Automatic switching of a hybrid mattress from a reactive to active mode upon healthy volunteer immobility

KEY WORDS
:Healthy volunteer
:Hybrid mattress
:Mobility
:Pressure redistribution

Aim: Hybrid mattresses are increasingly being used in UK healthcare due to their ability to be rapidly switched from a reactive mode to providing active alternating therapy. This study investigated a new hybrid mattress designed to automatically switch from its reactive to active mode where a person remains immobile for at least 60 minutes. **Methods**: Healthy volunteers rested upon the test mattress for 90 minutes remaining relatively immobile for the first hour. After 61 or 62 minutes of immobility the mattress switched to its active mode for each volunteer. Pressure measurements were performed using a pressure map during the 90-minute session. **Results**: We recruited 10 healthy volunteers. These data were heterogeneous, and in the absence of a control mattress surface challenging to interpret. The two volunteers with the highest body mass index (BMI) >30 both experienced malfunctions of the pressure map system. **Conclusion**: The link between BMI and the functioning of the pressure map requires further investigation.

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Restricted patient mobility and activity are typically viewed as being clear risk factors for pressure ulcer (PU) development. The 2019 European Pressure Ulcer Advisory Panel (EPUAP), National Pressure Injury Advisory Panel (NPIAP), and Pan Pacific Pressure Injury Alliance (PPPIA) "*Prevention and Treatment of Pressure Ulcers/Injuries: Clinical Practice Guideline*" (2019) recommends that clinicians should "consider individuals with limited mobility, limited activity and a high potential for friction and shear to be at risk of pressure injuries." This recommendation supported by a consistent body of evidence with the proposal that clinicians should definitely follow this guidance.

While reductions in mobility and activity are widely accepted as risk factors for pressure damage, there has been surprisingly little attention to the measurement of these parameters in relation to PU development. Exton-Smith and Sherwin (1961) measured the number of times elderly patients moved in a hospital bed overnight. Where patients made more than 7.2 movements per hour, none developed PUs. However, in 10 patients who moved fewer than 2.9 times per hour 9 (90%) developed PU. This early association between low mobility and high incidence of PUs was not substantiated by later studies, such as Barbenel et al (1986), who found that patients at high risk of developing PUs could only be identified through complex calculations of the difference in the number of movements performed in bed on the first and second nights in hospital. No patient in this study developed pressure damage regardless of how rarely they moved overnight. The failure to substantiate the simple link between mobility and pressure damage largely closed attention on directly measuring movement and its link to pressure ulceration.

In recent years, there has been attention to the use of skin-mattress contact (interface) pressure measurements to help clinicians effectively reposition patients and to identify when an immobile patient requires a position change, for example Gunningberg and Carli (2016). Feedback on high pressure points on the body has been shown to help reduce the incident of PUs (Behrendt et al, 2014) where 2/213 (0.9%) patients developed category II PUs where feedback on high pressure points was provided with 10/209 (4.8%) of patients developing similar wounds in the absence of feedback on where high pressures were applied to the skin.

In addition to the use of interface pressure measurement to identify high pressure points on the body, mattresses that contain cells filled with air (as in many hybrid mattresses and all active alternating pressure air mattresses) could potentially be used to identify, and react to, long periods of patient immobility. When a patient moves on an air mattress, this results in a small volume of air being displaced from the cells that could be measured by a pump connected to the mattress as the 'back pressure' of air moved from the cells. This report considers the ability of a new hybrid mattress (SMARTresponse, Direct Healthcare Group, Caerphilly) to automatically switch from a static (reactive) mode to an alternating pressure (active) mode where human healthy volunteers remained relatively immobile upon the mattress for at least one hour.

METHODS

Adult volunteers (aged over 18 years with no upper limit), all members of staff from the Welsh Wound Innovation Centre, were invited to rest upon the test mattress. All participants were provided with information upon the study and if they consented to participate, they completed a consent form. There were few inclusion and exclusion criteria for this study; participants had to be aged over 18 years old and had to be able to position themselves upon the test mattress and be able to enter and leave the bed safely. The test mattress was CE marked and used within its intended purpose. All testing was approved by Cardiff University School of Medicine ethics committee.

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 to 100mmHg with stated accuracy to be ±20% across the measurement range. The pressure mat was placed upon the upper surface of the test mattress and covered with a single sheet.

Subjects were invited to wear loose fitting clothing during measurements and lay upon the test mattress in a supine position — flat on their backs, with feet no more than shoulder width apart and their arms rested by their side. Each subject rested on the test mattress for 90 minutes with minimal to no movement over the first 60 minutes to allow time for the mattress to sense the subject was immobile and switch to its active mode. Contact pressures were recorded across the entire 90-minute participation of each subject. After 90 minutes the subject exited the bed, and the bed exit alarm function was checked to have activated. 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.

The continuous pressure measurements were reviewed for each subject and the following measurement point were identified for each subject. The maximum applied pressure across the subject's body was recorded after 30 minutes of immobility. The maximum pressure gradient observed across the body (mmHg/cm) was also recorded after 30 minutes of immobility to provide an estimation of local shear. During the mattress active phase, the sensor bearing the greatest pressure at the sacrum and buttocks five minutes after the start of the active phase was identified. The maximum and minimum pressures and pressure gradients at this sensor were recorded every five minutes until three full alternating cycles had been completed. In reactive mode the total surface area of the pressure mat that had over 10mmHg exerted was recorded after 30 minutes of immobility.

Given that there was no control surface used in this study, limited formal statistical testing was undertaken. The normality of the collected contact pressure data was tested using measures of skewness and kurtosis (SPSS, Version 26, IBM Corp). Significant skewness and kurtosis were found across the contact pressure data and any impact of age or body mass index (BMI) on contact pressures and pressure gradients were then compared using the nonparametric Independent Samples Mann-Whitney U test with statistical significance set at 0.05.

All data was collected in July 2021 within the mattress test laboratory at the Welsh Wound Innovation Centre. The safety of subjects and WWIC staff was paramount during the study. One subject per day was invited to attend the WWIC building at a specified time. Signage within the building directed the volunteer to the mattress test laboratory, a large area containing several hospital beds. Study information and a consent form were available within the test laboratory. One research nurse performed all measurements on the day wearing appropriate PPE and maintaining a minimum of two metres social distancing from the volunteer. Once the volunteer had taken their position upon the mattress, the research nurse remotely initiated pressure measurement. The volunteer was instructed to bring food and refreshments with them and were provided access to a specified toilet adjacent to the test laboratory. All equipment was cleaned thoroughly between each volunteer.

RESULTS

We recruited 10 subjects ranged in age from 31 to 62 years (mean±SD: 47.3±11.8 years), of these two were male. BMI ranged from 21 to 35; (mean±SD 26.3±4.6). There were four volunteers classified as overweight and two obese.

The test mattress switched from reactive to active mode for all immobile volunteers after either 61 (n=6) or 62 (n=4) minutes. The bed exit alarm was activated for all volunteers as they exited the mattress; in a single case the bed exit alarm was activated as the subject sat at the edge of the mattress before leaving the bed surface.

Contact pressure data from two volunteers was excluded from further examination following malfunctions of the pressure mat system observed on data examination before analysis. It was noted that the malfunctions occurred in the two subjects with the highest BMI (33.4 and 35.0). *Table 1* details volunteer demographic information along with both the maximum contact pressure and pressure gradient for each subject while the test mattress operated in reactive mode. Body contact area with the pressure mat is also shown in *Table 1*. Volunteers were separated into groups depending on their age (under or over 50 years) and BMI (under or over 24) to allow comparison of any impact of age or BMI on the contact pressure or pressure gradient data. Neither age or BMI significantly affected maximum contact pressures, pressure gradients or contact area where the test mattress operated in reactive mode (all Mann-Whitney U-tests $p>0.05$).

Table 2 illustrates the maximum and minimum contact pressures and pressure gradients for each volunteer while the test mattress acted in active mode. The minimum contact pressure while the test mattress was in active mode was higher among volunteers with a BMI over 24 (mean minimum contact pressure±SD: 25.7±19.2) than in volunteers with a BMI under 24 (mean minimum contact pressure±SD: 5.2±3.4). However, this difference did not achieve statistical significance (Mann-Whitney

Table 1. Contact pressure, pressure gradient, and contact area of the body bearing at least 10mmHg pressure while the test mattress was in reactive mode

Volunteer	Age (years)	Gender	Body mass index	Contact pressure (mmHg)	Pressure gradient (mmHg/cm)	Contact area (cm^2)
1	34	Female	23.7	48.9	8.7	154.6
2	37	Female	26.9	30.3	5.4	40.7
3	31	Female	23.3	20.5	3.4	146.5
4	54	Female	22.0	100.0*	17.8	496.3
5	56	Female	25.3	38.6	5.0	358.0
6	57	Female	21.0	50.5	9.0	268.5
7	45	Female	35.0	X†	X†	X†
8	62	Male	33.4	X†	X†	X†
9	37	Male	26.2	100.0*	23.7	2375.9
10	60	Female	26.1	37.4	5.5	488.2
Mean (standard deviation)				**53.3 (30.4)**	**9.8 (7.2)**	**541.1 (759.2)**

** Pressure mat saturated at 100mmHg (maximum possible reading) due to contact from either elbow or heel with mat.*
† Missing data due to mat malfunction seen in data preparation.

Table 2. Maximum and minimum contact pressures and pressure gradients as the test mattress acted in active mode

Volunteer	Maximum contact pressure (mmHg)	Minimum contact pressure (mmHg)	Maximum pressure gradient (mmHg/cm)	Minimum pressure gradient (mmHg/cm)
1	31.0	4.7	2.7	0.9
2	41.6	6.3	6.7	0.9
3	31.6	2.2	3.6	1.2
4	47.4	10.1	4.8	1.1
5	32.6	12.6	3.0	1.2
6	19.1	3.8	3.4	0.7
7	X†	X†	X†	X†
8	X†	X†	X†	X†
9	74.7	38.3	9.9	1.5
10	74.0	45.8	8.9	0.7
Mean (SD)	**44.0 (20.5)**	**15.5 (16.9)**	**5.4 (2.8)**	**1.0 (0.3)**

† *Missing data due to mat malfunction seen in data preparation.*

U p=15.0, 2-sided exact significance p=0.057). No other comparison between age or weight and contact pressures and pressure gradients approached statistical significance while the test mattress was in active mode.

DISCUSSION

The present study confirmed that the test mattress switched automatically from a reactive to active mode following approximately 60 minutes of volunteer immobility. The bed exit alarm generally activated on leaving the bed although, There was also a lack of testing with regard to whether volunteers had moved over the first 60 minutes, which would have caused the mattress to remain in reactive mode. in one case this alarm activated as the volunteer sat at the edge of the mattress before leaving the bed. Little interpretation can be provided around the contact pressures, contact area and pressure gradients recorded from the volunteers who rested on the test mattress given the lack of a control surface in this study. Generally, there was considerable heterogeneity between subjects in their contact area, pressures and pressure gradients. Furthermore, these differences may be challenging to interpret given the wide margin of error (±20%) around the pressure measurements provided by the pressure mat. It was interesting that the two volunteers with the highest BMI (both >30) experienced malfunctions in the performance of the pressure mat and further investigation may be warranted to explore the performance of the mat among individuals with high BMI? In active mode the contact pressures experienced by the volunteers were broadly similar to contact pressures measured on other hybrid mattress systems (Clark et al, 2019), suggesting the performance of the test mattress matched other hybrid mattresses.

Limitations

The major limitations of the current study were the lack of a control mattress surface and the wide errors around the pressure measurements due to the sensors used in the construction of the pressure mat. There was also a lack of testing with regard to whether volunteers had moved over the first 60 minutes, which would have caused the mattress to remain in reactive mode.

Implications for clinical practice

Hybrid mattresses are becoming increasingly common in healthcare, primarily due to the potential for rapid deployment of active surfaces where patient need demands (Fletcher et al, 2016). The test mattress holds potential for providing additional protection for immobile patients where the mattress automatically detects patient immobility and switches from reactive static mode to an active alternating mode. Fletcher et al (2015) noted other benefits of hybrid mattress use, such as improved patient comfort and quality of sleep with greater ability to self-reposition and move independently in bed. Hybrid mattresses may be particularly helpful in community and social care settings given the ability to rapidly provide higher degrees of protection against pressure damage by switching to an alternating mode. This may be especially helpful where the mattress is able to monitor immobility and automatically switch to its alternating mode.

Declaration of interest

This study was funded by the Direct Healthcare Group who had no involvement in study design, data collection and analysis or reporting. WUK

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