Interactions between pressure-redistributing mattresses and transfer devices: a laboratory study

KEY WORDS
- Matress
- Pressure-redistributing mattresses
- Pressure ulcer
- Transfer devices

Background: Transfer devices are used in combination with pressure-redistributing surfaces to ease the manual repositioning of patients. Little attention has been paid to the impact of a transfer device upon the pressures applied by pressure-redistributing surfaces. **Aims:** The study aims to identify the effects of two transfer devices on the pressure redistribution provided of healthy volunteers while they rested on two static and two active mattresses. **Methods:** Continuous measurements of contact (interface) pressure were made using a BodiTrak 1 pressure measurement mat. **Results:** Comparison of the contact pressures between each mattress and the cotton sheet, WendyLett and HighBackSling identified three combinations that significantly reduced contact pressures during use of the transfer devices. **Conclusions:** In the current study the reduction in contact pressure upon use of a transfer device was not consistent across all test surfaces and it may be premature to consider that all use of transfer devices may reduce contact pressure.

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In acute and elderly care, multiple horizontal transfers occur — these can involve transfers into and out of bed, along with repositioning of patients while they are in bed. Repositioning patients while in bed is a common practice undertaken to help prevent pressure ulcer (PU) development and is strongly recommended in the International Pressure Ulcer Clinical Practice Guidelines (EPUAP, NPIAP, PPPIA, 2019). The frequent repositioning of patients in bed can however be very strenuous both for patients and nurses, given that this intervention typically occurs every two to four hours, both day and night.

One recommendation within the International Pressure Ulcer Guidelines (EPUAP, NPIAP, PPPIA, 2019) directly addresses the use of patient transfer devices (slings and sheets intended to make horizontal transfers easier to perform). This recommendation was 'do not leave moving and handling equipment under the individual after use, unless the equipment is specifically designed for this purpose.' The primary concern when considering leaving a transfer device *in situ* is whether the device would compromise the pressure redistribution provided by the bed mattress. Clark et al (2015) reported laboratory measurements of interface contact pressure between a flat anatomical mannequin and an active support surface (contains air cells that inflate and deflate over a fixed time period to alter the sections of the body that bear mechanical loading), with and without a transfer sheet placed upon the mattress surface. In their study, Clark et al (2015) identified that the use of the transfer sheet reduced the minimum pressures applied to the mannequin, a finding consistent with the earlier work by Mellson and Richardson (2012). The current study expanded on these studies and identified the effects of two transfer devices upon the pressure redistribution provided to healthy volunteers while they rested upon two static and two active mattresses.

Aim

The objectives of the study were to determine the contact pressures applied to the sacrum and heels of healthy volunteers by four pressure redistributing mattresses and to assess whether the introduction of transfer devices between the volunteers and the mattress surface degraded, or improved, the ability of the mattress to provide pressure redistribution.

METHODS

This evaluation explored the sacral and heel contact pressures measured as 10 volunteers rested upon four pressure redistributing mattresses with and without the introduction of two transfer devices between the volunteers and the mattress surface. The mattresses and transfer devices used in this evaluation were CE marked and used within their intended purpose. The study was approved by the Cardiff University School of Medicine Ethics Committee.

Participants

Adult volunteers (aged over 18 years with no upper limit) were invited to rest upon the support surfaces. All participants were provided with information sheets about the evaluation and if they consented to participate, a copy of their signed consent form.

Inclusion criteria

- Aged over 18 years
- Able to position themselves upon the test mattresses and leave the bed safely.

Exclusion criteria

- Under 18 years.
- Unable to access or leave the test mattresses independently.

Measurements

Due to the length of time measurements required to be collected, volunteers were invited to attend the Welsh Wound Innovation Centre over two days, no more than 48 hours apart. Subjects were asked to wear loose fitting clothing during the measurement periods and lay upon each mattress in a supine position — flat on their backs, with feet no more than shoulder width apart and arms resting by their side.

Each mattress was set up according to the manufacturers' instructions and covered with a cotton sheet. The order of presentation of the mattresses and transfer devices to volunteers followed predetermined randomisation schedules. The four mattresses were the Dyna-Form Mercury (non-powered reactive mattress), the Carital Optima (powered reactive mattress), the Quattro (powered Active mattress) and the Dyna-Form Mercury Advance (powered hybrid mattress), all manufactured by the Direct Healthcare Group (Caerphilly, Wales). The two transfer devices were the WendyLett slide sheet and the HighBackSling *in situ* sling (Direct Healthcare Group).

Each volunteer rested on each static mattress for 15 minutes while each permutation of transfer device was in place (no transfer device — cotton sheet), WendyLett slide sheet or HighBackSling *in situ* sling). On the two active mattresses, the time spent lying on the mattress was increased to 30 minutes for each permutation of transfer device allowing the mattress pump to reach its stable operation. *Table 1* sets out the combinations of mattress and transfer device and total time each participant was followed during the study.

After each 15- or 30-minutes rest on the mattresses and transfer devices, the volunteer was invited to stand and ambulate for 10 minutes. The volunteer then returned to the mattress and the next permutation of transfer device was investigated.

Table 1. Permutations of mattress and transfer devices investigated

Dyna-Form Mercury		Time (mins)	Quattro		Time (mins)	Mercury Advance		Time (mins)	Carital		Time (mins)
Static	WendyLett	15	Alternating	WendyLett	30	Static	WendyLett	15	Static	WendyLett	15
	HighBackSling	15		HighBackSling	30		HighBackSling	15		HighBackSling	15
	No transfer device	15		No transfer device	30		No transfer device	15		No transfer device	15
						Alternating	WendyLett	30			
							HighBackSling	30			
							No transfer device	30			
		45			90			135			45

Continuous measurements of contact (interface) pressure were made using a BodiTrak 1 pressure measurement mat (Vista Medical, Canada) with surface dimensions of 203cm by 86cm and a measurement range of 0–100mmHg with stated accuracy to be ±20% across the measurement range. The pressure mat was placed upon the upper surface of the test mattresses and covered with a cotton sheet. The pressure measurement mat was calibrated following manufacturer's recommendations before use. During measurements, subjects were free to use their own headphones and devices to listen to audio content.

While in static mode the recording frame containing the pressures across the participant's body that marked 10 minutes after lying down was located and the sensors that recorded the highest pressure over the sacrum/buttocks and the heels were identified and the contact pressures at these two sensors were recorded. Where mattresses operated in alternating mode, the recording frame that marked 20 minutes after lying down was located and the sensors that recorded the highest pressures at sacrum/buttocks and heel were identified. These sensors were recorded at 60-second intervals until the recording ended to allow identification of the maximum and minimum applied pressure over a full mattress alternating cycle. So the patient was stabilised for 10/20 minutes and recording occurred for the remaining 5/10 minutes?

RESULTS

We recruited 10 participants ranging from 19 to 69 years of age (mean: 41.8 years; standard deviation (SD): 15.8), and three were male. Body mass index (BMI) ranged from 19.6 to 37.2 (mean±SD: 25.8±5.4; with two overweight and 2 obese).

Table 2. Contact pressures measured at the sacrum and heels upon the four mattresses when covered with a single cotton sheet

Mattress	Mean sacral maximum pressure (mmHg), (SD)	Mean sacral minimum pressure (mmHg), (SD)	Mean heel maximum pressure (mmHg), (SD)	Mean heel minimum pressure (mmHg), (SD)
Dyna-Form Mercury	62.9 (28.1)	*NR	77.2 (24.9)	*NR
Carital	62.7 (22.5)	*NR	71.8 (31.8)	*NR
Quattro	76.9 (27.4)	44.5 (33.9)	88.7 (22.9)	42.0 (37.7)
Mercury Advance (static)	58.1 (18.5)	*NR	89.6 (17.1)	*NR
Mercury Advance (alternating)	63.4 (23.1)	26.5 (22.2)	88.4 (24.6)	33.1 (30.8)

*NR: not recorded; *In static mode only the maximum contact pressure was recorded*

Table 3. Contact pressures measured at the sacrum and heels upon the four mattresses when covered with the WendyLett slide sheet

Mattress	Mean sacral maximum pressure (mmHg), (SD)	Mean sacral minimum pressure (mmHg), (SD)	Mean heel maximum pressure (mmHg), (SD)	Mean heel minimum pressure (mmHg), (SD)
Dyna-Form Mercury	47.8 (25.1)	*NR	50.7 (21.9)	*NR
Carital	48.4 (17.3)	*NR	66.4 (32.2)	*NR
Quattro	62.9 (20.5)	19.7 (12.6)	86.2 (25.5)	29.5 (37.7)
Mercury Advance (static)	44.2 (16.5)	*NR	67.4 (31.4)	*NR
Mercury Advance (alternating)	58.3 (21.8)	25.2 (26.4)	80.0 (26.8)	26.9 (29.9)

*NR: not recorded; *In static mode only the maximum contact pressure was recorded*

Table 4. Contact pressures measured at the sacrum and heels upon the four mattresses when covered with the HighBackSling in situ sling

Mattress	Mean sacral maximum pressure (mmHg), (SD)	Mean sacral minimum pressure (mmHg), (SD)	Mean heel maximum pressure (mmHg), (SD)	Mean heel minimum pressure (mmHg), (SD)
Dyna-Form Mercury	60.6 (24.9)	*NR	72.9 (30.9)	*NR
Carital	45.9 (15.6)	*NR	75.5 (27.1)	*NR
Quattro	64.7 (21.3)	27.5 (18.8)	85.2 (18.6)	30.0 (16.7)
Mercury Advance (static)	52.6 (16.5)	*NR	92.2 (15.4)	*NR
Mercury Advance (alternating)	69.1 (15.1)	27.9 (10.8)	96.8 (7.4)	29.3 (30.5)

*NR: not recorded; *In static mode only the maximum contact pressure was recorded*

Table 2 details the contact pressures recorded on the four mattresses where the mattress was covered with a cotton sheet. The large standard deviations relative to the mean values, along with evidence of both skewness and kurtosis within the data, prompted the use of non-parametric statistical tests to compare mattresses. There were no significant differences between the maximum and minimum contact pressures recorded across the four tested mattresses at either the sacrum or heel position (maximum sacral contact pressures; Friedman test x^2=4.84; degrees of freedom=4; *p*=0.30; maximum heel contact pressure x^2=6.95, degrees of freedom=4, p=0.139; minimum sacral contact pressure Wilcoxon Signed Ranks Test z=-1.17; *p*=0.24, minimum heel contact pressure z=-0.56, *p*=0.57).

Tables 3 and 4 describe the mean contact pressures recorded when the WendyLett slide sheet or HighBackSling were positioned between the participants and the surface of the mattresses. The maximum contact pressures at the sacrum/buttocks and heels were higher on the two alternating mattresses than on the static surfaces (WendyLett Sacrum maximum contact pressures x^2=10.7; degrees of freedom=4; p=0.03; heel maximum contact pressures x^2=13.6; degrees of freedom=4; *p*=0.009; HighBackSling Sacrum maximum contact pressures x^2=12.2; degrees of freedom=4; p=0.016; Heel maximum contact pressures x^2=9.9; degrees of freedom=4; *p*=0.04). The increase in the maximum heel contact pressures is challenging to interpret where the HighBackSling was in place as the heels did not contact the sling. It is possible that the introduction of the sling changed loading across the body and possibly increased the loading on the heels. Depending on the material of the sling, the patient may slide or fidget. There were no significant differences between the minimum contact pressures applied to the sacrum/buttocks or heels upon the two alternating surfaces where the WendyLett or HighBackSling were in place.

Comparison of the contact pressures between each mattress and the cotton sheet, WendyLett and HighBackSling identified three combinations that significantly changed contact pressures during use of the transfer devices. The maximum contact pressure at the heel was reduced on the Dyna-Form Mercury mattress through introduction of the WendyLett transfer sheet (x^2=9.6; degrees of freedom=2; *p*=0.08). Both transfer devices reduced the maximum and minimum sacral contact pressures on the Quattro (Maximum sacral contact pressure x^2=8.6; degrees of freedom=2;*p*=0.01; Minimum sacral contact pressure x^2=6.2; degrees of freedom=2; *p*=0.04). The introduction of the transfer devices did not significantly change contact pressures at the sacrum/buttock or heels while participants rested on the Carital or Mercury Advance (either static or alternating).

The impact of gender, body mass and age on the recorded contact pressures were explored through a series of one-way ANOVAs. Gender influenced the maximum heel contact pressures on the static Mercury Advance mattress with the HighBackSling in place; this resulted from all female participants having 100mmHg applied at the heel on this mattress; the pressure mat has a range from 0–100mmHg and any pressures over 100mmHg are truncated to 100mmHg. This truncation will have affected many of the analyses, particularly at the heel where high pressures may be anticipated. Age appeared to influence the minimum sacral/buttock contact pressures on the Quattro mattress with no transfer device; participants under 42 years had higher sacral/buttock minimum pressures than did older participants (F=13.36, *p*=0.006). Older participants also had lower maximum sacral/buttock contact pressures on the Carital mattress with WendyLett transfer sheet. Body Mass Index influenced heel contact pressures on the Carital (with no transfer device) and Mercury Advance (in static mode) with no transfer device. In both cases participants with lower BMI had higher heel contact pressures; however, on the Dyna-Form Mercury Advance maximum sacral contact pressures were higher among participants with high BMI.

DISCUSSION

While the data generated in this study is relatively complex, several trends were observed. For example when covered with a cotton sheet there were no significant differences between the maximum contact pressures at the sacrum/buttock across the four tested mattresses. Nor did the maximum heel contact pressures differ across mattresses. There were no significant differences between the minimum sacral and heel contact pressures between the two alternating mattresses. The relative similarity between the contact pressures applied by the tested pressure-redistributing surfaces was unexpected and it is interesting to speculate whether the four surfaces would provide similar clinical outcomes in terms of PU incidence or healing rates.

BMI, age and gender appeared to influence recorded contact pressures in a small number of tests; there was no consistent trend across all tested mattresses and combinations of transfer devices to suggest demographic parameters routinely affected contact pressure.

The introduction of a transfer device rarely resulted in any statistically significant changes in contact pressure. Where a significant difference was found the introduction of a transfer device reduced the maximum heel contact pressure on the Dyna-Form mattress (WendyLett sheet), and both maximum and minimum sacral contact pressures on the Quattro mattress (where either the WendyLett or HighBackSling transfer devices were used). Reductions in contact pressure following introduction of a transfer device were also reported by Clark et al (2015) and by Mellson and Richardson (2012) and may reflect changing friction between the body and the mattress surface due to the introduction of the device (Clark et al, 2015). In the current study, the reduction in contact pressure upon use of a transfer device was not consistent across all test surfaces and it may be premature to consider that all use of transfer devices may reduce contact pressure. Interestingly the two transfer devices did not produce statistically significant increases in contact pressure across any of the tested pressure-redistributing surfaces. WUK

Declaration of interest

This study was funded by the Direct Healthcare Group who had no influence over test methods, results, analysis, and reporting of the data.

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