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ORIGINAL ARTICLE

Microclimate and development of pressure ulcers and superficial skin changes

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Abstract

This study aims to evaluate the microclimate and development of pressure ulcers and superficial skin changes. A prospective cohort study was conducted in an acute care ward in Indonesia. Risk factors for pressure ulcers and superficial skin changes were identified based on the Bergstrom Braden conceptual model. Microclimate data were collected every 3 days for 15 days while the development of pressure ulcers and superficial skin changes was observed every day. Pressure ulcers and superficial skin changes were developed in 20 of the 71 participants. Total mean difference in skin temperature was higher for patients with pressure ulcers and superficial skin changes ($0{\cdot}9 \pm 0{\cdot}6^{\circ}$C) compared with controls ($0{\cdot}6 \pm 0{\cdot}8^{\circ}$C) ($P = 0{\cdot}071$). Binary logistic regression predictor values for pressure ulcers and superficial skin changes were 0·111 for type of sheet and 0·347 for Braden Scale results. In conclusion, difference in skin temperature seems to be a predictor for pressure ulcer development and superficial skin changes, while synthetic fibre sheets are able to maintain a beneficial microclimate.

Introduction

Pressure ulcers have become a global problem in both Western and Asian countries, developed and developing countries and in all health care settings. In 2006, the prevalence of pressure ulcers in Europe was 18·1% (1) and in the United States, it was 15%, with an incidence of 7% (2). However, in 2008, the incidence of pressure ulcers in Indonesia was 28·4% (3), which is higher than other areas in Asia, such as Hong Kong with an incidence of 25·16% (4) and Japan with an incidence of 3·64% (5).

According to Bergstrom Braden conceptual model (6), development of pressure ulcers is based on two primary factors: pressure and tissue tolerance. The pressure factor is determined by intensity and duration, whereas tissue tolerance is commonly influenced by intrinsic factors (from the patients) and extrinsic factors (from the external environment). Until now, a preventive approach was only based on pressure factors, which focused in two modalities in clinical settings: turning position and application of expensive support surfaces. Meanwhile, exploration into tissue tolerance seems to have been overlooked.

Key Messages

- pressure ulcers have become a global burden in both developed and developing countries; however, several contributing or confounding factors of pressure ulcers are still unknown.
- thus, the aim of this study was to evaluate the role of microclimate in development of pressure ulcers and superficial skin changes and to validate the role of hospital bed sheet to reduce incidence of pressure ulcers and superficial skin changes
- the first step of analysis was to investigate microclimate status between pressure ulcers and skin changes group compared with normal skin group. Independent *t*-test confirmed that the skin temperature status between groups ($P = 0{\cdot}07$) was marginally significant. Further

analysis conducted using binary logistic regression confirmed the role of hospital bed sheet with the odds ratio of 0·111 and a 95% confidence interval (CI) of 0·012–1·032
- our finding confirmed that development of pressure ulcers and superficial skin changes are related to increasing of microclimate status (skin temperature); besides, hospital bed sheet has a potential role to reduce incidence of pressure ulcers and superficial skin changes by creating physiological microclimate environment
- this study illuminated a new pathological process in pressure ulcers development and also suggested a new modality to prevent pressure ulcers

In 2009, European Pressure Ulcer Advisory Panel (EPUAP) and National Pressure Ulcer Advisory Panel (NPUAP) redefined the definition of pressure ulcers as a localised injury to the skin and/or underlying tissue usually over a bony prominence, as a result of pressure, or pressure in combination with shear (2). However, this new definition and classification system have not elucidated the scope of the problems. Moreover, these two important pressure ulcer advisory panel agree that several contributing or confounding factors are still unknown; hence, this research is important to investigate the role of microclimate on pressure ulcers development.

According to Gefen's mathematical model, microclimate conditions will affect skin tolerance leading to superficial skin changes (7). The terms of superficial skin changes also has been proposed by the Shifting the Original Paradigm Expert (8). Using the term 'superficial skin changes', we also capture blanchable erythema, maceration, dermatitis, and categories I and II pressure ulcers in this study.

Microclimate concept

Nowadays, the microclimate (external environment) between patient's skin and support surfaces has been recognised as a missing factor in the pathological process of pressure ulcers (9,10). At present, microclimate refers to skin temperature and skin moisture (9), but it may or may not include air movement (10). However, in this study, we consider microclimate to mean skin temperature and skin moisture between patient's skin and support surface.

Skin temperature

Previous studies have investigated skin temperature as the quantitative measurement of pressure ulcer development (11–16) and some more studies found that development of diabetic ulcers (17–19) and chronic venous diseases (20–22) can also be predicted by skin temperature. As a microclimate variable, skin temperature has been correlated with the level of tissue injury in animal study (23) and in human study, it has been shown to increase by 1·2°C in 24–96 hours before pressure ulcers develop (24).

Skin moisture

Presence of moisture has been known as the subjective indicator of pressure ulcer development, as it used as a subscale of Braden Scale (6) and a quantitative measurement to predict pressure ulcers (25). Increased skin moisture also contributes to maceration and skin breakdown (26), it weakens the stratum corneum, leading to skin damage by external forces (27). Moreover, a positive linear correlation has been found between skin moisture and the coefficient of friction (28). Conversely, an excessive dryness of the skin leads to damage by cracking (29).

Interaction between skin and textiles

In addition, any surface that has contact with the skin has a potential to alter the microclimate (30), including the contact between textiles and skin (29,31). Thus, the bed climate has an important function in preventing pressure ulcers (32). In fact, most standard hospital beds are covered by plastic, which is an impermeable barrier. Although a plastic bed cover is useful for protecting a mattress (33), it cannot maintain a good physiological microclimate (34). Therefore, the purpose of this study was to evaluate the relationship between microclimate and the development of pressure ulcers and superficial skin changes.

Methods

Research design

This was a cohort prospective study with purposive sampling.

Settings and participants

The research was conducted in an acute care setting in Wahidin Sudirohusodo Hospital, Makassar, a regional hospital which served eastern Indonesia during dry season (March to October 2012). This ward has 354 beds with each room containing 4–6 beds. The hospital bed dimensions were $190 \times 90 \times 13$ cm (length, wide and thick), made from foam mattress and covered by plastic. The hospital beds' mattress was covered by 100% cotton sheet. In this study, we also used synthetic fibre sheets randomly, which were made up of 42% cotton and 58% polyester.

Average room temperature of 30°C and room humidity of 60% were the ventilation systems based on windows without using air conditioning. As there is no information about cut-off point of Braden Scale in acute care setting in Indonesia, we used a Braden Scale score of 18 or lower (at risk) as the inclusion criteria. Patients aged 18 years or above, and with no presence or history of pressure ulcers and/or skin changes on admission day were included. Exclusion criteria were refused to participate and contraindication for lateral turning. Patients and/or family members gave an informed consent. The skin colour of the participants is Asian colour with yellow or brown without dark skin tones.

Data collection

Factors associated with pressure ulcers development were investigated based on the Bergstrom Braden frame

concept (6). Data were collected through patient measurements, medical records, and observation of each patient and the environment. These data included demographic data (age, gender, medical diagnosis), Braden Scale, underpad status, interface pressure, type of bed, vital signs (blood pressure, pulse, respiratory rate and body temperature), room climate (room temperature and humidity) and microclimate (skin temperature and skin moisture).

Microclimate was measured at the sacrum area as the targeted area and at periumbilical skin as the control site. To identify targeted area, we made an imaginary line connecting the spina iliaca anterior superior dextra and sinistra. The observed area was 5 cm below this line alongside the midvertebralis line. Meanwhile, we measured the periumbilical skin area within 5 cm in diameter as the control area.

Room climate (temperature and humidity), type of bed sheet and vital signs were also recorded. First, we measured skin temperature and skin moisture at the periumbilical area as the control area. Then, participants' skin temperature and skin moisture at the sacral area were measured. We put a multipad sensor on the sacral area to record the interface pressure. These measurements were repeated every 3 days from admission until the 15th day, or whenever pressure ulcers and superficial skin changes occurred. Daily skin inspections were performed to identify the development of pressure ulcers and superficial skin changes.

Instruments used

Interface pressure was measured using a multipad sensor (Palm-Q, Kanagawa, Japan). This device has five sensors with a range of 0–200 mmHg and an accuracy of ±3 mmHg. Skin temperature was measured using an infrared digital thermometer (Raytek ST 60; Fluke Company, Santa Cruz, CA) with a measurement ranging from 30 to 600°C and an accuracy of ±1%. This thermometer was a non contact sensor, so we used a 7-cm guideline between the sensor and the skin to maintain the same relative distance on different days. Skin moisture was measured using a Corneometer® CM 825 (Courage+Khazaka Electronic GmbH, Koln, Germany). The measuring system is based on capacitance measurement of a dielectric medium with a measurement time of 1 second. This device has an accuracy of ±3 arbitrary units (au) and a range of 0–120 au. Room climate (temperature and humidity) was recorded using a hygrometer. When participants left their beds, we delayed measuring for at least 15 minutes for acclimatisation. All measurements were taken between 08:00 AM and 12:00 AM to avoid the circadian rhythm effect.

Pressure ulcers development was evaluated based on the EPUAP staging systems and the category of superficial skin changes was evaluated by a wound expert panel. Daily skin observation was performed to evaluate the development of pressure ulcers. Determination between non blanchable erythema and blanchable erythema was conducted by finger pressure or transparent plastic at the erythematous area. To reduce bias, all measurements and observations were made by single investigator.

Ethical considerations

This study was conducted with an approval from the ethics committee of the Department of Medical Sciences, Kanazawa University (Ref. No. 301) and Wahidin Sudirohusodo Hospital (Ref. No. LB.3·2/3·2.2/00221/2011). The study purpose and procedures were explained orally to participants and their family members before they gave their informed consent; moreover, participants had the right to drop out from the research without giving any explanation.

Data analysis

Skin temperature, skin moisture and interface pressure data were averaged from at least three values within the range of measuring devices to obtain daily mean. Then we calculated total mean days by using daily mean as numerator and number of observation days as denominator. Since another data were single data, we directly calculated total means.

Descriptive data were analysed using univariate analysis to delineate the characteristics of the participants. The Chi-square test and the Fisher's exact test were performed to evaluate patient characteristics between the group of patients with superficial skin changes and without skin changes.

Furthermore, we used the independent t-test to evaluate the role of the microclimate between the group with pressure ulcers and superficial skin changes and the group with no skin changes. All descriptive data were identified as n (%), while continuous data were identified as mean ± standard deviation. To predict the development of pressure ulcers and superficial skin changes against independent variables, we used binary logistic regression analysis. In the univariate analysis, we established $P = 0{\cdot}05$ as the level of significance, whereas in multivariate analysis, all variables with $P = 0{\cdot}1$ were entered into binary logistic regression. All statistical analyses were performed using the Statistical Package of Social Sciences (SPSS) version 16·0 software (SPSS Inc., Chicago, IL).

Results

Of the assessed 188 participants, we excluded 102 for several reasons: 29 already had pressure ulcers, 19 declined to participate, 33 had pain, 1 had skin maceration, 19 had critical health conditions and 1 was uncooperative. Thus, 86 participants were included and received informed consent; however, at the end of study, only 71 participants remained. Twenty had pressure ulcers and superficial skin changes while 51 had no skin changes. The most common wound type was category II pressure ulcer ($n = 6$, 30·0%) (Table 1) and the most common location was in the lower sacral area ($n = 11$, 47·8%) (Table 2).

There was a significant difference in gender between those with pressure ulcers and superficial skin changes versus those with no skin changes ($P = 0{\cdot}010$). An independent t-test showed that the total mean Braden Scale score was lower in the group with pressure ulcers and superficial skin changes ($M = 10{\cdot}8$, SD = ±2·2) compared with the group with no skin changes ($M = 15$, SD = ±1·7) ($P < 0{\cdot}000$). All of the subscale Braden Scale scores showed a significant difference

Table 1 Type of skin changes

Type of skin changes	*n* (%)
Pressure ulcer category I	5 (25·0)
Pressure ulcer category II	6 (30·0)
Blanchable erythema	5 (25·0)
Maceration	3 (15·0)
Dermatitis	1 (15·0)

Table 2 Distribution of skin changes based on locations

Locations	*n* (%)*
Lower sacrum	11 (47·8)
Sacrum	6 (26·2)
Buttock	2 (8·7)
Trochanter	3 (13·0)
Lumbar	1 (14·3)

*Some participants have skin changes in more than one location.

of $P < 0{\cdot}05$ (Table 3). In a comparison of the total skin temperature difference between the sacrum and the control area, the difference was marginally significant in the group with superficial skin changes compared with that in the group with no skin changes ($P = 0{\cdot}071$) (Table 4).

From all of the significant differences, we performed multivariate analysis using the binary logistic regression backward mode at the significance level of $P = 0{\cdot}1$. After adjustment, the variables of gender, type of sheet, underpad and total mean difference were excluded and two risk factors remained: type of sheet and Braden Scale score. Type of sheet had an odds ratio of 0·111 and a 95% confidence interval (CI) of 0·012–1·032. The Braden Scale score had an odds ratio of 0·347 and a 95% CI of 0·206–0·585 (Table 5).

Discussion

To the best of our knowledge, this research represents one of the few microclimate studies in clinical setting. As mentioned in the literature review, several studies have investigated microclimate in clinical setting (24,25), another studies have investigated skin temperature in laboratory setting (34–35) and other studies have used mathematical models to explore skin temperature (7,36) in correlation with development of pressure ulcers.

Table 3 Demographics and characteristics of patients with skin change development

Participants characteristics	Skin changes ($n = 20$)	No skin changes ($n = 51$)	*P*-value
Age, mean ± SD	51·7 ± 16·4	48·8 ± 14·5	0·483
Gender, *n* (%)			
Male	7(35·0)	35(68·6)	0·010
Female	13(65·0)	16(31·4)	
Braden score (mean ± SD)	10·8 ± 2·2	15·0 ± 1·7	0·000
Sensory perception	2·6 ± 1·1	3·2 ± 0·8	0·024
Moisture	1·8 ± 0·4	3·1 ± 0·5	0·000
Activity	1·0 ± 0·2	1·3 ± 0·5	0·007
Mobility	1·7 ± 0·5	2·4 ± 0·6	0·000
Nutrition	2·5 ± 0·6	3·0 ± 0·4	0·006
Friction and shear	1·2 ± 0·4	2·0 ± 0·2	0·000

Pressure ulcers and superficial skin changes

In this study, we found that the most common anatomic location of pressure ulcers and superficial skin changes was in the lower sacrum region (coxygeus, intertriginous; 27%), similiar with previous study (37). It can be understood by the fact that impact of high pressure over bony prominences leads to internal damage (38), while influence of microclimate leads to a decrease in skin tolerance, which results in superficial skin problems (7). Thus, in correlation with Bergstom Braden conceptual concept, microclimate seems to be related to skin tolerance problems (6).

A previous prevalence study conducted in USA found that in acute care setting, the classified 86 ulcers were categorised as unspecified ulcers (37). There were still ongoing discussion on how to differentiate pressure ulcers and other superficial skin problems, such as moisture lesion, incontinence-associated dermatitis, intertriginous dermatitis and moisture-associated skin damage (39–43). Hence, in this study, we use superficial skin changes as a proposed term by SOPE expert panel (8) to denote non pressure ulcers findings.

Additionally, we found that the mean Braden Scale score was lower in the group with pressure ulcers and superficial skin changes than in the group with no skin changes ($10{\cdot}8 \pm 2{\cdot}2$ and $15{\cdot}0 \pm 1{\cdot}7$; $P < 0{\cdot}00$). In Indonesia, the Braden Scale has been translated into Indonesian and has been demonstrated to have a sensitivity of 80% and a specificity of 54% with a cut-off point of 12 in Intensive Care Units (44). We also found that the Braden Scale has an odds ratio of 0·347 with a negative coefficient, meaning that an increasing Braden Scale score indicates a reduced risk of pressure ulcers.

Microclimate findings

Using infrared thermography, skin temperature has been reported to have high correlation ($r = 0{\cdot}999$) in comparison with contact sensor and high reliability (0·937) (13). In this study, we found that skin temperature can be used to identify the risk of pressure ulcer development and superficial skin changes. We found that total skin temperature differences among groups were marginally significant ($P = 0{\cdot}071$). This finding is consistent with Sae-Sia *et al.* (24) who found that skin temperature increases by 1·2°C in 24–96 hours before pressure ulcers develop.

As postulated by Sae-Sia *et al.* (24), there are two possible linking for increasing temperature: first, prolonged pressure from body weight at sacrum point results in occlusive skin blood flow leading to inflammation and second, accumulation between sacrum skin and support surfaces (24). In this study, all of the hospital beds are foam mattress, covered by plastic, which possibly create heat accumulation between patient skin and support surfaces. Moreover, average macroclimate (room) temperature of 30°C also stimulated increasing microclimate temperature.

Table 4 Univariate analysis of risk factors for skin change development

Risk factors	Skin changes ($n=20$)	No skin changes ($n=51$)	*P*-value
Total means sacrum temperature (°C), mean ± SD	38·6 ± 0·7	38·4 ± 0·8	0·331
Total means sacrum moisture (au), mean ± SD	45·8 ± 19·8	49·3 ± 17·3	0·464
Total means umbilicus temperature (°C), mean ± SD	37·6 ± 0·9	37·7 ± 0·9	0·570
Total means umbilicus moisture (au), mean ± SD	38·8 ± 18·6	44·9 ± 17·4	0·197
Total difference skin temperature (°C), mean ± SD*	0·9 ± 0·6	0·6 ± 0·8	0·071
Total difference sacrum moisture (au), mean ± SD**	6·9 ± 18·1	4·3 ± 19·0	0·615
Total maximum interface pressure (mmHg), mean ± SD	42·5 ± 21·6†	29·8 ± 11·2‡	0·077
Total mean room temperature (°C), mean ± SD	29·5 ± 1·5	29·8 ± 1·5	0·451
Total mean room moisture (%), mean ± SD	68·4 ± 7·9	66·4 ± 5·7	0·255
Total mean body temperature (°C), mean ± SD	37·0 ± 0·5	36·9 ± 0·7	0·537
Total mean pulse, mean ± SD	82·6 ± 9·9	78·9 ± 16·5	0·357
Total mean systolic blood pressure (mmHg), mean ± SD	131·5 ± 34·1	135·2 ± 28·9	0·652
Total mean diastolic blood pressure (mmHg), mean ± SD	85·6 ± 21·0	85·1 ± 18·9	0·927
Total mean respiratory rate, mean ± SD	22·4 ± 4·3	23·3 ± 4·8	0·480

*Total difference temperature = (mean sacrum temperature) − (mean periumbilical temperature).
**Total difference moisture = (mean sacrum moisture) − (mean periumbilical moisture).
†$n=13$.
‡$n=20$.

Table 5 Multivariate analysis of risk factors for skin change development

	β	*P*-value	Exp(B)	95% CI
Type of sheet	−2·194	0·053	0·111	0·012–1·032
Total mean Braden score	−1·057	0·000	0·347	0·206–0·585
Constant	13·620	0·000	8·228	

Corneometer has been known as a gold standard in measuring skin hydration; however, we are unable to demonstrate the role of skin moisture in the development of pressure ulcers and superficial skin changes. This is because the average room temperature was higher as 30°C and the average room humidity was 60%, which lead to high perspiration on sacrum area in both groups. It was reported that highest hydration values reduce the sensitivity of capacitance method (45). However, Bates-Jensen *et al.* (25) and Guihan *et al.* (46) confirmed that increasing subepidermal moisture is an early sign of development of pressure ulcers.

Role of bed sheet

Pressure ulcers and superficial skin changes occurred in 28% of patients ($n=20$). Of these, 85% ($n=17$) used a standard hospital sheet made of 100% cotton, whereas 15% ($n=3$) used a synthetic fibre sheet ($P=0·089$). The synthetic fibre sheet has three layers: the first layer, which has direct contact with the skin, has permeability to absorb and send moisture to the second layer, while the second layer has a diffusion ability to distribute excessive moisture to the third layer, which then retains it.

According to Derler *et al.* (47), a sheet of synthetic fibre can reduce the coefficient of friction three fold compared with a standard hospital sheet. Textiles play at least three roles in maintaining a favourable microclimate between the patient's skin and the support surface: wicking away perspiration, reducing heat insulation and reducing the coefficient of friction (48,49). Thus, textiles have a role in the prevention or formation of pressure ulcers and other superficial skin changes (29,31).Using the backward mode, we found the remaining two predictor variables. The odd ratio was 0·111 for a fibre sheet, meaning that patient who uses a standard hospital sheet has a higher risk for the development of pressure ulcers and superficial skin changes. Thus, the combination of a proper support surface and a favourable bed sheet could effectively prevent pressure ulcers and superficial skin changes.

Subscale friction and shear scores were significant in the clinical setting. We found that subscale friction and shear scores for the group with pressure ulcers and superficial skin changes ($1·2 \pm 0·4$) were significantly lower than those for the group with no skin changes ($2·0 \pm 0·2$) ($P=0·000$). A management approach that considers friction and shear may involve using an appropriate technique for turning and repositioning the patient and using a favourable support surface sheet that can control the microclimate and reduce the coefficient of friction.

Study limitations

During the study, many participants dropped out as a result of medical conditions (such as getting worse, unable to turning lateral, pain), medical procedures (such as postoperative procedure, transferred to intensive care unit, haemodialysis schedule) or personal choice. Moreover, the limitation of time by the protocol of measurement between 8:00 AM and 12:00 AM made it possible to measure parameters in only 2–3 participants a day. High humidity (60–80%) and high temperature (±30°C) in the ward stimulated perspiration, making the measurement of skin moisture difficult. In addition, because of device problems, we only obtained interface pressure data from 33 participants, so that they were not entered in a stepwise-reduction of logistic regression analysis, which made us unable to evaluate the relationship between pressure ulcer development and interface pressure.

Implication in clinical practice

Our findings will be useful in a clinical setting because these measurements were not serial observations, meaning that the monitoring of skin temperature can be performed at one time point using a comparison with another site.

In our results, 45% of wounds were superficial skin changes and 47·8% were located in the lower sacrum (buttocks, interriginous of gluteus). This finding reinforces the paradigm shift from a pressure ulcer problem to more widespread problems (superficial skin changes) and from bony prominence problems to whole buttock problems.

In addition, total skin temperature differences were marginally significant compared with the control site. Thus, skin temperature can be useful for detecting the early signs of any skin changes. This quantitative measurement is more reliable than a subjective evaluation and is also useful for patients with dark skin tone, in which the presence of erythema is sometimes difficult to evaluate. The evidence from this study suggests that skin temperature can be useful as a predictor measurement in order to establish preventive care.

Conclusion

Increasing skin temperature can be used as a quantitative measurement to predict the development of pressure ulcers and superficial skin changes and to evaluate support surface capability against microclimate factors. In addition, the use of a synthetic fibre sheet has the potential to control microclimate conditions between the patient's skin and support surface, which can reduce the development of pressure ulcers and other superficial skin changes. Finally, we can conclude that increasing skin temperature as a microclimate variable has a relationship with the development of pressure ulcers and superficial skin changes. Conversely, the type of bed sheet has a role in maintaining a favourable microclimate to prevent skin changes.

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