Comparison of Sacral Skin Temperature of Thai Adults Lying on a Thai Hospital Mattress and a Krajud Mat

Wipa Sae-Sia, Luppana Kitrungrote

Abstract : *Heat accumulation between the skin and support surface can induce high skin temperature and skin breakdown, as well as pressure ulcer development. The purpose of this crossover experimental design study was to compare the sacral skin temperatures (SSTs) of 32 healthy Thai subjects lying on a Thai hospital mattress and on a local natural leaf (Krajud) mat. Each subject's SSTs were initially measured while lateral on each support surface, then while supine for 2 hours, and then again while lateral. No significant difference was found among the subjects' baseline SSTs between the two types of support surfaces. However, the subjects' SSTs at the end of being supine for 2 hours on the hospital mattress were found to be higher than when they were on the Krajud mat ($p < 0.0001$). The decrease in SSTs while lying on the Krajud mat is attributed to the mat's cooling effect. The benefits of using Krajud mats for hospitalized and/or home-bound patients are worthy of further study.*

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Keywords: *sacral skin temperature, pressure ulcer, support surfaces, Krajud mats*

Introduction

Pressure ulcer (PU) development remains a significant healthcare problem. The most vulnerable area for a PU is the sacrum.[1] From 11.2% to 47% of medical and surgical patients in Thailand developed pressure ulcers,[2,3,4] The etiology of PU is multi-factorial. Pressure, shearing force, and friction, in combination with temperature and humidity, are the most important factors for PU development.[5-7] Previous studies have shown that prolonged pressure duration is related to heat accumulation between skin and support surfaces[4,7,8] and that this heat accumulation causes increased skin temperature.[9]

When the skin is warmed beyond approximately 33°C (depending on the core temperature), perspiration in the area markedly increases.[10, 11] Excessive moisture can diminish tissue tolerance by decreasing epidermal tissue tensile strength and the mechanical protective property of the skin layers of the stratum corneum[10,] leading to maceration, rashes and weakening of the epidermis.[5,12] Previous studies have found the mechanical strength of the stratum corneum, at a skin temperature of 35°C, to be 25% of the strength it has at 30 °C.[13] The stratum corneum has been found to be 25 times weaker, at a relative humidity of 100%, than at 50% relative humidity.[14] Excessive moisture also increases the level of friction and shearing force against the skin and support surface,[15]

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with friction and shear force doubled when the skin is over hydrated.[10] Heat accumulation between the skin and support surface can induce elevated skin temperature. As the temperature increases, moisture increases and the skin's stratum corneum becomes softer, exhibits weaker protective properties and, ultimately, leads to skin breakdown. Prior research has shown that one's sweat rate doubles for every 1.5 °C increase in skin temperature.[16,17] Regular repositioning, or turning at least every 2 hours, is considered essential nursing care those at high risk of PU development.[18,19] However, none of the previous studies was found to examine skin temperature between one's sacrum, when supine for two hours, and the supporting surface.

Histological studies, using animal models, have found severity of tissue damage to be correlated with an increase in applied temperature and pressure. Kokate and associates[20] noted damage was not observed in superficial or deep tissue among animals when a temperature of 25 °C and pressure of 100 mmHg were applied for five hours. However, they found deep tissue damage resulting among animals with 35°C heat application, while both 40°C and 45°C temperatures caused animal tissue to experience both cutaneous and subdermal damage. In addition, they reported that visible erythema and edema were present as soon as the 45°C temperature sensor was removed. Flam and Raab,[21] using thermography, noted that increased skin temperature may be an early indicator of PU development. In addition, Newman and Davis[22] found that almost half of the elderly patients studied who had increased sacral skin temperature as indicated by an abnormal thermography developed a PU within 10 days of hospital admission.

Alternating pressure air, special foam, and low air loss mattresses often are used for those at risk of PU development.[7,23] The effectiveness of the support surfaces is determined by redistribution of pressure, shear and friction management, temperature, and moisture control. Previous studies have investigated support surfaces in terms of interface pressure,[6,23,24] transcutaneous oxygen tension and blood flow.[25] Although investigations regarding skin temperature and moisture removal of various mattresses have been undertaken in the USA,[26,27] no such study is known to have been conducted in Thailand. Special PU prevention mattresses, due to their costs, usually are found only in regional and provincial hospitals. Thus, there is a need to find inexpensive support materials that help reduce or maintain one's skin temperature and remove moisture.

In southern Thailand, natural mats are usually made of Krajud leaves (Lepironia articulata (Retz) Domin), a water-sedge from the cyperaccae family[28] that grows in eastern and southern Thailand.[29] Lying on a Krajud mat reportedly provides a sense of comfort in terms of not feeling too warm or too cool.[28] Therefore, it is felt that Krajud mats need to be investigated as to whether they might be effective alternative support surfaces for maintaining one's skin temperature. No study could be located in the English language or in Thai publications regarding the examination of the skin cooling effect of Krajud mats. Thus, the purpose of this study was to compare sacral skin temperature (SST) among healthy Thai subjects when lying on a standard Thai hospital mattress and a Krajud mat for 2 hours. We hypothesize that the mean of SST of subjects lying on a Krajud mat would be lower than the SST mean of those lying on a hospital mattress.

Method

Subject and design

A crossover experimental design was employed for this study. Prior to initiating the study, human subject approval was obtained from the Ethic Committee of the researchers' university. Thirty-three individuals were recruited from an urban community in southern Thailand via posted advertisements that informed potential subjects about the study and requested their participation. Inclusion criteria required subjects to have a normal range of oxygen saturation, oral temperature, and blood pressure, and no history of cardiovascular disease, diabetes, immune system problems or peripheral vascular disease as perceived by the subjects. The researcher informed the potential subjects about the study, that their data and identity would be maintained confidentially, and that they had the right to withdraw at any time without repercussions.

Based on a pilot experiment and previous studies,[4] a sample size of 33 was sufficient to detect the significance of SST difference with a power of 80 and a significance level of 0.05. After cleaning the data, the data from 32 subjects were used for final analysis. The subjects predominantly were single (75%), Buddhist (75%), women (78.1%), with a mean age of 25.8±7.3 years and who had a high school or higher level of education (84.4%). In addition, most were non-smokers (90.6%) and non-drinkers (87.5%).

Setting

All SST measurements were taken in a non-air-conditioned, nursing skills laboratory, at the researchers' university, where the standard Thai hospital mattress used and the ambient temperature were typical of those in Thai hospital settings.

Instrumentation

A hospital mattress and a Karjud mat were the two support surfaces used to compare SSTs in this study. The typical standard Thai hospital mattress is made of coconut fiber covered with a synthetic plastic polymer. This mattress is then covered with a fitted sheet, a waterproof half sheet, and a cotton drawsheet in the lower back area to prevent the mattress from being soiled. A Krajud mat is made of dry Krajud leaves. Those dry leaves are flattened and covered with white-mud before the mat is woven.[28]

The SST of each subject was measured every 20 seconds via a t-type thermocouple skin sensor (SST-1) (Physitemp, Clifton, NJ) attached to a Dual Channel Thermocouple thermometer (Cole-Parmer Instruments, Vernon Hills, IL). An RS-232 Adapter (Cole-Parmer) allowed transfer of output from the DuaLogR System® (in the thermometer) to the laptop computer. Thermocouple probes are known to be linear in the physiologic range and are accurate to± 0.1°C (Cole-Parmer). Linearity was verified against a water bath and a mercury thermometer prior to data collection.

Room temperature and humidity were recorded before and after each SST measurement via a combination digital hygrometer/thermometer (Control Company, Friendswood, TX). All measurements were taken between 07.30 and 12.30 hours between the months of October and January.

Protocol

Prior to their SSTs being measured, subjects took off their underwear and put on standard hospital gowns, sat for 20 minutes to acclimate to the environment, and had their oral temperature, blood pressure and oxygen saturation measured. Subjects, in pairs of two, were randomly assigned a support surface to initially lie on. They then simultaneously had their SSTs measured. One was measured on the standard hospital mattress, the other on a Krajud mat. SST-1 sensors were attached, via non-allergenic tape, to their sacral area, 5 cm above the coccyx. Their lower extremities were covered with a light bath blanket in order to create a controlled micro-environment around the SST sensors. Each subject's SSTs were measured continuously for 5 minutes in the lateral position (t0), then every 30 minutes for 2 hours while supine (t1-t4), and again continuously for 5 minutes in the lateral position (t5). The subjects were given a

20-minute break after the measurements on their initial support surface to allow their skin's microvasculature function to return to baseline prior to lying on the other support surface. Each subject then was asked to lie on the other support surface and the same measurement procedure again was followed. Subjects spent approximately 4.5 hours in the laboratory setting.

Data analysis

Descriptive data were analyzed using percentages, means, and standard deviations. The inferential statistics of paired t-tests, independent t-tests, and repeated analysis of variances were used for the SST data. The level of significance was set at $p < 0.05$.

Results

Environmental monitoring

The ambient temperature at completion of all measurements (30.1± 0.7 °C) was slightly higher than at the beginning of the measurements (28.8± 0.8°C) ($t_{(31)} = -8.0$, $p < 0.001$). The mean humidity at the end of the measurements (66.0±6.4%) was significantly lower than the mean humidity at the beginning of the measurements (72.3±5.2%) ($t_{(28)} = 6.4$, $p < 0.001$).

Sacral skin temperature differences between the two different support surfaces

No significant difference in SST ($t_{(62)} = -0.02$, $p = 0.99$) was found between the hospital mattress (34.25±0.8°C) and the Krajud mat (34.25±1.1°C) when subjects were initially lateral (t0). However, a significant difference was found in the mean SST, by group, when subjects were supine for 2 hours on the hospital mattress and on the Krajud mat ($F_{(1,62)} = 37.8$, $p < 0.0001$), by time ($F_{(4,248)} = 264.7$, $p < 0.0001$) and a group by time interaction ($F_{(4,248)} = 38.9$, $p < 0.001$) **(Figure 1)**. The mean SST at the end of the subjects being supine for 2 hours (t4) revealed their mean SST on the hospital mattress to be higher (36.40±0.3°C) than on the Krajud mat during the same period (35.19±0.4°C) ($p < 0.0001$) **(Figure 1).**

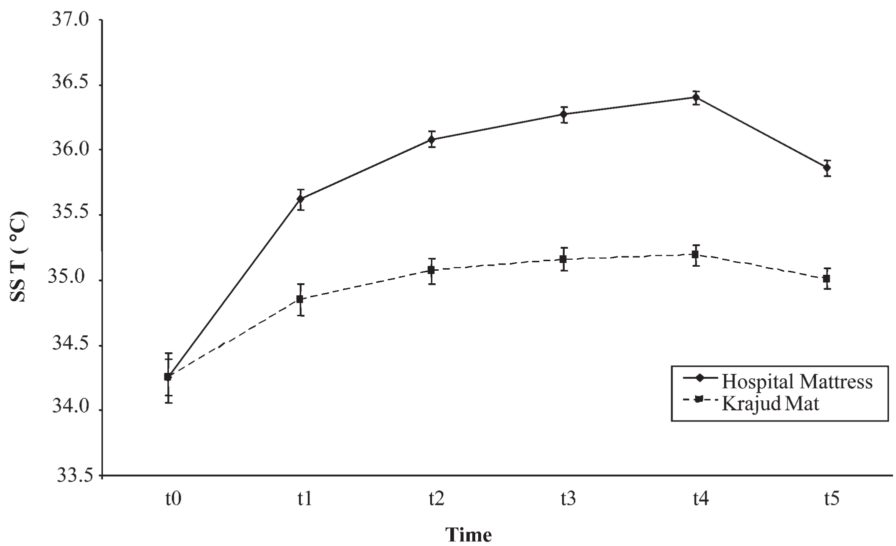

Figure1 Mean ± SE sacral skin temperature from baseline in the lateral position (t0), after 30 (t1), 60 (t2), 90 (t3), 120 (t4) minutes lying on supine position, and after turning to the lateral position (t5) ($p < 0.0001$) ($n = 32$)

After the subjects turned from being supine to being lateral for 5 minutes, the mean SST (t5) on the Krajud mat and on the hospital mattress was significantly different ($t_{(31)} = -9.8$, $p < 0.0001$). The mean SST when the subjects were laterally on the hospital mattress (35.9±0.3°C) was significantly higher than for those on the Krajud mat (35.0±0.5°C). **(Figure 1).**

The results showed the same direction of the mean SST lying on the two different support surfaces when subjects either participated in the early morning or in the late morning. In the early morning (08.00 to 10.00 hours), the mean SST between groups at the end of being supine for 2 hours on the Krajud mat was significantly lower than that of those on the hospital mattress. In the late morning, the mean SST at the end of being supine for 2 hours (10.30 to 12.30 hours) was also significantly different. The mean SST when the subjects were supine on the Krajud mat was lower than that of those on the hospital mattress **(Table 1).**

Table 1 Mean and standard deviation (SD) of sacral skin temperature while subjects participating in the early morning and late morning (n =32)

Time	Hospital Mattress Mean ± SD	Krajud Mat Mean ± SD	p value
Early morning	35.77 ± 0.3°C	34.75 ± 0.4°C	< 0.0001
Late morning	35.95 ± 0.3°C	35.20 ± 0.4°C	< 0.0001

There was a significant difference in the mean difference between the SST and the support surface temperature by group ($F_{(1,60)} = 56.0$, $p < 0.0001$), by time ($F_{(4,57)} = 49.0$, $p < 0.0001$), and a group by time interaction ($F_{(4,57)} = 4.2$, $p < 0.005$). The higher mean difference was found between the SST and the Krajud mat compared to that found between the SST and the hospital mattress **(Figure 2).**

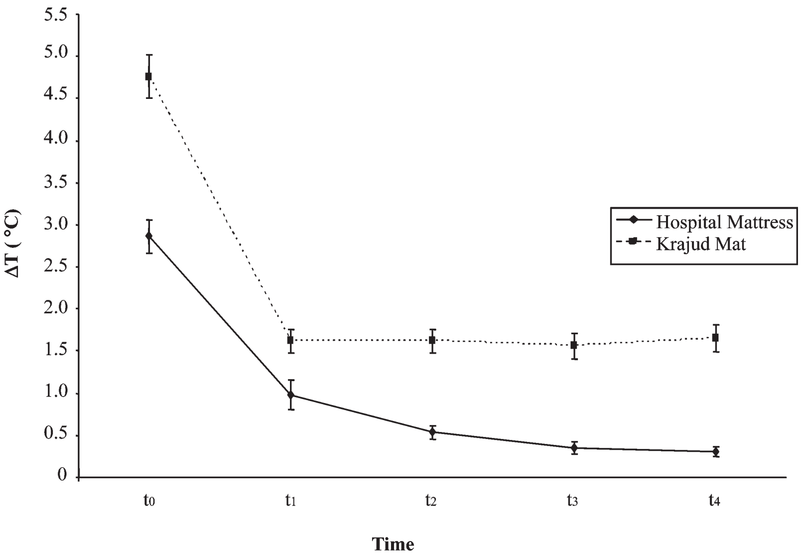

Figure 2 Mean difference ± SE between sacral skin temperature and material temperature when subjects lying on the lateral position (baseline, t0) and after 30 (t1), 60 (t2), 90 (t3), and 120 (t4) min lying on supine position (p < 0.005) (n = 32).

Discussion

The findings reveal that the SST when subjects were supine on the Krajud mat was significantly lower than when supine on the hospital mattress for 2 hours. The mean SST varied 1.2°C between the two support surfaces when subjects were supine. Although the mean SST of 35.2°C on the Krajud mat was out of the recommended "safe zone" for preventing skin breakdown in animal studies, applicability of animal findings to humans is questionable. However, a SST of 35.2°C produced while supine on a Krajud mat for 2 hours more likely will prevent skin breakdown than being supine for the same time on a standard Thai hospital mattress that produces a higher SST (36.4°C).

The skin cooling effect of the Krajud mat may be related to the characteristics of the Krajud leaves and the mat structure. Electron microscopy of Krajud leaves has found them to have a looser structure (higher porosity) than the plastic covering used on standard hospital beds (Scientific Equipment Center, Prince of Songkla University). Krajud mats are made of Krajud leaves placed together, thereby producing air space between each strip. Thus, the Krajud leaf's loose structure, as well as the space between the strips of leaves in the mats, may facilitate heat transfer from one's skin to the environment.

One also should not ignore the water absorption properties of a Krajud mat,[30] which may facilitate absorption of sweat (produced by an increased SST between skin and the mat). Although no study could be located that directly has examined the moisture absorption rate of Krajud mats, it is known that Krajud mats absorb polluted water better than do other materials.[30] Comparison of the water absorption rate of the Krajud mat and the plastic covering the standard hospital bed used in this study revealed the mat (293.85 g/m^2) to have a water absorption rate 732 times greater than the plastic (0.41 g/m^2) (Cobb Method, ISO 535, laboratory center, Faculty of Argo-Industry, Prince of Songkla University).

Since skin temperature is affected by ambient temperature, humidity, and moisture, it is less likely that the difference found in the SSTs when supine between the mat and bed was due to differences in ambient temperature and humidity. The higher room temperature at the end of the experiments was due to the fact that the measurements were undertaken at midday, when the room temperature was slightly higher than the room temperature in the early morning, when the measurements began. The lower humidity at the end of the experiment corresponded to the higher room temperature of midday. This is most interesting when recognizing that within the same ambient temperature and humidity, subjects supine on the Krajud mat also had a lower mean SST compared to those supine on the plastic covered hospital mattress.

One can not overlook the fact that skin temperature also is affected by the specific heat of the cover and the composition of the support surface.[15] Standard Thai hospital mattresses generally are made of coconut fiber and covered with plastic, which has heat insulation properties and facilitates increased heat flux and relative humidity secondary to perspiration.[31] In addition, being supine on a standard Thai hospital mattress may lead to increased shear and friction force and thus increase the risk of PU development. However, since the surface area of a Krajud mat is soft, smooth, and has a spongy morphological structure, shear and friction should be less than that of a standard Thai hospital mattress.

The higher mean difference found between the SST and the Krajud mat, from the initial lateral measurement to the end of being supine for 2 hours compared to the mean difference between the SST and the hospital mattress, also supports the belief that Krajud mats have good air ventilation properties. Higher temperature differences between skin surface and support surface are known to result in increased heat transfer from the skin to the support surface.[32] The findings of this study show that the temperature gradient between the subjects' sacral area and the Krajud mat was greater (T = 1.7 °C) than that between their sacral area and the hospital mattress (T = 0.3°C). Heat appears to have been transferred more quickly when the subjects were supine on the Krajud mat than when they were supine on the hospital mattress. A significant increase was noted in the SST increments from the initial lateral measurement to each 30 minutes of being supine on the hospital mattress compared to being supine on the Krajud mat. This finding suggests that the longer a patient lies on a standard Thai hospital mattress, the greater the increase of his/her SSTs. On the other hand, the SSTs from initial lateral measurement to each 30 minutes of being supine on the Krajud mat were rather constant over 2 hours. According to Dubois,[33] body temperature elevation of 1 °C increases tissue metabolism by 10%. Therefore, it would be assumed that tissue metabolism and waste products increase less when one is supine on a Krajud mat compared to being supine on a plastic-covered hospital mattress. The findings of this study suggest that lying on Krajud mat may prevent increased SST and reduce the risk of skin breakdown if other related risk factors are managed.

Conclusions and Limitations

The findings of this study provide evidence that a Krajud mat has a skin cooling effect when a health subject is supine for 2 hours. Thus, Krajud mats would be considered for use as a support surface material for mobility, sensory and motor function impaired home-based and hospitalized patients, as well as those with a chronic illness. The reduction of one's SST, wherein PU commonly develops, may reduce the risk of PU formation. In addition, pressure loading, shear force, nutritional status, moisture, and hydration status should be addressed and managed. Additional studies are needed to examine the skin cooling effect of Krajud mats among high risk people.

Generalization of these findings needs to be approached with caution, since ambient temperature and humidity were not controlled and could have influenced the findings. Therefore, they should be controlled in future studies.

In addition, Krajud leaves might be an alternative cover for hospital mattresses used in Thailand instead of the plastic covering currently used, especially for those at high risk of PU development. However, further study is needed regarding the skin cooling effect of Krajud mats and PU incidence among high-risk individuals. Since Krajud mats are made from readily available, natural material, they may be an inexpensive, cost-effective support surface for home-bound patients.

Although the findings of this study may not readily be generalized to home-based or hospitalized patients due to the limitation of different sample characteristics, they provide fundamental evidence that Krajud mats have better skin cooling properties than standard Thai hospital mattresses. The implications of these findings need to be applied to clinical settings after future study of the effect of Krajud mats on skin cooling among hospitalized and home-based patients.

The findings of this study also suggest that more frequent turning intervals would reduce tissue metabolic waste products from increasing the SSTs, especially when patients lie on a hospital mattress with a plastic covered sheet. For example, a turning interval every 1 hour could reduce the amount of tissue metabolic waste products better than turning every 2 hours. However, further study is needed.

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การเปรียบเทียบอุณหภูมิผิวหนังบริเวณก้นกบของคนไทยที่มีสุขภาพดีขณะนอนบนเบาะโรงพยาบาลและบนเสื่อกระจูด

วิภา แซ่เซี้ย, ลัพณา กิจรุ่งโรจน์

บทคัดย่อ: อุณหภูมิที่เพิ่มขึ้นจากการสะสมความร้อนระหว่างผิวหนังกับที่รองรับเป็นปัจจัยหนึ่งที่ทำให้ผิวหนังถูกทำลายและเกิดแผลกดทับได้ การวิจัยแบบสลับเปลี่ยน (crossover) ครั้งนี้มีวัตถุประสงค์เพื่อเปรียบเทียบอุณหภูมิผิวหนังบริเวณก้นกบของกลุ่มตัวอย่างที่มีสุขภาพดี 32 คนขณะนอนบนเบาะโรงพยาบาลและบนเสื่อกระจูด กลุ่มตัวอย่างแต่ละคนได้รับการวัดอุณหภูมิผิวหนังบริเวณก้นกบขณะนอนบนที่รองรับแต่ละประเภท ในท่าตะแคง ท่านอนหงาย 2 ชั่วโมงและท่านอนตะแคงอีกครั้ง ผลการวิจัยพบว่าไม่มีความแตกต่างอย่างมีนัยสำคัญของค่าพื้นฐานของอุณหภูมิผิวหนังบริเวณก้นกบของกลุ่มตัวอย่างในขณะนอนท่าตะแคงบนที่รองรับทั้งสองประเภท แต่พบว่าอุณหภูมิผิวหนังบริเวณก้นกบของกลุ่มตัวอย่างเมื่อนอนหงายบนเบาะโรงพยาบาลครบ 2 ชั่วโมงสูงกว่าอุณหภูมิผิวหนังบริเวณก้นกบเมื่อนอนหงายบนเสื่อกระจูดอย่างมีนัยสำคัญ ($p < 0.0001$) การลดลงของอุณหภูมิผิวหนังบริเวณก้นกบขณะนอนหงายบนเสื่อกระจูดเป็นผลมาจากความเย็นของเสื่อกระจูด การวิจัยครั้งต่อไปจึงควรมีการศึกษาถึงประโยชน์ของการนำเสื่อกระจูดไปใช้กับผู้ป่วยที่อยู่ในโรงพยาบาลและหรืออยู่ที่บ้าน

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