ORIGINAL RESEARCH

Effects of Mattress Material on Body Pressure Profiles in Different Sleeping Postures

Fan-Zhe Low, BEng, Matthew Chin-Heng Chua, PhD, Pan-Yin Lim, BEng, and Chen-Hua Yeow, PhD

ABSTRACT

Objectives: This study compared the body contact pressure profiles of 2 types of mattresses: latex and polyurethane.
Methods: Twenty participants were required to lie down on the different mattresses in 3 different postures for 6 minutes, and their body contact pressure profiles were recorded with a pressure mat sensor.
Results: The data indicated that the latex mattress was able to reduce the peak body pressure on the torso and buttocks and achieve a higher proportion of low-pressure regions compared with the polyurethane mattress.
Conclusions: Latex mattress reduced peak body pressure and achieved a more even distribution of pressure compared with polyurethane mattress across different sleeping postures. (J Chiropr Med 2017;16:1-9)
Key Indexing Terms: *Posture; Supine Position; Sleep; Beds; Pressure Ulcer*

INTRODUCTION

Annually, sleep disorders affect up to 40% of the US adult population and are often associated with morbidity and mortality.[1,2] Sleep quality plays an instrumental role in the overall wellness of our lives, whereby a good sleep can help facilitate a normal circadian rhythm and thus lessen fatigue and improve physical regeneration.[3,4] Poor sleep quality can be attributed to a variety of environmental factors, which include temperature, light, noise, and mattress quality.[5,6] Addison et al[7] reported that 7% of sleep problems were due to uncomfortable mattresses, which affect the loading of the spine during sleep.[4]

Several previous studies have suggested that mattress material can affect sleep quality.[8-10] Dickson[11] noted increased sleep quality of human participants sleeping on natural wool. Okamoto et al[12] further reported that body temperature was higher in participants sleeping on an air mattress than on a futon mattress. Moreover, Tonetti et al[13] found that expanded polyurethane-viscoelastic mattresses exhibited improved actigraphic sleep parameters of sleep onset latency and sleep efficiency, compared with traditional spring mattresses.

In addition, effective heat loss through the use of a high-rebound breathable mattress may facilitate restorative sleep.[14] An electromyography-based human-mattress compatibility study by Park et al[15] reported significantly lower muscle activities, together with greater participant relaxation rating, for the spring mattress compared with the Tempur mattress, during tossing and turning.

However, it is difficult to compare the result of these prior studies because different types of mattress were investigated. Furthermore, it is important to note that these studies adopted different methods, such as actigraphy, body temperature, polysomnography, contact pressure profile, and questionnaires.

Body contact pressure is a measure of the distribution of the body weight across the surface of the body in contact with the mattress.[16] A well-designed mattress often possesses the ability to minimize high-pressure points applied onto the body.[17,18] However, if the mattress is not suited for the person, pressure sores may develop at body regions where the pressure is concentrated.[19] The regions affected by higher pressure often include the buttocks, shoulder, and back,[17,20] which may consequently affect the quality of sleep and result in lethargy or body stiffness throughout the day.[21] A recent study by Bae and Ko[22] compared the bed positions of hospital mattresses and found that the head-foot angle of 30° was the best position to mitigate the possibility of decubitus ulcers occurring in patients at the high-pressure-risk regions.

In view of these previous studies, there is still a lack of research that specifically compares latex mattresses to polyurethane foam mattresses, considering that both mattress types are common mattresses used in hospital

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Paper submitted April 22, 2016; in revised form September 2, 2016; accepted September 5, 2016.
1556-3707

http://dx.doi.org/10.1016/j.jcm.2016.09.002

beds.[20,23] A biomechanical comparison of these mattresses across different sleeping postures will allow us to provide new insights into their pressure-distributing capabilities. Therefore, the objective of this study was to evaluate the effect of different types of bed material (latex and polyurethane foam) on the body contact pressure profiles in various sleeping postures, using peak body pressure and pressure distribution as outcome measures.[17,24,25] We hypothesized that the latex mattress would perform better in reducing the body contact pressure profiles across different sleeping profiles, compared with polyurethane foam mattress. The purpose of this study was to evaluate the performance of different mattress materials in order for hospitals to determine the type of mattress best suited for patients by reducing risk of pressure sores.[26,27]

Methods

Participant Recruitment

Twenty young healthy participants (10 men, 10 women; height: 1.67 ± 0.07 m, weight: 59.8 ± 11.1 kg) were recruited in this study. Informed consent was obtained in accordance with approval from the National University of Singapore's Institutional Review Board before commencement of the trials. The participants had no history of back, shoulder, or neck pain for the past month and were instructed to put on their usual sleepwear during the conducting of the sleep experiments.

Test Protocol

All trials were conducted at a motion analysis laboratory at the local university. The participants were required to lie down on 2 different mattresses (latex foam, Sofzsleep, model Delight, and high-density polyurethane foam, Masterfoam, model Masterfoam 1000), where the sequence of mattress conditions was randomized. A standard pillow was provided throughout the trials. The purpose of the pillow was to allow the participants to lie comfortably on the beds, and a similar pillow was used throughout the trials.

For each mattress, the participants were instructed to adopt 3 different postures[1]: lying on the back (in the soldier posture),[2] lying on the side, and[3] lying on the front (in the freefaller posture). The participants were asked to lie down comfortably on the mattress for 6 minutes for each posture. A single-blind approach was adopted, whereby the participants did not know the material of the mattress that they were lying on.

A pressure mat sensor (Pressure Mapping Sensor 5400N, Tekscan, Boston, MA) was first calibrated on the different mattresses using fixed weights and then used to capture the body contact pressure profiles in a video format for 6 minutes for each posture at a sampling rate of 4 Hz. The collected data were then converted to a compatible format in Matlab (MathWorks, Natick, MA) for further processing (Fig 1).

Data Processing

For the back posture, the back torso and buttocks regions were identified for pressure comparison. For the side posture, the regions were the side torso (inclusive of the upper arm and shoulder) and the buttocks. For the front posture, only the front torso (chest and stomach region) was identified. Two outcome measures were evaluated to compare the latex and polyurethane foam mattresses, namely the average peak body contact pressure in each region and the average body contact pressure distribution based on the pixelated data captured from each region. For the video, 6 frames were processed for each posture at each minute interval from 1 minute to 6 minutes, where the average peak body contact pressure were over an average of 6 frames. For the average pressure distribution, the threshold was set at 3 psi, whereas the pressure data were categorized into 10 distinct bands that identified the pressure distribution.

Statistical Analysis

A paired *t* test was used to compare the mean peak body contact pressures between the 2 mattresses in each posture. All significance levels were set at $P < .05$.

Results

Our mean body contact pressure distribution data (Figs 2-4) indicated that the latex mattress had a higher proportion of body surface area (90.9%-96.1%) in the range of 0 to 0.6 psi across all 5 identified regions compared with the polyurethane foam mattress (82.1%-91.8%). On the other hand, the polyurethane foam mattress had a higher proportion of body surface area (7.4%-14.9%) in the range of 0.6 to 1.2 psi compared with the latex mattress (3.7%-9.5%).

In terms of the mean peak body contact pressure for the back posture, the peak pressures at the back torso and back buttocks were significantly lower, by 26.1% ($P < .001$) and 28.4% ($P < .001$), respectively, for the latex mattress compared with the polyurethane foam mattress (Fig 5). For the side posture (Fig 6), the mean peak body contact pressures at the side torso and side buttocks were significantly lower, by 35.1% ($P < .001$) and 28.2% ($P < .001$) for the latex mattress, relative to the polyurethane foam mattress. For the front posture (Fig 7), the mean peak body contact pressure at the front torso was significantly lower, by 30.9% ($P < .001$) for the latex mattress, comparison with the polyurethane foam mattress.

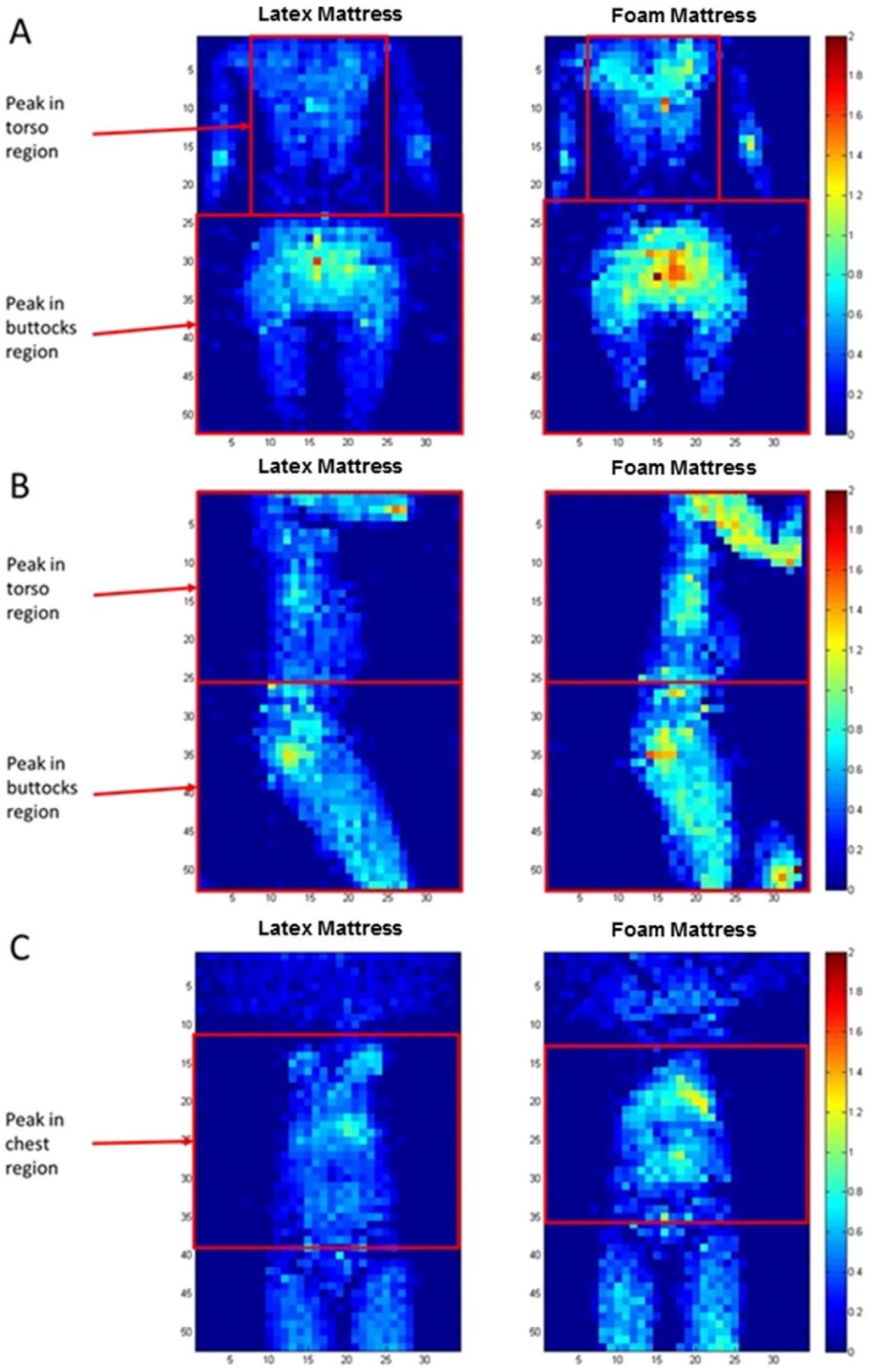
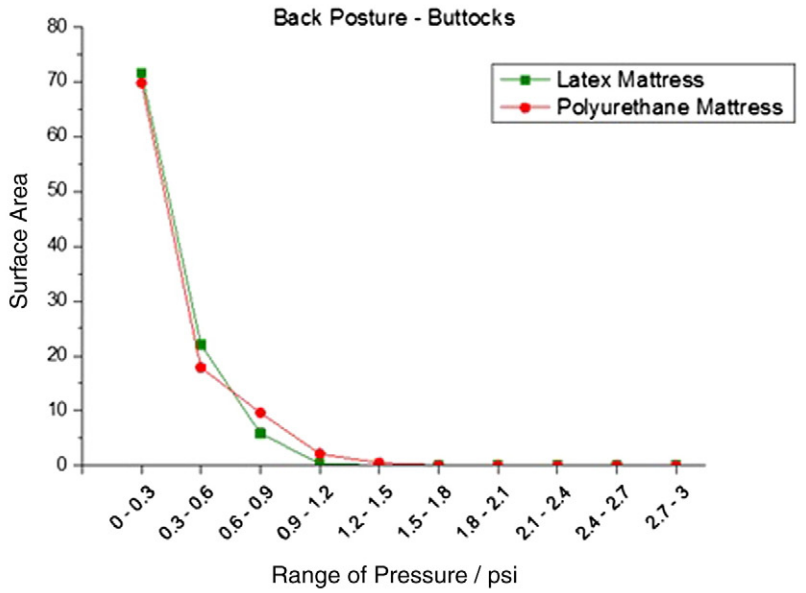


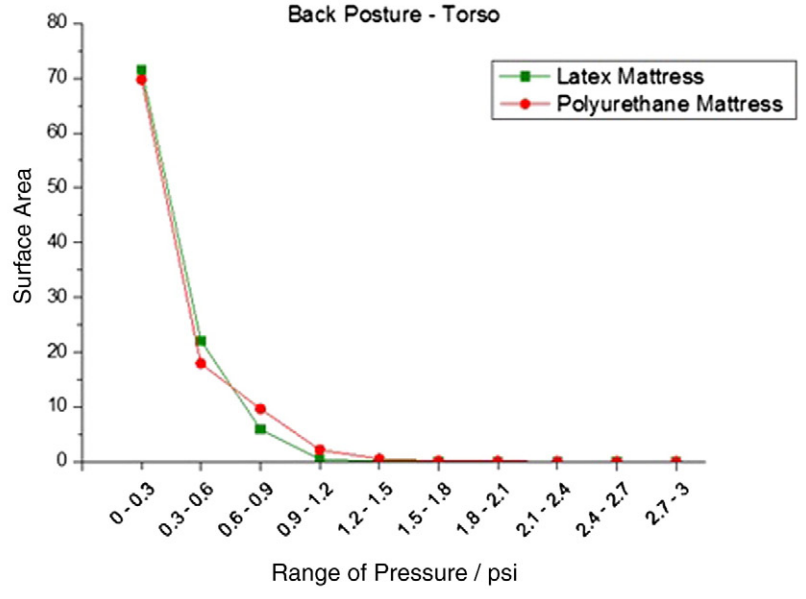
Fig 1. *(A) Regions identified in the pressure mat sensor for the back posture. (B) Regions identified for the side posture. (C) Regions identified for the back posture.*

A



	0 - 0.3	0.3 - 0.6	0.6 - 0.9	0.9 - 1.2	1.2 - 1.5	1.5 - 1.8	1.8 - 2.1	2.1 - 2.4	2.4 - 2.7	2.7 - 3.0
Latex	71.58	22.07	5.87	0.38	0.080	0.022	0	0	0	0
Polyurethane	69.77	17.87	9.62	2.13	0.49	0.082	0.022	0.011	0	0.007

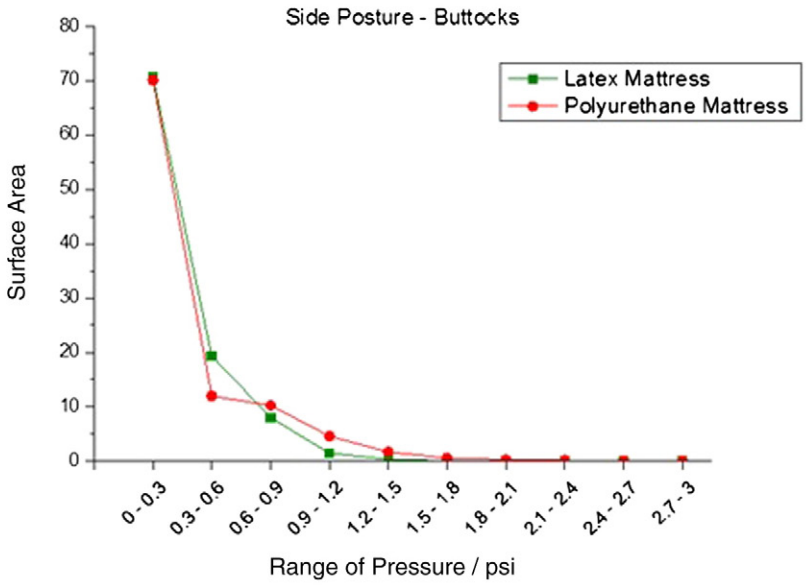
B



	0 - 0.3	0.3 - 0.6	0.6 - 0.9	0.9 - 1.2	1.2 - 1.5	1.5 - 1.8	1.8 - 2.1	2.1 - 2.4	2.4 - 2.7	2.7 - 3.0
Latex	71.58	22.07	5.87	0.38	0.080	0.022	0	0	0	0
Polyurethane	69.77	17.87	9.62	2.13	0.49	0.082	0.022	0.011	0	0.007

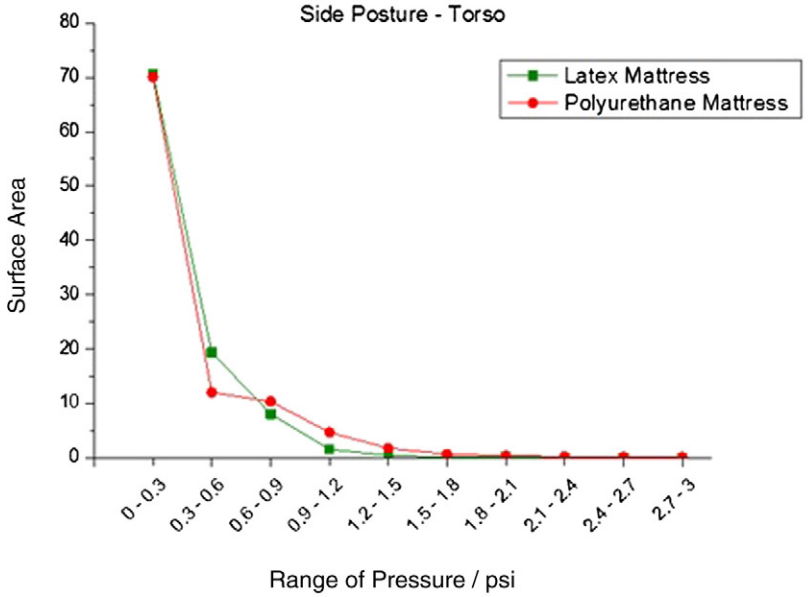
Fig 2. *Pressure distribution for the back posture at the (A) buttocks region and (B) torso region. psi, Pounds per square inch.*

A



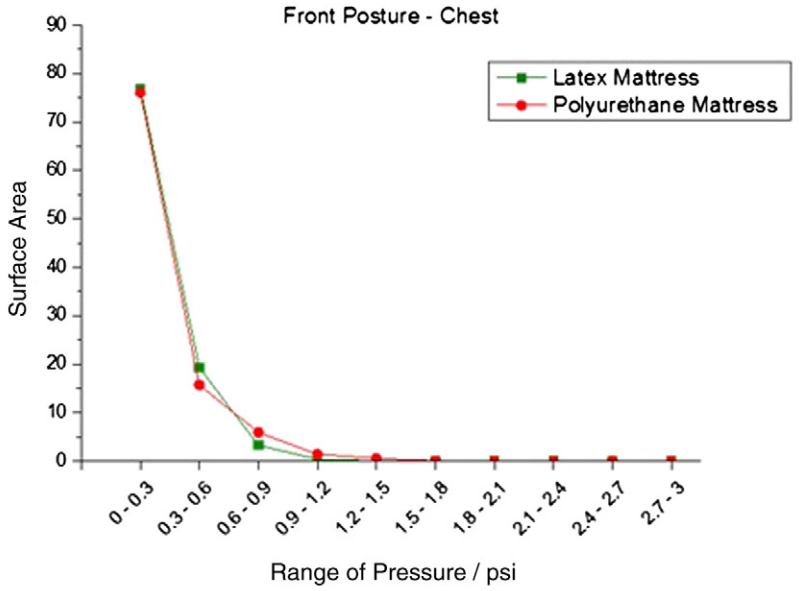
	0 - 0.3	0.3 - 0.6	0.6 - 0.9	0.9 - 1.2	1.2 - 1.5	1.5 - 1.8	1.8 - 2.1	2.1 - 2.4	2.4 - 2.7	2.7 - 3.0
Latex	70.63	19.33	8.01	1.50	0.37	0.090	0.044	0.037	0	0
Polyurethane	70.10	12.01	10.32	4.62	1.71	0.60	0.32	0.17	0.084	0.024

B



	0 - 0.3	0.3 - 0.6	0.6 - 0.9	0.9 - 1.2	1.2 - 1.5	1.5 - 1.8	1.8 - 2.1	2.1 - 2.4	2.4 - 2.7	2.7 - 3.0
Latex	70.63	19.33	8.01	1.50	0.37	0.090	0.044	0.037	0	0
Polyurethane	70.10	12.01	10.32	4.62	1.71	0.60	0.32	0.17	0.084	0.024

Fig 3. *Pressure distribution for the side posture at the (A) buttocks region and (B) torso region. psi, Pounds per square inch.*



	0 - 0.3	0.3 - 0.6	0.6 - 0.9	0.9 - 1.2	1.2 - 1.5	1.5 - 1.8	1.8 - 2.1	2.1 - 2.4	2.4 - 2.7	2.7 - 3.0
Latex	76.89	19.26	3.30	0.45	0.093	0.015	0	0	0	0
Polyurethane	76.08	15.73	5.97	1.43	0.62	0.11	0.036	0.023	0.005	0

Fig 4. *Pressure distribution for the front posture at the chest region. psi, Pounds per square inch.*

Discussion

Little is known about how a latex mattress compares with a polyurethane foam mattress in terms of body contact pressure distribution. Thus, the objective of this study was to evaluate the effect of different types of bed material (latex and polyurethane foam) on the body contact pressure profiles in various sleeping postures, using peak body pressure and pressure distribution as outcome measures. The key findings of this study are that[1] the latex mattress was able to significantly reduce peak body contact pressure on the torso and buttocks by up to 35.1% for the various sleeping postures compared with the polyurethane foam mattress, and[2] the latex mattress exhibited higher proportions (96.1%) of low-pressure regions than that of the polyurethane foam mattress (91.8%). Generally, these results clearly indicate the capability of the latex mattress to minimize high body contact pressure points while maintaining a relatively low body contact pressure profile across the different body regions across different sleeping postures and potentially giving better comfort to the user. The findings may be useful for clinics and hospitals in determining the type of mattress material suitable to improve patients' comfort and reduce risk of pressure sores caused by extended usage.

Mechanical Behavior of Latex and Its Suitability

The ability of the latex mattress to achieve a more even and lower distribution of stress regions across the body can be attributed to its mechanical properties. Ellies[28] stressed that the natural cushioning properties of latex are important for meeting comfort seat design requirements. Chiu and Shiang[29] reported that latex insoles were able to absorb 35% more impact energy than polyurethane insoles, which further highlighted the cushioning properties of latex under low-impact energy conditions. In addition, this high damping property of latex[30,31] also limits the transfer of motion to neighboring areas; hence compression to a region by a body is localized. This is critical in ensuring an even distribution of stress concentration throughout the body.

Next, the high spring-back characteristic of latex compared with polyurethane means that it maintains its original unstressed shape longer. This is reflected in a study conducted by Marchant,[32] whereby both latex and polyurethane cushions underwent dynamic indentation, and the hysteresis results indicated that latex cushions had better resilience. The high spring-back property of latex ensures that repeated use of the mattress in different positions does not cause uneven distribution of stress from residual deformities.

The low temperature sensitivity of the latex material compared with the polyurethane foam cushion is another factor that is an important consideration in the material selection of the mattress. Saunders et al[33] studied the modulus changes of both polyurethane foam and latex over a range of temperatures from –30°C to 160°C. The latex foam was relatively constant throughout the entire range,

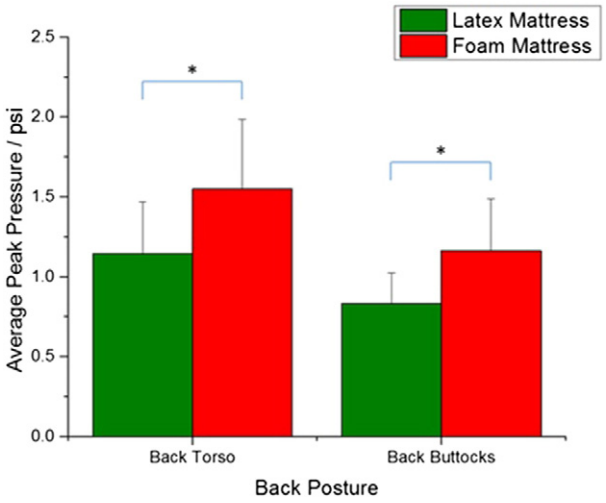


Fig 5. *Average peak pressure for the back posture where the vertical lines above the plots represent standard deviation and * indicates a significant difference with P < .05. There was a significant decrease in average peak pressure for the back torso (t(19) = –5.77, P < .001) and for the back buttocks (t(19) = –6.55, P < .001). psi, Pounds per square inch.*

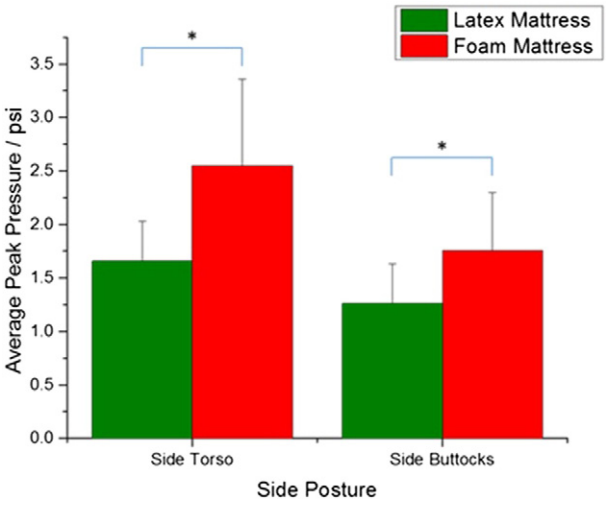


Fig 6. *Average peak pressure for the side posture where the vertical lines above the plots represent standard deviation and * indicates a significant difference with P < .05. There was a significant decrease in average peak pressure for the side torso (t(19) = –5.82, P < .001) and for the back buttocks (t(19) = –4.40, P < .001). psi, Pounds per square inch.*

whereas the polyurethane foam varied considerably. High temperature sensitivity of the modulus polyurethane foam would result in uneven distribution of material stiffness throughout the mattress. For example, regions with more contact with the user's body would be at a higher temperature (36°C) and a lower modulus, compared with regions that are in less contact with the body and hence are colder and stiffer.

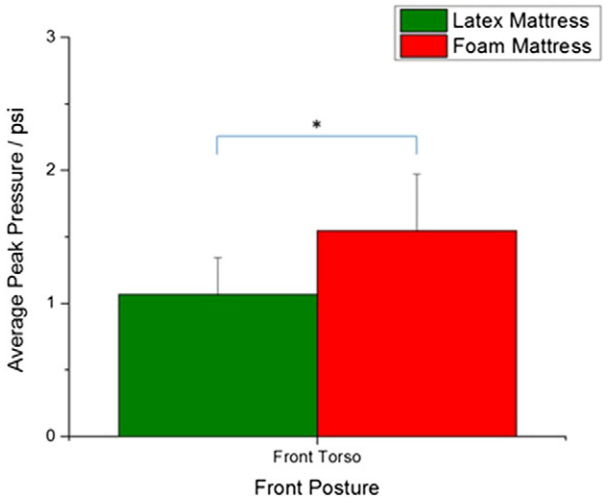


Fig 7. *Average peak pressure for the front posture where the vertical lines above the plots represent standard deviation and * indicates a significant difference with P < .05. There was a significant decrease in average peak pressure for the front torso (t(19) = –8.56, P < .001). psi, Pounds per square inch.*

Limitations

A limitation of the study is that the measurement of the body contact pressure profiles for the 2 mattress types was over only 6 minutes. The results may be different for longer periods of sleep because the viscoelastic behavior coupled with the heat transmitted from the body to the mattress may affect its mechanical properties and the resulting stress distribution on the body. A longer exposure time would be more realistic because it would include variation in pressure profiles and development of pressure sores. Future works would include longer periods of body contact pressure profile measurement over a 7-hour sleep study, which is the average nightly duration of sleep. Additional data collection, such as electroencephalography-based sleep cycles, electromyography, and qualitative questionnaires, would also be included in future works to fully compare the effect of latex and polyurethane mattresses on sleep.

Another limitation of this study is the limited number of 20 participants, which may not generate results that are accurately representative of the general population. Future works will include greater number of participants to be measured and compared.

Conclusions

Collectively, our findings indicate that participants lying on the latex mattress exhibited significantly lower mean peak body contact pressures at the front, side and back torso, and side and back buttocks for all 3 different sleeping postures than on the polyurethane foam mattress. These findings also suggest that the latex mattress exerts lower

peak pressure points to the user in the common sleeping postures, which in turn may translate into better sleep comfort and quality for the user. This information may help inform mattress materials to improve patients' comfort and to reduce risk of pressure sores caused by extended usage.

Funding Sources and Conflicts of Interest

Sofzsleep supplied the latex foam mattress for the experimental work in this paper. This study was supported in part by the Ministry of Education AcRF Tier 1 grant under Grant R-397-000-143-133. No conflicts of interest were reported for this study.

Contributorship Information

Concept development (provided idea for the research): F.Z.L., M.C.H.C., P.Y.L., C.H.Y.,

Design (planned the methods to generate the results): P.Y.L., F.Z.L.

Supervision (provided oversight, responsible for organization and implementation, writing of the manuscript): C.H.Y., M.C.H.C.

Data collection/processing (responsible for experiments, patient management, organization, or reporting data): P.Y.L., F.Z.L.

Analysis/interpretation (responsible for statistical analysis, evaluation, and presentation of the results): M.C.H.C.

Literature search (performed the literature search): F.Z.L., P.Y.L.

Writing (responsible for writing a substantive part of the manuscript): P.Y.L., M.C.H.C.

Critical review (revised manuscript for intellectual content, this does not relate to spelling and grammar checking): C.H.Y.

Practical Applications

- Latex mattresses can reduce peak body pressure compared with polyurethane mattresses across different sleeping postures.
- A higher proportion of low-pressure regions on the body was observed with a latex mattress.
- The high damping property of latex limits transfer of body motion to neighboring regions.
- The peak pressure region is typically the buttocks while sleeping in the supine and side posture.
- Hospitals should use latex mattresses for bedridden patients to reduce bedsores.

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