing wheelchair cushions include the degree of immersion and envelopment they provide to assist with pressure redistribution, especially over bony prominences. Due to a lack of high-level evidence regarding the pressure redistribution properties of wheelchair cushions for patients with SCI, clinicians often rely on expert

opinion and their own experience to guide their clinical practice. Yuen and Garrett (2001), using a single case study design involving a 19-year old male patient with T8 paraplegia, found that the Roho® (air) cushion registered significantly lower harmful levels of pressure at the buttock-cushion interface than the Jay® (fluid) and PinDot (foam) cushions, measured using the Xsensor® Pressure Mapping System (XSENSOR Technology Corporation, Calgary, Alberta, Canada). A number of other studies have also found that Roho® cushions resulted in the lowest interface pressures for patients with SCI (Gil-Agudo *et al*., 2009; Koo, Mak & Lee, 1996). However, McInnes, Cullum, Bell-Syer and Dumville (2008), in a Cochrane Library review, concluded that there was insufficient evidence to draw conclusions on the value of seat cushions in general.

Standard clinical practice in our rehabilitation unit is that Roho® Quadtro Select HP™ (air) cushions are provided for patients with SCI who are at the greatest risk of pressure ulcers. This cushion is comprised of a series of soft, flexible, inter-connected air cells, divided into four quadrants. This practice is based on clinical experience and the limited evidence cited above that air-filled cushions are superior to gel/fluid or foam cushions. However, there are some practical limitations associated with the use of Roho® cushions, including the fact that the nature of its air-flow system reduces postural stability, which can be a problem for a person with SCI. In addition, Roho® cushions have a valve system, which can be damaged through manual handling and may necessitate costly cushion repair or replacement. Roho® cushions also require precise clinical assessment to measure the level of inflation to provide optimal pressure redistribution, with a small margin for error. Although this assessment can be easily performed in the setting of a rehabilitation centre, once the person returns to the community or a residential facility, maintenance can become problematic.

The Vicair® Academy Adjuster™ cushion is an alternative air-filled cushion that contains sealed pyramid-shaped cells of air within five compartments. The number of air cells can be increased or decreased from the segmented cushion to provide pressure redistribution and postural support as indicated for each individual. Vicair® cushions have certain features that overcome some of the practical disadvantages associated with the Roho® cushions, including greater postural stability, durability and no need for further adjustment or maintenance after the initial set-up. However, although there are manufacturer's guidelines regarding the usage of the Vicair® cushion, no published studies were found that have investigated the pressure redistribution properties of the Vicair® cushion compared with the Roho® cushion or indeed to any other air-filled cushion.

The aim of this study was to prospectively compare the pressure redistribution qualities of the Roho® and Vicair® cushions for patients with SCI at risk of pressure ulceration. It was hoped that this study would provide evidence to guide clinical practice regarding wheelchair cushion selection for patients with SCI.

Methods

Study design

A series of single case studies were conducted, incorporating an alternating treatment phase, based on the methodology used by Yuen and Garrett (2001) and following the key recommendations of Tate *et al*. (2008). Approval was obtained from the Royal Adelaide Hospital Research Ethics Committee. Funding was provided through a Royal Adelaide Hospital Allied Health Research Grant. The authors declare no conflict of interest.

Setting and timelines

The study was undertaken at the Hampstead Rehabilitation Centre (HRC). HRC is a 150-bed campus of the Royal Adelaide Hospital providing rehabilitation for patients following SCI, orthopaedic conditions or amputations, stroke, brain injury, burn injury and other neurological or medical disorders. Patients were sequentially recruited into the study over a 6-month period, with recruitment times dependent on staff being available to cover the principal investigator's (MT) clinical workload.

Participants

Patients were eligible for participation if they were inpatients, over 18 years of age, with a complete SCI, at high risk of pressure ulceration as measured by a score of 16 or less on the Braden Risk Assessment Scale (Bergstrom, Braden, Laguzza & Holman, 1987) and no current pressure ulceration on their buttocks or thighs. Patients were excluded if they were unwilling to participate, unable to understand English or had a cognitive problem, which interfered with their ability to provide consent. Informed, written consent was obtained. Basic demographic information was recorded for each participant. No identifying personal information was recorded, and hence anonymity of participants was preserved.

Intervention

The study design, based on that of Yuen and Garrett (2001), consisted of two phases that were conducted over a 2–3-week period.

Phase 1 involved an alternating treatment design, where the two nominated cushions, namely the Roho® Quadtro Select HP™ and Vicair® Academy Adjuster™ cushions, were tested over seven consecutive working days. On each day, both cushions were mapped on a single occasion, with the cushion order randomised day-to-day. The purpose of Phase 1 was to compare the pressure redistribution qualities of the two cushions.

Phase 2 involved three further days of pressure measurement using the cushion that had demonstrated

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the lower pressures during Phase 1. In this second phase, pressure measurements were taken three times a day, with each testing time being a minimum of two hours apart, thus generating nine measurements. The purpose of Phase 2 was to check for consistency of response over time.

The cushions were set up for each participant in accordance with the manufacturers' guidelines at the commencement of their data collection period. At every testing occasion, participants were transferred via lifter to be seated in their own fitted wheelchair, with footplates supporting their feet and their arms either resting on the wheelchair armrests (if fitted) or on their lap, as per the testing position described by Cochran and Palmieri (1980). The wheelchair set-up was individualised for each participant, with factors such as the back rest angle and seat size kept constant for each participant across the study period. After participants were seated in their chair with the cushion and pressure map in situ, they were instructed not to re-adjust their posture for the duration of the measurement procedure. The rehabilitation provided to participants did not change from that provided routinely.

Measurements

The primary measurement tool for this study was the Xsensor® Pressure Mapping System, which was applied as per the manufacturer's guidelines. This is comprised of a thin flexible pad, containing a grid of pressure sensors, which is placed between the cushion and the body (see Fig. 1). This pad is interfaced with a computer, which enables snapshot measurements of pressure (mmHg) in the pressure cells across the pad. For the purposes of this study, data obtained from the Xsensor® Pressure Mapping System for each pressure cell were categorised as being between 60 and 99 mmHg or 100 mmHg or greater. These two categories were used based on the methodology of Yuen and Garrett (2001), because it has been shown that seating pressures between 60 and 99 mmHg have the potential to compromise tissue health for people with SCI, with pressures ≥100 mmHg greatly increasing the risk of compromised tissue health. Data from pressure cells that recorded pressures of less than 60 mmHg were discarded, as these represent areas of the cushion with no weight bearing or limited weight bearing (at a level that is unlikely to compromise tissue health).

FIGURE 1: *Xsensor® Pressure Mapping System pad.*

Each participant had interface pressure readings taken after sitting on the test cushion for eight minutes during each testing occasion. A preliminary investigation undertaken revealed that pressure readings using the Xsensor® Pressure Mapping System took some time to stabilise and that stable pressure readings had occurred by eight minutes.

Data analysis

The number of pressure cells measuring between 60 and 99 mmHg and ≥100 mmHg were calculated from the raw data obtained from the Xsensor® Pressure Mapping System. The results for each participant were analysed by visual inspection of the graphic presentation of each participant's data. For Phase 1, the number of cells in the 60–99 mmHg and ≥100 mmHg categories were compared between the two cushions, with more cells in the ≥100 mmHg category indicating a greater risk of compromised tissue health. For Phase 2, the number of cells in the 60–99 mmHg and ≥100 mmHg categories were compared with the data recorded in Phase 1 using the same cushion. In addition, Phase 1 data from all three participants were combined, and negative binomial GEE regression models were fitted to test for a difference between the two cushions in the number of cells in the 60–99 mmHg and ≥100 mmHg categories. These analyses were undertaken using SAS Version 9.2 (SAS Institute Inc., Cary, NC, USA).

Results

One patient who was invited to participate in the study refused consent. Descriptive data for the three participants is shown in Table 1.

Figures 2–4 illustrate the number of pressure cells recorded using the two cushions in Phase 1 and with the single cushion in Phase 2 of the study for each of the three participants. Figure 5 presents summary data for each of the three participants during Phase 1.

During Phase 1, the Roho® cushion consistently recorded fewer cells with pressures ≥100 mmHg than the Vicair® for all three participants (see Figs 2–4). The differences between the two cushions were less evident for the number of cells recording pressures between 60 and 99 mmHg. For Participant 1, the number of cells between 60 and 99 mmHg was lower for the Roho® than the Vicair® cushion on all measurement occasions (Fig. 2), whereas the results were more variable for Participants 2 and 3 (Figs 3,4).

A negative binomial GEE regression model revealed that there was no significant difference between the two

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TABLE 1: *Descriptive data for the three participants*

	Participant 1	Participant 2	Participant 3
Gender	Male	Male	Male
Age (years)	39	48	27
Level of SCI	C7, ASIA A	T5, ASIA A	C4, ASIA A
Cause of SCI	Trauma	Aortic dissection	Trauma
Duration of SCI (months)	8.5	6.0	6.8
BMI (kg/m^2)	25	29	21
Braden Risk Assessment Scale score	11	15	13
Type of wheelchair	Manual	Manual	Powered

SCI, spinal cord injury; BMI, body mass index; kg, kilograms; m, metres; ASIA, American Spinal Injury Association.

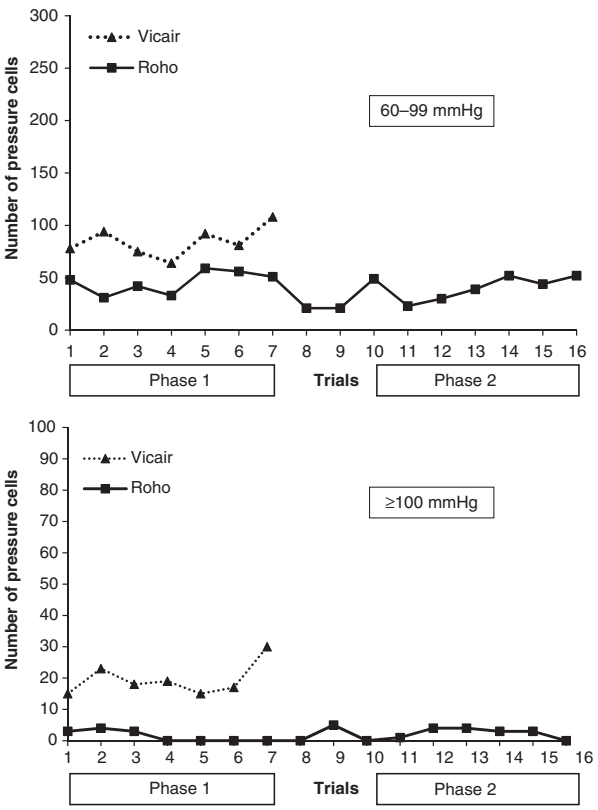

FIGURE 2: *Number of pressure cells for each cushion for Participant 1 during Phase 1 and 2.*

cushions in the number of cells recorded in the 60–99 mmHg range ($P = 0.32$). However, a significant difference was found between the two cushions for cells

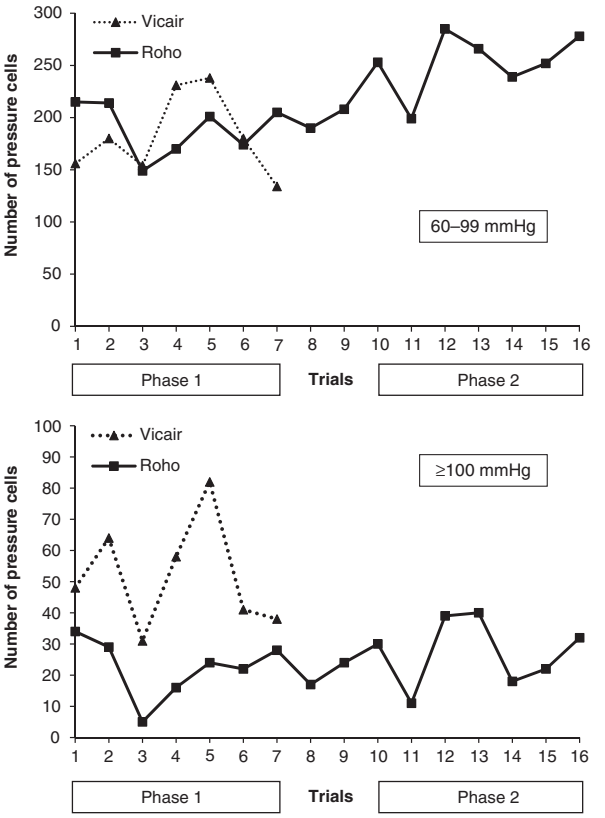

FIGURE 3: *Number of pressure cells for each cushion for Participant 2 during Phase 1 and 2.*

≥100 mmHg ($P < 0.0001$), where the number of cells with pressures ≥100 mmHg was 3.22 times higher for the Vicair® cushion than the Roho® cushion (95% confidence interval 1.86, 5.58).

During Phase 2, where the cushion with the lower pressures from Phase 1 (i.e., Roho® cushion for all 3 participants) was tested over a further 3-day period, the pressure readings obtained were reasonably consistent with those seen during Phase 1 (Figs 2–4).

Discussion

The aim of this study was to compare the pressure redistribution qualities of two air-filled wheelchair cushions for patients with SCI. The Roho® cushion demonstrated better pressure redistribution qualities than the Vicair® cushion, in that there were significantly fewer pressure cells with high pressures (≥100 mmHg) recorded using the Roho® cushion than the Vicair® cushion for the three participants. The Roho® cushion also demonstrated fewer pressure cells with pressures of 60–99 mmHg than the Vicair® cushion for Participant 1, but not for the other two participants. Pressure readings recorded during Phase 2 with the Roho® cushion were reasonably consistent with those obtained in Phase 1. Thus, this study has provided evidence that the Roho® cushion has superior

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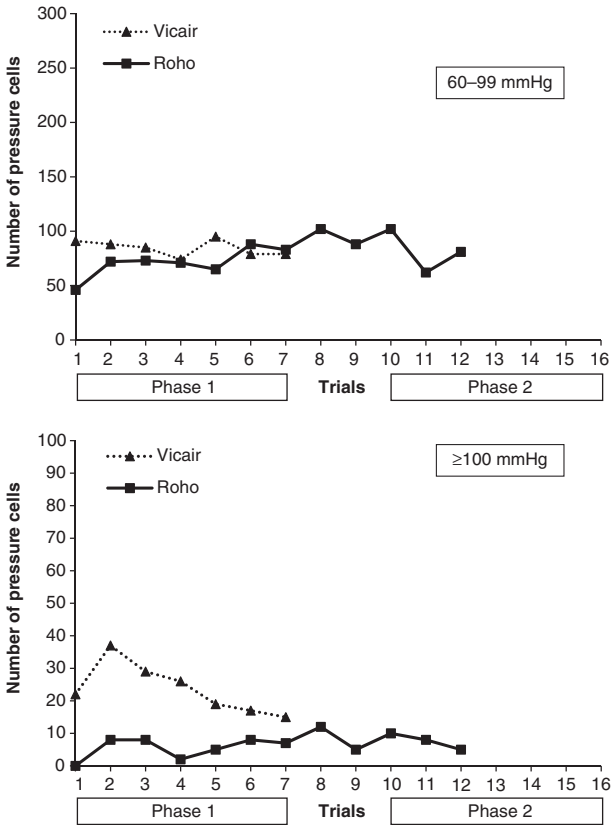

FIGURE 4: *Number of pressure cells for each cushion for Participant 3 during Phase 1 and 2.*

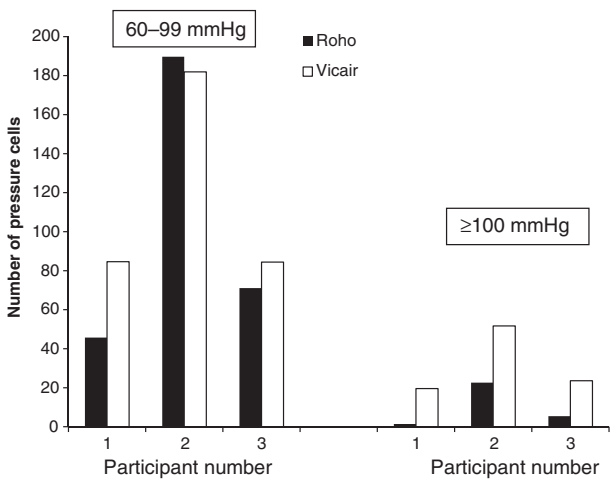

FIGURE 5: *Summary data (mean number of pressure cells) for all three participants during Phase 1.*

pressure redistribution qualities compared with the Vicair® cushion for patients with complete SCI.

In terms of the study design, a series of single case studies was undertaken, rather than a larger randomised controlled study, as this method allows each individual to act as their own control. This is particularly important in investigating patient groups like the SCI population, where individual differences can have a major influence on outcomes (Garber, 1985; Garber & Dyerly, 1991). The case study design that we used was based on the methodology of Yuen and Garrett (2001). Phase 1 allowed direct comparison of the two cushions over a number of days, and Phase 2 was undertaken to check for consistency of results for the cushion generating the lower pressures during Phase 1. Prior to commencement of the study, consideration was given to inclusion of an initial baseline phase for every participant. However, once the study was underway, we decided to eliminate this phase, as two of the three participants were using cushions other than Roho® and Vicair®, hence even if baseline stability had been established, it would not necessarily have been valid for the Roho® and Vicair® cushions. Furthermore, Phase 2 enabled us to assess for stability of response. As an outcome measure, the Xsensor® Pressure Mapping System is highly regarded for measuring interface pressures in terms of its accuracy, sensitivity, reliability and ease of use, and it was ideal for the purposes of this study (Karki & Lekkala, 2006).

Our study sample, although small, was typical of the SCI population, being relatively young and male (Cripps, 2008). There are no studies with which our results can be directly compared. However, like previous studies, we found superior pressure redistribution qualities associated with the Roho® cushion for patients with SCI (Gil-Agudo *et al*., 2009; Koo *et al*., 1996; Yuen & Garrett, 2001).

There are a number of limitations of the study that restrict the generalisability of our results, the most important being the small sample size and single case study design. In addition, we only included inpatients with relatively recent SCI for practical reasons relating to the time-intensive nature of the data collection period. Therefore, our results cannot be generalised to the community dwelling SCI population with longer-term injuries. Another limitation of the study was the relative inexperience of the principal investigator (MT) in the use of the Vicair® cushion, in contrast with her extensive experience with the Roho® cushion. In view of this inexperience, practical advice was sought about the Vicair® cushion from overseas and interstate colleagues prior to the data collection period, and it was ensured that both cushions were carefully set up for each participant in accordance with the manufacturers' guidelines. Finally, it is acknowledged that measurement of interface pressure is only one index of tissue overload, and other measures such as tissue perfusion, skin temperature and humidity are also important (Makhsous *et al*., 2007).

Clearly, further research is required on larger patient samples to support our findings, and also to elucidate whether the optimal form of cushioning varies between

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subgroups of patients (e.g. dependent on level and severity of SCI, type of wheelchair, underweight vs. overweight). In addition, the comparative effectiveness of these cushions, in terms of other outcomes, including patient-rated comfort and ease of use, needs to be evaluated.

The clinical implications of our study are that it provides evidence to guide clinicians in the choice of wheelchair cushions for patients with recent SCI. As a result of our study, our practice will be to provide Roho® cushions initially for patients with a complete SCI who are at high risk of pressure ulceration. However, given the variability between people, each person's individual circumstances and response will continue to be carefully monitored and other cushions, including the Vicair®, will be considered. In conclusion, the Roho® cushion provided pressure redistribution qualities that were superior to the Vicair® cushion for a small sample of patients with a recent complete SCI.

Acknowledgements

The authors acknowledge the three study participants; Vicki Hume, Senior Occupational Therapist, HRC; Thomas Sullivan, Statistician, University of Adelaide for statistical assistance; A1 Scooters and Wheelchairs for providing the cushions; staff of the Occupational Therapy Department, HRC; Lynne Price, Occupational Therapist, for practical advice regarding the Vicair® cushion; and the HRC Volunteers for funding Dr Kathy Stiller in her position at HRC.

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