Introduction

According to Ousey (2005) there are numerous pressure redistributing devices commercially available for wheelchair users and people with reduced mobility, in particular those who are often confined to their chairs for extended periods of time. This includes equipment such as cushions and chairs with varying properties such as gel, air pockets, memory foam, flotation type cells, or a combination (National Institute of Health Care Excellence [NICE], 2014; Stockton and Rithalia, 2008). Currently, WaterCell® technology is comparable in cost to similar devices commercially available. Despite this equipment being readily available to the healthcare professional to prescribe and the end user to utilise, NICE (2014) and Stockton and Rithalia (2008) have recognised a dearth of evidence on the efficacy of seating equipment. Not only is there a lack of evidence to support the prescription of such equipment, there is also limited evidence in regards to end user collaboration in both design and evaluation (Geyer et al. 2003; Crane and Hobson 2002). In other fields such as ergonomics, the motor industry has successfully collaborated with end users to develop effective and comfortable seating (Rutter, Becka and Jenkins 1997). Prior studies that have noted the importance of comfort/discomfort in seating (Stockton and Rithalia 2008; Crane and Hobson 2002) found that inappropriate seating can affect the ability to carry out functional activities, ultimately leading to pain, and 'equipment abandonment' (Crane and Hobson 2002, pg1). Discomfort may not always be verbalised by end users as they wish to be seen as compliant. Discomfort may then be assessed by consideration of other methods including nonverbal communication and changes in physiological observations.

Remaining seated for extended periods of time increases the risk of pressure ulcer development in particular over the gluteal region, as the soft tissue is compressed between two surfaces (Krouskop 1983; Schubert and Héraud 1994). Seminal work by Kosiak (1959) found that average interface pressures of 60 - 70 mm Hg for one to two hours may lead to the development of a pressure ulcer. This is due to when seated in a neutral sitting position weight is borne over a smaller surface area (Cook and Miller Polgar 1995), resulting in higher interface pressures in the gluteal region (Barbenel 1991; Defloor and Grypdonck 1999). In England during 2014, 27,000 people were found to have a pressure ulcer each month (NHS England 2014). These pressure ulcers impose a substantial health economic burden on the United Kingdom's (UK) National Health Service. Guest et al. (2015) found that wounds are currently costing the NHS £5 billion per year. The European Pressure Ulcer Advisory Panel [EPUAP] and National Pressure Ulcer Advisory Panel [NPUAP] and the Pan Pacific Pressure Injury Alliance [PPPIA] (2014) along with NICE (2014) have already issued guidance on the treatment and prevention of pressure ulcers. In contrast Stockton, Gebhardt, and Clark (2009) found that guidance for people whilst seated is significantly less comprehensive.

Materials and Methods

<u>Test Protocol</u>

The purpose of the project was to evaluate the impact of WaterCell® technology and the effect on pressure redistribution and self-reported comfort and discomfort scores of adults with mobility problems who remain seated for extended periods of time.

The project objectives were to establish:

1. The pressure reducing qualities of WaterCell® Technology in three CareFlex chairs: Hydortilt, Smartseat, and Smartseat Pro.
2. Whether there is a link between self-reported comfort and discomfort scores of adults and the pressure redistribution qualities of WaterCell® Technology

The evaluation studied the following variables:

Interface pressure measurements using the XSensor® pressure measurement system were taken as according Brienza et al. (2001) interface pressure mapping is now an accepted method used by researchers to evaluate pressure redistribution in seating. With Lung et al. (2014) reporting on common measurements taken such as; average pressure, peak pressure, peak pressure index, peak pressure gradient, peak pressure ratio, and dispersion index. In this study three snapshot readings were taken across the gluteal region (mmHg peak and average). Comfort and discomfort scores: comfort is a difficult concept to define (Redfern 1976) and is poorly understood and consistently under evaluated (Pearson 2009). Seminal work of Hertzberg (1958 cited in Openshaw 2011, p. 24) hypothesised that comfort and discomfort are not two different states of consciousness, but “that there is only one, discomfort, and that ‘comfort’ is only the absence of discomfort”. Zhang, Helander, and

Drury (1996) reported in their study that participants reported comfort as being associated with well-being while discomfort was associated with soreness, pain, and tiredness. In order to address this complex concept and to corroborate the objective and subjective measures with defining comfort and discomfort, this study used a validated tool (Crane and Hobson 2002) adapted by the researchers for suitability in this study. Adaptation was approved by the original author. Physiological observations were also taken, not to assess tissue tolerance, but as a nonverbal indicator of general comfort and discomfort. The rationale was based upon Crane and Hobsons (2002) work where they note that patients find it difficult to express comfort whilst seated. Whereas findings from pain studies in critical care patients note that the recording of physiological dimensions of blood pressure, pulse, respiratory rate, perspiration, aid the practitioner in the assessment of discomfort and pain (Puntillo et al. 2002). It is surmised that when one is comfortable and pain free, one's physiological observations should respond by decreasing (Williams, Lesley, Bingham and Brearly 2011). However Arbour and Gelinas (2010) suggest in their study that physiological observations are not as consistent as self-reported scores and should only be used if behavioural cues are absent. Skin inspection was recorded in order to follow best practice (NICE 2014) and to record any changes during the trial period.

Recruitment

Participants were recruited using purposive sampling and snowballing technique (Streeton, Cooke, and Campbell 2016) this included: identified participants from a previous study who agreed to be consulted regarding future studies, advertisement on social media sites, and presentations. The snowballing method is created 'from a series of referrals made within a group of people who know one another, the cyclic nature permitting loops in which a named contact from one source knows someone from an earlier wave' (Platzer and James 1997, cited in Streeton, Cooke, and Campbell 2016).

Participants

Twelve participants were recruited to the study and screened using an inclusion and exclusion criteria. The sample population from the study group were drawn from volunteers in the local community who were adults with mobility problems and who remained seated for extended periods of time.

Ethical Approval

Ethical approval to conduct the study was sought and granted by the University of Salford Ethics committee. Participants were informed that withdrawal from the study would not affect their access to healthcare services and anonymity was guaranteed. Information about study participants was kept confidentially and managed according to the requirements of the Data Protection Act (1998), The Research Governance Framework for Health & Social Care (Department of Health 2005), the University of Salford Ethics Committee and University of Salford College of Health Research Governance Procedures.

Procedure

Once the participants had been recruited to the study verbal consent was obtained and a date identified to trial the chair. The participant was then randomly allocated to one of three chairs comprising WaterCell® technology and asked to use and evaluate it for one week. Delivery and set up of the chair by the seating company was supervised by the researchers to limit external independent variables such as company influence; foot rests, arm rests, and seat depth were deployed according to the participant's anthropometric data. On day one consent forms were signed and baseline demographic information, physiological observations, skin inspection, and interface pressure measurements (IPM) were obtained in their current chair and repeated in the trial chair. IPM, physiological observations, and skin inspection were repeated at day seven in the trial chair. During the measurement of IPM both foot rests and arm rests were employed to ensure participants were seated in a neutral position. Verbal and written instructions were left with the participant.

Equipment

XSensor® PX100 (SUMED Int.) was used to collect IPM's. Trewartha and Stiller (2011) and Stinson et al. (2013) report how this system is used by healthcare practitioners to assess the pressure redistribution qualities of seating devices. The system contains a sensor mat, with grids of parallel conductive strips, one millimetre thick, with a measurement grid of 450mm x 450mm, containing 1296 sensing points. Data recorded is represented as colour coded maps of pressure distribution as well as peak and mean pressure readings at specific time stages. Three snapshot readings were taken for a full five minute period across the gluteal region (mmHg peak and average), with a settling time of eight minutes (Crawford et al. 2005). Clinical observations of respiratory rate, pulse rate, and blood pressure were collated to gauge physiological responses in relation to comfort and discomfort. A validated rating questionnaire (Crane 2004) was completed by each participant to evaluate comfort/discomfort. The participants also completed a daily skin inspection using the NHS Midlands and East and Wounds UK (2013) guide.

Data Analysis

Post data collection mean and peak pressure across the gluteal region were analysed. The mean peak pressure index was calculated over a $10cm^2$ area equating to nine sensors (3 x 3) on the pressure mat surrounding the highest recorded peak pressure value (ISO 2015). This area equates to the approximate contact area of an ischial tuberosity. SPSS v 22 with an alpha level set *(P= <0.05)* was used to:

i) summarise the mean/standard deviation for the demographic data, peak pressure index and mean pressures

ii) explore if there is a correlation between comfort and pressure redistribution.

Results

Demographics

The participants recruited ranged in gender, age, height, weight, and body mass index. Five were male, seven were female, and five of the group were wheelchair users (Table 1). The chairs were randomly allocated to the participants.

Table 1: Participant demographics

Participant Number	Gender	Age	Height m	Weight kg	Wheelchair User	BMI kg/m²
1	F	72	1.57m	88	no	35.7
2	F	46	1.56m	79	yes	24.4
3	M	27	1.80m	106	yes	32.7
4	F	73	1.52m	55	no	23.7
5	M	53	1.82m	108	yes	32.6
6	F	19	1.66m	50	yes	18.1
7	M	81	1.77m	102	no	32.5
8	M	82	1.69m	94	no	32.9
9	F	81	1.44m	101	no	48.7
10	F	81	1.57m	57	no	23.1
11	M	59	1.78m	80	yes	25.2
12	F	84	1.57m	44	no	19.5

Observations and Discomfort Intensity Ratings

Physiological observations and skin inspection were recorded at day one and day seven (Table 2). Decreases were observed in BP for 50% of the participants and respiratory rate (RR) for 33% of the participant's. Two participants reported a category one pressure ulcer, one of which resolved by the end of the trial. Discomfort intensity rating (DIR) was low for 100% of the participants and general discomfort assessment (GDA) ranged from very low to medium (Table 2)

Table 2: Observation and Discomfort Intensity rating

Participant Number	Observation BP= blood pressure RR= Respiratory rate	Baseline Chair	7 Days	Discomfort Intensity Rating	General Discomfort Assessment
1	BP	112/64	130/77	15	33
	Pulse	66	68		
	RR	12	14		
	Skin	intact	intact		
2	BP	112/78	126/81	14	36

	Pulse	71	81		
	RR	19	21		
	Skin	L Buttock Category 1 Pressure Ulcer	L Buttock Category 1 Pressure Ulcer		
3	BP	111/74	139/101	13	40
	Pulse	73	88		
	RR	13	15		
	Skin	intact	intact		
4	BP	144/77	119/68	16	28
	Pulse	77	85		
	RR	13	17		
	Skin	intact	intact		
5	BP	171/93	169/87	11	49
	Pulse	67	68		
	RR	18	20		
	Skin	intact	intact		
6	BP	126/64	108/71	16	28
	Pulse	68	62		
	RR	18	15		
	Skin	intact	intact		
7	BP	114/53	119/61	21	43
	Pulse	59	60		
	RR	21	15		
	Skin	intact	intact		
8	BP	152/69	152/95	21	26
	Pulse	75	64		
	RR	18	17		

	Skin	Category 1 Pressure Ulcer	Healed category 1		
9	BP	143/71	157/64	13	25
	Pulse	67	73		
	RR	17	18		
	Skin	intact	intact		
10	BP	150/62	154/52	49	15
	Pulse	74	83		
	RR	18	16		
	Skin	intact	intact		
11	BP	141/87	121/76	20	10
	Pulse	70	76		
	RR	20	20		
	Skin	intact	intact		
12	BP	115/63	128/72	8	30
	Pulse	80	83		
	RR	21	20		
	Skin	intact	intact		

Peak and average pressure and peak pressure index

Descriptive statistics using IBM SPSS v22 were calculated in order to measure the average pressures and peak pressures at day one and day seven on the trial chairs. There was a slight increase in mean pressure at day seven across the three chairs although all chairs displayed low mean pressures (Table 3). There was a slight increase in mean peak pressure index at day seven across the three chairs (Table 3).

Table 3. Descriptive Statistics: Average Pressures and PPI

	N	Minimum (mmHg)	Maximum (mmHg)	Mean (mmHg)	Std. Deviation
Day 1 Average	12	32.60	50.30	42.0083	6.53570
Day 7 Average	12	32.10	54.00	44.0333	6.41282
Day 1 PPI	12	64.30	194.80	134.2583	43.95983
Day 7 PPI	12	61.10	199.80	136.2833	35.30827
Valid N (listwise)	12				

Descriptive statistics were calculated using IBM SPSS v 22 to calculate the mean and standard deviation of the GDA and DIR (Table 4). The results illustrate that the trial chairs had low GDA and DIR.

Table 4: Descriptive statistics of General Discomfort Assessment and Discomfort Intensity Rating

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
General Discomfort Assess	Chair 1	4	38.75	8.808	4.404	24.73	52.77	30	49
	Chair 2	4	33.25	12.366	6.183	13.57	52.93	20	49
	Chair 3	4	29.75	6.946	3.473	18.70	40.80	25	40
	Total	12	33.92	9.539	2.754	27.86	39.98	20	49
Discomfort Intensity Rating (Average)	Chair 1	4	14.75	5.315	2.658	6.29	23.21	8	21
	Chair 2	4	12.75	2.754	1.377	8.37	17.13	10	16
	Chair 3	4	15.00	4.000	2.000	8.64	21.36	13	21
	Total	12	14.17	3.904	1.127	11.69	16.65	8	21

Explore if there is a correlation between discomfort and pressure redistribution.

SPSS v22 was used to conduct a series of Pearson Product Moment correlations to test if there were significant correlations between the test variables- comfort, PPI, average pressure and area. Based on the results of the study there was no significant correlations with all p values being greater than 0.05 (*p =.995- .113*).

Discussion

Prior studies have noted the scarcity of literature regarding people at risk of pressure ulcers whilst seated (Stockton, Gebhardt, and Clark 2009; EPUAP, NPUAP, PPPIA 2014; NICE 2014) and have called upon researchers, clinicians, and manufacturers to cultivate this area of clinical research. Stakeholders and end users are the key to well informed research on seating. This has been well documented by leading authors in the field who not only call for more research to be conducted, but also draw attention to equipment abandonment if seating is found to be uncomfortable and/or unsuitable (Geyer et al. 2003; Crane and Hobson 2002). End user collaboration in the automotive industry on pressure redistribution, comfort, and discomfort has been leading the way in developing car seat technology (Kyung and Nussbaum 2007). There is abundant room for further progress in determining effective clinical decision making in regard to seating considering factors such as: pressure reducing qualities of the seating, the individuals' level of perceived comfort, and best practice guidance. Failure to recognise these elements may lead to unsuitable prescription of equipment and concordance by the end user (Shectman et al. 2001).

1. The pressure reducing qualities of WaterCell® technology

Average Pressure

The results of this study indicate that the mean pressure 42 to 44.03mmHg offers lower average interface pressures than those reported to cause potential injury (Kosiak, 1959) and compare favourably with Kim and Chang's (2013) study of healthy participants who recorded average pressures of 60.95mmHg to 61.97mmHg in two different types of seat cushion. However, these results differ as our study recruited from a diverse age group and disabled population, Kim and Chang (2013) also recorded average pressure for seventy seconds whereas our evaluation recorded average pressure for five minutes.

Peak Pressure Index

Peak pressure index studies are difficult to source in order to make assumptions of the pressure redistributing properties of WaterCell® technology. These results differ from some published studies in seating due to the diversity of the sample population, for example when evaluating cushions, the participants can be wheelchair user or non-wheelchair user (Burns et al. 1999) and spinal cord injury patients and the elderly (Ferrarin et al. 2000). In contrast the peak pressure index findings from this small evaluation study of 137.5mmHg to 138.35mmHg compare in some aspects to findings by Gil- Agudo et al. (2009) who found maximum peak pressure under the ischial tuberosities ranged from 102mmHg to 207.5mmHg in forty-eight people with spinal cord injuries. Noteworthy differences are the length of time peak pressures were measured, 1.5 minutes compared to five minutes and the diversity of participant's, which is distinctive in our study in comparison to previous research studies.

2. A link between self-reported comfort/ discomfort scores of adults and the pressure redistribution qualities of WaterCell® technology.

There was no correlation found using SPSS v22 Pearson's Moment Correlation between comfort/discomfort intensity ratings and the pressure redistribution variables (PPI, Average pressure and area) across the chairs. Comfort/discomfort is a major factor for people when they decide whether to use a pressure redistributing device or not (Stockton and Rithalia 2008). These findings would suggest that from the mean DIR 14.17 and GDA Scores 33.92, the three trial chairs were not reported to be uncomfortable and therefore found to be comfortable for the 12 participants. This study is analogous to previous studies that have reported on the possibility of an association between pressure redistribution and comfort. The largest study sourced using 100 healthy volunteers with care seats found no association between the two (Lee et al. 1993). Although we used small numbers the results are similar with the difference being that our study was with a disabled population using specialist armchairs.

Conclusion

In conclusion this small scale evaluation found that WaterCell® Technology offers average and peak pressures that are comparable with other studies already published. No correlation was found between pressure redistribution and discomfort, with the participants indicating that the chairs were comfortable with low scores in their DIR and GDA evaluations. The current findings add to the body of literature regarding seating and its place in the twenty-four hour prevention and management of pressure ulcers. However more research is needed with a larger sample size *(n=37)* and other types of seating to further explore correlations between pressure redistribution and discomfort. Savings in regard to the prevention of pressure damage may be made with the use of WaterCell® technology, however this cannot be clearly ascertained in this study.

Limitations

The sample size of the study can be considered as a limitation. Another limitation is asking the participants to adopt a neutral seated position and remain still during the recording of interface pressure measurements. Confounding variables such as the amount of time participants sat in the trial chair once the researchers had left cannot be excluded. Caution is advised when interpreting pressure mapping results alone due to errors from hysteresis (lagging effect of the pressure mat) and creep (increase in pressure whilst force remains constant) plus any hammocking effect from the mat.

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