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Application of the sheepskin mattress in clinical care for pressure relieving: a quantitative experimental evaluation

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A B S T R A C T

This study aimed at quantitatively evaluating the effectiveness of sheepskin mattress (SSM) in pressure relieving, and then variables of peak pressure (mmHg) (PP), average pressure (AP) and contact area (cm^2) (CA) at the total, back, sacrum and heel regions of 18 students supinely lying in a control mattress (CM), standard hospital mattress (SHM), SHM + SSM, SSM + CM and AM + CM were measured and contrasted. Paired-*T* test with a significant level of .05 shows that: the intervention of SSM significantly increased the total CA of SHM by 395.6 cm^2 and lowered its PP and AP by 8.8 and 2.0 mmHg respectively; further, the pressure distribution of SSM + CM was superior to that of AM + CM. The reliability of this study, with exception of the heel area, was proven to be good. Overall, the sheepskin mattress is an effective product in pressure reliving.

1. Introduction

High peak pressure is commonly deemed as a direct factor leading to the ulceration (De Simon, La Penna, Napoletano, & Uccioli, 2002; Klaesner, Hastings, Zou, Lewis, & Mueller, 2002; Nijs et al., 2009). According to a clinical report from the US, the incidence of pressure ulceration among the long-term hospitalized patients ranged 10 to 18% (Clark, Bours, & Defloor, 2002; Cuddigan, Berlowitz, & Ayello, 2001). The long time loading and the high pressure (Cherry & Ryan, 1997; Defloor, 2000) are two prerequisites for the development of pressure ulceration. Particularly, contact pressure between the skin and the mattress determines the capillary circulation. When the pressure is larger than 10 kPa, based on the observation from Color Doppler Flow Image, the capillary circulation is closed (Rithalia & Gonsalkorale, 1998). Hence, the critical purpose of nursing is to both lower the magnitude of applied pressure and ameliorate the blood supply at the pressed location.

Not only the length of stay in hospital is prolonged by the ulceration, but also the amount of expenses for the medical treatment is significantly augmented. A survey from the UK reported that the total cost in the ulcer treatment has been estimated as 1.4 to 2.1 billion pounds annually (Bennett et al., 1998). Besides, the occurrence of ulcer was also significantly correlated with the amputation, immobility and even with the shortened life span (De Simon et al., 2002; Klaesner et al., 2002; Nijs et al., 2009). Therefore, the problem of ulceration should be considered seriously and the prevention strategies should be designed as early as possible. Comparing with the active treatment, advance interventions in the nursing stage appear to be crucial. Fortunately, current literatures concluded a series of constant low pressure (CLP) system and they were mainly classified into two groups (McInnes, Jammali-Blasi, Bell-Syer, Dumville, & Cullum, 2011): one was the low-tech CLP, for instance, the sheep skin and air mattress; another one was the high-tech CLP, for example, alternative pressure air mattress (APAM). The low-tech CLP was aimed to reduce the magnitude of pressure by way of directly increasing the contact area; while the APAM was composed of large air units and it adjusted the contact area by inflation or deflation of these units; additionally, purposely inflating or deflating shifted the centre of pressure and avoided the long time loading on the same place. Although the APAM succeeds in both improving the pressure distribution and shifting the loading periodically, according to current clinical studies, it was not significantly superior to the low-tech CLP products in ulcer prevention and the cost of the APAM was several times higher than that of the low-tech CLP (McInnes et al., 2011).

Among low-tech CLP products, both sheepskin mattress (SSM) and air mattress (AM) have been commonly used in the clinical practice and these approaches have been approved to be effective in ulcer prevention (Jolley et al., 2004; McGowan, Montgomery, Jolley, & Wright, 2000; McInnes et al., 2011). McGowan et al. first reported the intervention of the SSM in clinical care. They recruited 297 post-operated patients and during their nursing period the sheepskin mat was prescribed. Their results indicated that the mattress significantly lowered the incidence of ulceration [RR = 0.30, 95% confident interval (CI): 0.17 to 0.52]. Further, the outcomes of Jolley et al. showed that the incidence of ulceration of their 539 in-hospitalized patients decreased from 9.0% (20/223) to 5.5% (12/218) (RR = 0.58, 95% CI: 0.35 to 0.96) with the help of SSM. Therefore the SSM was

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manifested to be effective in ulcer prevention for the long-term hospitalized patients. However, until now neither the quantitative assessment of the sheepskin mattress in pressure relief, nor comparisons between the sheep skin and other low-tech CLP systems have been made.

Furthermore, questions concerning on the SSM were proposed: what the mechanism and how the effectiveness of SSM in pressure relieving were, did the SSM performed superior to other CLP products, did the results of pressure reliving was reliable and repeatable. Therefore, the aim of this study was first to quantitatively evaluate the effectiveness of the SSM in pressure relief by the way of comparing the contact pressure with and without the usage of the SSM upon a standard hospital mattress; and then to compare the distinctions between the SSM and AM; finally reliability of this study was analyzed. Since the positive and consistent outcomes of the SSM in ulcer prevention have been reported, two hypotheses were proposed: the first one was that SSM would significantly ameliorate the pressure distribution in each contacting area, reduce its magnitude and provide a much larger area to support; the second one was that results of the study would be reliable and repeatable.

2. Methods

2.1. Study design

This study was designed as an experimental one, therefore two criteria were followed: the first one was that two types of the control group [control mattress (CM) and standard hospital mattress (SHM)] and the experimental one (CM + SSM and SHM + SSM) were available and distinctions between the control group and experimental one would be analyzed by the model of paired-*T* test; the second one was that the testing order in each day's measure was randomized for each subject and all the subjects were randomly assigned to one of those mattresses, which were also combined randomly within the four types of basic mattresses.

2.2. Subjects

Since this study was designed as an experimental one and according to the similar studies summarized by Vanderwee, Grypdonck, and Defloor (2008), a strategy of small sample size was opted. Besides, as Hopkins (2000) recommended that the predictive sample size for the test–retest study was approximately equaling to "$8s^2/d^2$", where *s* is the typical error, while *d* is the change in the mean. In this study, we followed the examples of Hopkins (2000) and the *s* was considered as 1.5 times higher than *d* in order to achieve a reasonable typical error with the minimum sample size, so that the sample size was calculated as 18. Moreover, healthy adult students have been widely enrolled in the experimental studies (Vanderwee et al., 2008) in mattress evaluation.

Therefore, 18 healthy students (11 males and 7 females, leisure clothing, such as T-shirt and slacks were asked before measurement) aged 20 to 27 were recruited from our institution. The body weight and height were first measured and then BMI was calculated. Because overweight or obesity would result a larger contact pressure, according to the survey of the overweight Chinese adult (Ministry of Health, P.R. China, 2004), those students with a BMI larger than 24.5 were excluded; moreover, those students who reported with back pain would also not be further considered. Each type of mattress was tested by all the 18 subjects. Before the measurement, aims and procedures of this study were first orally explained to the subject who conformed to our inclusion criterion; and then if they were willing to continue, a written agreement was provided. This agreement not only narrates the background, aims, methods and risks of the study, but also includes the benefits and privacy protection of participating. If they agree with the content, they will sign this agreement with their name and hand them in before the first day's measurement. All procedures of this study were supervised by ethic committees of the University and followed the principles of the Declaration of Helsinki.

2.3. Mattress

Four mattresses were provided: an SSM (60 × 90 × 5 cm, own-fabricated, Chengdu, China) which was tanned under the guidelines of Australian Medical Sheepskin (Australian Standards: As4480.1) and the mean diameter of hair is 22.5 μm, mean length is 26.3 mm and density is 3095/cm^2; a SHM (180 × 90 × 6 cm, HuaZhiJie Ltd., Chengdu, China) which was composed of the foam and coir mat with thickness of 3 cm; an AM (180 × 90 × 6 cm, HuaZhiJie Ltd., Chengdu, China) which was constructed by air strips with 10 cm interval; a CM (180 × 90 × 3 cm, HuaZhiJie Ltd., Chengdu, China) which is made of 3 cm coir mat. Five mattress types were available for measure: SSM + SHM, SSM + CM, AM + CM, SHM and CM.

2.4. Pressure measurement

The mFLEX pressure measuring system (mFLEX: 32 × 32, Rsscan international, Belgium) was utilized to gain the contact pressure between the body and the mattress surface. The size of this system is 2100 mm × 890 mm × 4 mm, the area of pressure sensors is 1920 mm × 762 mm, the number of sensor is 1024, the range of measure is 0–100 mmHg (0–13 kPa) and the frequency is 5 Hz. Calibration was made before measurement.

Anatomically, the protrusions of bone, such as scapula at back, sacrum of buttock and foot calcaneus, construct a plane to support the whole body weight (Buckle & Fernandes, 1998), at which relative higher contact pressures are usually observed. Although these places are more risky to develop ulcers, the majority of the body mass is concentrated at the middle of the body in supine posture and the highest incidence of ulceration was found at the sacrum area (Daideri et al., 2006; S. V. Rithalia & Gonsalkorale, 2000). Meanwhile, suggested by Allen, Ryan, and Murray (1993), in supine posture, pressure distribution of six sub-areas were proposed to be studied: occipital, back, sacrum, buttock, heel and elbow. However, since the occipital and elbow were rarely observed with ulceration, these two positions were excluded; further, as the sacrum and buttock were too near to differentiate, they were combined as the sacrum area. Therefore, four-mask model was available (Fig. 1): total, back, sacrum and heel area. Pressure variables of the peak pressure (PP) (mmHg), average pressure (AP) (mmHg) and contact area (CA) (cm^2) were gained for each region by the software of mFLEX (V4.0, Rsscan international, Belgium). Only one experienced observer was assigned to complete all the analysis to eliminate the inter-observer's error.

Participants were asked to wear their own leisure clothing, such as T-shirt and slacks; further a procedure of 3 to 5 minutes of warm up was provided and made sure that each subject could adjust his or her own supine posture to be a natural and comfort one. When the subjects lay in the bed in supine posture (Fig. 2) without moving further and their plantar pressure becoming stable, the mFLEX system was switched on randomly by the researcher and then 10 second data were recorded, within which 50 frames (10 s × 5 Hz) of pressure distribution patterns have been saved. Thereby, the subject is not aware of the whole measuring process and only one trial was required for each measurement. The overall time cost for one trial was estimated as no more than 6 minutes, especially 10 seconds of recording could ensure that the subject keeps his or her comfortable posture stilly. The same procedure was repeated in other two successive days in order to explore the inter-session reliability and repeatability of the measurement.

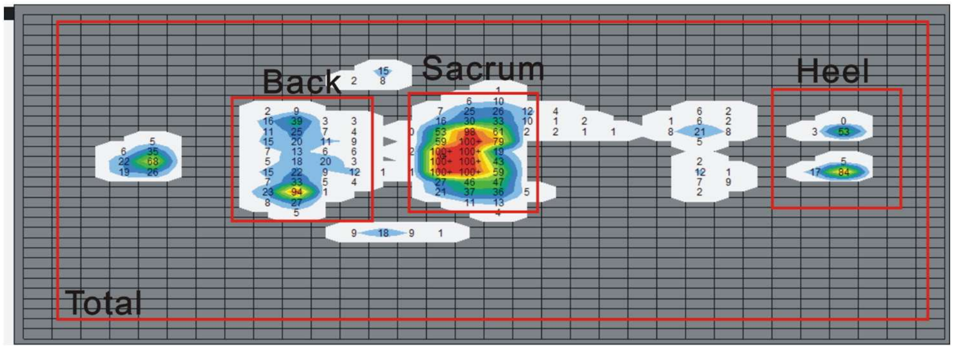

Fig. 1. Four masks model for data analysis.

2.5. Data processing and statistical analysis

Fifty frames of pressure distribution pattern were first averaged individually and then within the group. At first, normal distribution was tested by Q-Q plot; and then paired-*t* test and reliability analyses were used for statistical analysis. Variables of coefficiency of variance (CoV) and intraclass correlation coefficiency (ICC) (Hopkins, 2000) were recommended for reliability evaluation, where CoV = (typical error) / (mean value of the three trials). The higher the CoV is, the lower the repeatability (Ramanathan, Kiran, Arnold, Wang, & Abboud, 2010). Moreover, when ICC < 0.5, the reliability is poor; while 0.5 < ICC < 0.75 indicates a medium reliability and ICC > 0.75 shows a good to excellent reliability (Portney & Watkins, 1993). All the analysis models were executed under the software of SPSS (V16.0, SPSS Inc., USA) with significant level of .05.

3. Results

Mean age of the students is 24.2 ± 1.7 years, mean height is 167.9 ± 8.2 cm, mean body weight is 58.8 ± 7.7 kg and mean BMI is 20.8 ± 1.4. All obtained data in supine posture followed the normal distribution.

The reliability of CA was demonstrated to be excellent (Table 1) at the total, back and sacrum positions, where CoV and ICC ranged from 5.1 to 10.7% and 0.92 to 0.97. Meanwhile, a moderate to good reliability of AP and PP was observed at these three areas and CoV and ICC ranged from 8.0 to 23.2% and 0.70 to 0.93. However, all the pressure variables at heel displayed poor reliability by showing a relative higher CoV (28.7 to 62%) and lower ICC (0.22 to 0.76) value.

Significant changes were observed when SSM was used, especially in the total, back and sacrum area. The application of SSM significantly reduced the pressure of SHM by 8.8 mmHg for PP ($p = .01$) and by 2.0 mmHg for AP ($p = .01$) in the total area; and that of CA was also significantly increased by 395.6 cm^2 ($p = .000$). A better outcome was found for the CM + SSM, where the total CA was enlarged by 646.1 cm^2 ($p = .000$ for all) and the PP and AP were lowered by 7.0 mmHg ($p = .02$) and 9.0 mmHg ($p = .000$) individually (Fig. 3 and Table 2), in contrast with the usage of CM. No significant differences were found between SHM and SSM + SHM ($p > .05$) in the back area; whereas the optimal pressure relief was obtained at the sacrum position, where 212.6 cm^2 ($p = .02$) augment of CA, 10.3 mmHg ($p = .02$) and 10.1 mmHg ($p = .01$) deduction of PP and AP were observed for SSM + SHM, in contrast with that of SHM.

Compared with AM + CM, SSM + CM significantly reduced the total PP and AP by 6.8 mmHg ($p = .031$) and 8.8 mmHg ($p = .000$) individually, while that of total CA was enlarged by 435.2 cm^2 ($p = .000$). 41.6 and 14.2 mmHg reduction of PP ($p = .000$) and AP ($p = .001$) and 182.7 cm^2 ($p = .001$) rising of CA were found at the back position for the SSM + CM. Similar effect was also obtained at the position of the sacrum. (Fig. 4 and Table 2).

The key point of pressure relieving is the increase of the contact area. The four mattress types exhibited an increasing trend in total, back and sacrum areas (Fig. 5). The largest CA was found for the SSM + SHM, which is 435.2 cm^2 higher than that of CM in total area, 182.7 cm^2 in back area and 183.9 cm^2 in sacrum area; while only a small distinctions existed between the SSM + CM and SSM + SHM. CA of CM and AM + CM were the lowest one.

Fig. 2. Supine postures for measurement.

Table 1
Reliability analysis of three pressure variables under each four areas.

Variables	Mean of three trials	Typical error	CoV (%)	ICC	95% Confidence interval Lower	95% Confidence interval Upper	*P* value
Total-PP[a]	94.9	7.6	8.0	0.70	0.6	0.8	.000**
Total-AP[a]	19.7	1.9	9.7	0.93	0.9	0.9	.000**
Total-CA[b]	2185.4	112.0	5.1	0.97	1.0	1.0	.000**
Back- PP	49.0	11.3	23.2	0.86	0.8	0.9	.000**
Back- AP	16.4	3.3	20.2	0.85	0.8	0.9	.000**
Back-CA	614.3	65.8	10.7	0.92	0.9	0.9	.000**
Sacrum- PP	92.6	9.0	9.7	0.75	0.7	0.8	.000**
Sacrum- AP	30.5	4.4	14.5	0.76	0.7	0.8	.000**
Sacrum-CA	713.4	57.3	8.0	0.92	0.9	0.9	.000**
Heel- PP	69.2	19.8	28.7	0.68	0.6	0.8	.000**
Heel- AP	32.0	11.5	35.9	0.76	0.7	0.8	.000**
Heel-CA	85.3	53.0	62.0	0.22	−0.1	0.4	.068

** Significant level < .001.
[a] The unit of variable PP and AP is mmHg.
[b] The unit of variable CA is cm^2.

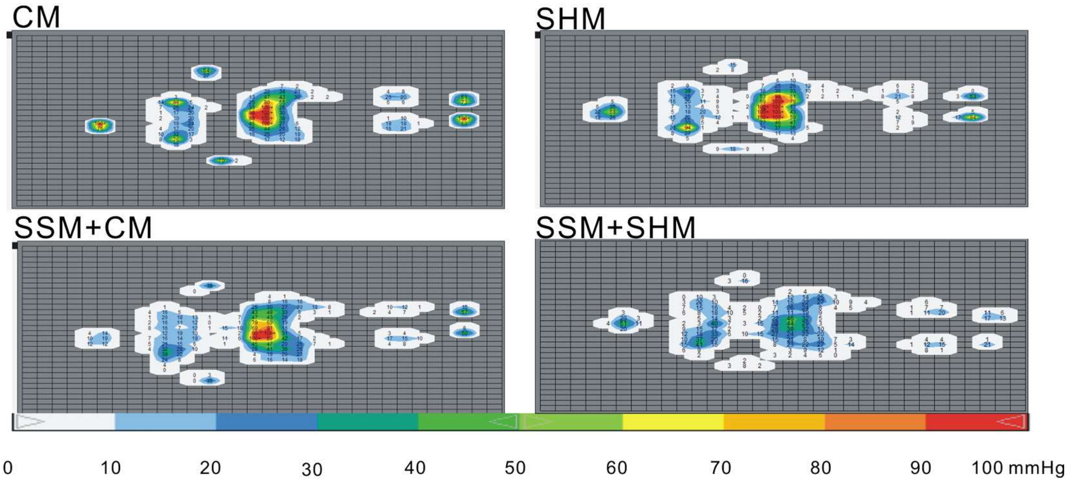

Fig. 3. Pressure distributions before and after the usage of sheepskin mattress upon the standard hospital mattress.

4. Discussion

In this study, the pressure distribution of supinely lying in SHM and CM with and without the SSM was first recorded and then the pressure relief of SSM was contrasted with that of the AM. Results showed that the intervention of SSM significantly increased the contact area and simultaneously lowered the magnitude of the contact pressure; moreover it functioned better than the AM in terms of pressure relief. The outcomes at all areas, with exception of the heel, were proven to be reliable. Finally the effectiveness of SSM in attenuating the pressure concentration was quantitatively explored.

Table 2
Paired-*t* test of the pressure distribution before and after the usage of sheepskin mattress upon two types of mattress.

M1	M2	Variables	Mean of M1	SD	Mean of M2	SD	Diff.	*p* value
CM	SSM + CM	Total-PP[a]	100.0	0.0	93.0	11.0	−7.0*	.020
		Total-AP[a]	28.8	3.3	19.2	2.4	−9.6**	.000
		Total-CA[b]	1573.0	230.5	2219.1	228.6	646.1**	.000
		Back-PP	77.3	18.9	43.2	10.4	−34.1**	.000
		Back-AP	24.7	6.2	16.1	3.5	−8.6**	.000
		Back-CA	475.2	99.9	629.9	101.9	154.7**	.000
		Sacrum-PP	99.6	1.6	89.3	15.8	−10.3*	.020
		Sacrum-AP	39.6	6.4	29.5	5.5	−10.1**	.000
		Sacrum-CA	564.0	74.5	776.6	73.5	212.6**	.000
		Heel-PP	95.5	11.6	67.4	25.0	−28.1**	.000
		Heel-AP	57.7	22.0	26.2	7.5	−31.5**	.000
		Heel-CA	59.7	22.9	86.2	21.2	26.5*	.003
SHM	SSM + SHM	Total-PP	100.0	0.0	91.2	13.4	−8.8*	.010
		Total-AP	18.4	2.2	16.4	2.8	−2.0*	.010
		Total-CA	2044.8	262.6	2440.4	330.7	395.6**	.000
		Back-PP	47.9	19.9	38.6	12.7	−9.3	.064
		Back-AP	15.3	3.8	13.5	3.5	−1.8	.090
		Back-CA	602.4	103.7	680.6	201.3	78.2	.062
		Sacrum-PP	100.0	0.0	87.6	20.5	−12.4*	.020
		Sacrum-AP	30.2	5.4	25.8	6.4	−4.4*	.010
		Sacrum-CA	633.2	73.2	792.0	111.7	158.8**	.000
		Heel-PP	64.9	28.3	56.5	24.7	−8.4	.20
		Heel-AP	32.2	12.6	23.7	9.8	−8.4*	.010
		Heel-CA	65.5	18.6	127.6	174.0	62.2	.16
AM + CM	SSM + CM	Total-PP	99.8	1.0	93.0	11.0	6.8	.031
		Total-AP	28.0	4.1	19.2	2.4	8.8	.000
		Total-CA	1783.9	278.9	2219.1	228.6	−435.2	.000
		Back-PP	84.8	20.2	43.2	10.4	41.6	.000
		Back-AP	30.3	10.7	16.1	3.5	14.2	.001
		Back-CA	447.2	108.7	629.9	101.9	−182.7	.001
		Sacrum-PP	99.7	1.4	89.3	15.8	10.4	.020
		Sacrum-AP	40.3	7.8	29.5	5.5	10.8	.002
		Sacrum-CA	592.7	120.1	776.6	73.5	−183.9	.023
		Heel-PP	74.3	32.7	67.4	25.0	6.9	.013
		Heel-AP	41.8	23.3	26.2	7.5	15.6	.262
		Heel-CA	71.9	23.5	86.2	21.2	−14.3	.208

* Significant level < .05.
** Significant level < .001.
[a] The unit of variable PP and AP is mmHg.
[b] The unit of variable CA is cm^2.

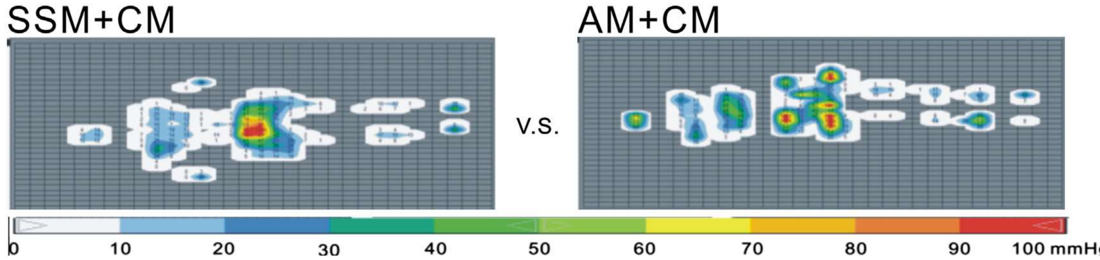

Fig. 4. Comparison between the sheepskin mattress and air mattress in pressure relief.

Prior to the intervention of SSM, the pressure distribution of SHM was recorded similar to that of CM. This finding implied that the current hospital mattress did not satisfy the basic needs for pressure relief. After the SSM was intervened, both the magnitude of pressure and the contact area were improved. Although, in comparison between the SHM and SSM + SHM, the significant reduction was only found at the sacrum area in SSM + SHM, it was beneficial for ulcer prevention. When compared with the AM, a significant advantage in pressure relief was also observed for the SSM group, therefore, the SSM was superior to that of the AM in attenuating the high pressure. Besides, as AM + CM still exhibited a higher pressure concentration, the effect of this protocol in ulcer prevention was doubted. Contact area increased from the hard surface to the SHM and then to the SSM; meanwhile, SSM significantly ameliorated the pressure distribution in each contacting area and reduced its magnitude, hence the first hypothesis of this study was confirmed.

In terms of reliability analysis of this study, the low CoV and high ICC were obtained and it indicated that outcomes of all pressure variables under the four regions, excluding the heel, were proven to be reliable. Our results were supported by the current literatures (Gurney, Kersting, & Rosenbaum, 2008; Zammit, Menz, & Munteanu, 2010): the larger contact area and the higher load, the better reliability would be attained. So, the second hypothesis was also approved.

The pressure relieving mechanism of SSM could be postulated as that when the subject lies in the surface of SSM, the long and high density hair surface could be easily bended to match the shape of the loading surface and a much larger contact area could be built to support the body weight. According to the equation of “pressure = force/contact area”, the magnitude of pressure can be lowered by the augmented contact area. Further, even though the surface of SSM is tightly pressed, minor gaps still exist within hairs and those spaces make the air circulation available. Therefore, the SSM is helpful for either avoiding the occurrence of ulcer or promoting the healing of ulceration. Meanwhile, in the nursing practice, this product could be utilized in the routine clinical care for pressure relieving purpose, such as ulcer prevention, post-operation care and ulceration treatment. This product on the one hand is easy to be used in the nursing process, just letting the body of patient directly contact with the mattress; on the other hand, it can be cleaned conveniently by the washing machine; other factors such as reasonable price, ease of keeping clean and shifting patient forecast its potential usage. Besides, the SSM could be cut into any purposed shape, such as the sitting pad for wheel chair or the supporter for the bone fracture. Thereby, with the help of SSM, the nursing quality and efficiency can be promoted.

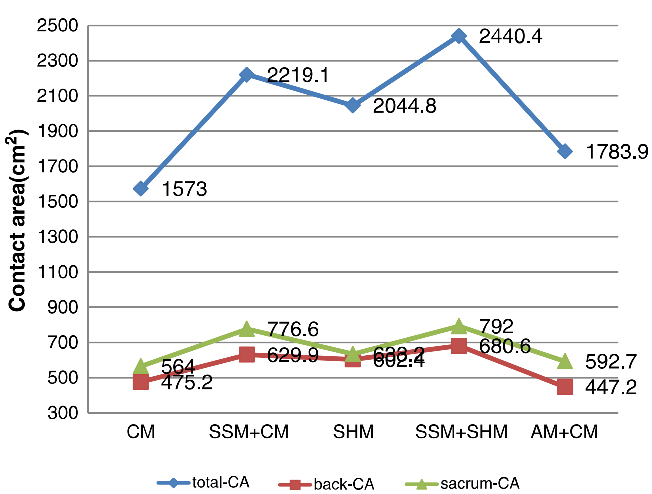

Fig. 5. changes of contact area across mattresses.

Although the hypotheses have been approved, several limitations should be considered while interpreting the results. Firstly, the hospital mattress used in our study was designed under the standard of China and it was constructed of the foam and coir mat with the thickness of three centimeter respectively. However, standard hospital mattress in the varied countries may differ from each other in terms of material, hardness and thickness, such as the standard hospital mattress reported by Defloor (2000) is a non pressure-reducing mattress made of 12-cm-thick cold foam with density of 40 kg/cm^3, hence comparisons between our results with others should be aware of those variations. Secondly, the samples size was small and the outcomes performed by those healthy subjects in our experimental study should not be generalized to other population. Since anthropological variations would result the significant differences in contact pressure, for instance the elder population would receive a lower peak pressure at sacrum area (Daideri et al., 2006). Thirdly, some PP exceeded the maximum rang (100 mmHg) of the measuring system, but part of pressure higher than 100 mmHg was meaningless, as the capillary circulation has already been cut off when the pressure passed 10 kPa (76 mmHg) (Rithalia & Gonsalkorale, 1998). Investigations still need to be done to further explore the effectiveness of the sheepskin mattress in improving the loading tissue's capillary circulation.

5. Conclusions

The sheepskin mattress is effective in increasing the contact area and reducing the magnitude the high pressure; meanwhile, its function is superior to that of the air mattress in terms of pressure relief. Therefore, this product can be used in the routine clinical care for pressure reliving.

Acknowledgments

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