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Clinical study

The effectiveness of small changes for pressure redistribution; using the air mattress for small changes

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KEYWORDS
Small changes;
Interface pressure;
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Pressure ulcer

Abstract Observing small changes (SCs) at specific sites is a new form of managing changes in position. We investigated SCs at specific sites considering interface pressure, contact area, body alignment and physical sensation in nine healthy female adults and evaluated SCs using the air mattress that was divided into six cells (A—F). Thirty-three SC combinations at one or several sites were evaluated. Pressure in the sacral region significantly decreased in 28 SC combinations compared with the supine position ($p < 0.05$), and the effect of pressure redistribution was greater when SCs were applied at several instead of a single site. The contact area at 17 of the 28 SC combinations significantly increased ($p < 0.05$). Among sites ranked based on interface pressure, body alignment and physical sensation, SCs at sites BCE, AE and BD were the most favorable. The common feature among these

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three combinations was that they involved tilting the buttock region and one other site. The findings suggested that SCs at the buttock region could reduce disruptions in alignment as well as the impact on physical sensation caused by the body sinking into the mattress and improve interface pressure redistribution via increased contact area with the mattress.

1. Introduction

Changing the position of the body every 2 h has been recommended to prevent pressure ulcers [1,2]. However, this is a burden not only for caregivers [3], but also for patients, as it can disrupt sleep [4]. Moreover, friction forces are closely associated with superficial skin lesions [5]. Therefore, avoiding such issues when changing body positions becomes crucial. A consensus panel that developed the Virginia Commonwealth University (VCU) guidelines, recommend providing mini-turns [6]. Exton-Smith et al. also reported that the incidence of pressure ulcers increases among elderly inpatients when the frequency of body movements decreases at night [7]. Movements with small amplitudes were measured in that study as a representation of small changes in body weight, since large body movements are artificially produced. Their results were the first to indicate the importance of small changes body weight to preventing pressure ulcers, and this generated the notion of incorporating such changes for patients who are unable to move independently.

Small, as opposed to large physical movements to change body position such as changing from the supine to the lateral position, are called "small changes" (SCs), and Lunde [8] stated that natural body movements can be mimicked by tilting the body by inserting a small pillow under the mattress.

Oertwich et al. [9] investigated the relationship between SCs and interface pressure as well as blood flow in the sacral region and found that SCs decreased pressure in the sacral region and increased blood flow. Because SCs could decrease the burden on caregivers, an air mattress for SCs is required at automatically changes body position.

Small changes have been generated at a single site, but generating SCs at multiple sites should elicit a further pressure redistribution effect on the sacral region. However, whether or not that is true remains unknown, and whether or not the body axis of patients becomes disrupted, or the patients experience discomfort after applying SCs has not been investigated as far as we can ascertain.

Therefore, we investigated these issues in healthy adult females using an Air mattress for SCs that was custom-designed to study SCs at several sites instead of a small pillow.

2. Materials and methods

2.1. Study design

This study was quasi-experimental.

2.2. Participants

The subjects were healthy adult females.

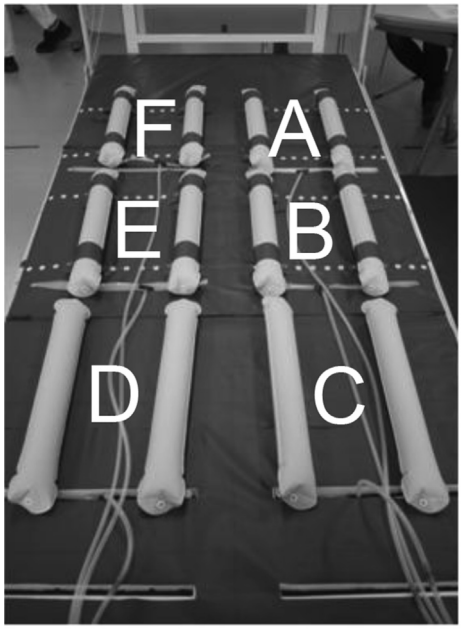
2.3. Air mattress for SCs

Cells A (left shoulder), B (left buttock), C (left calf), D (right calf), E (right buttock), and F (right shoulder) comprising two compartments each were placed under a high-performance, multifunction NEXUS air mattress (CAPE Co., Ltd., Yokosuka, Japan) that was modified to stationary mode (Fig. 1). All six areas could be independently and/or simultaneously inflated and deflated. Of the 63 conceivable combinations of individual or several SC sites, those that were symmetrical and those involving SCs only in Cells C or D were excluded. The remaining 33 combinations were measured. The internal pressure of the cells after inflation with air was 30 ± 3 mmHg.

2.4. Outcome measurements

2.4.1. Interface pressure

Changes in maximum pressure before and after SC were determined using a three-point interface pressure sensor (Pressure Scanning Aid Cello; CAPE Co. Ltd.), in which three sensor pads were positioned along an arc and the maximum value was automatically detected by one pad. The sensor could measure a range of pressure from 0 to 199 mmHg with a precision of ±4.0 mmHg.



We called SC sites A, B, C, D, E and F. Each of these six parts was composed of two cells, each cell being 46-cm-long with a diameter of 5 cm, as one unit. The cell closer to the center moved the torso, while the outer cell prevented falls. The space between these two cells was 15.5 cm in the inflated state. In this figure, the top is head side and the bottom is foot side.

Fig. 1 Air mattress for SCs (pictured as inflated state).

2.4.2. Contact area

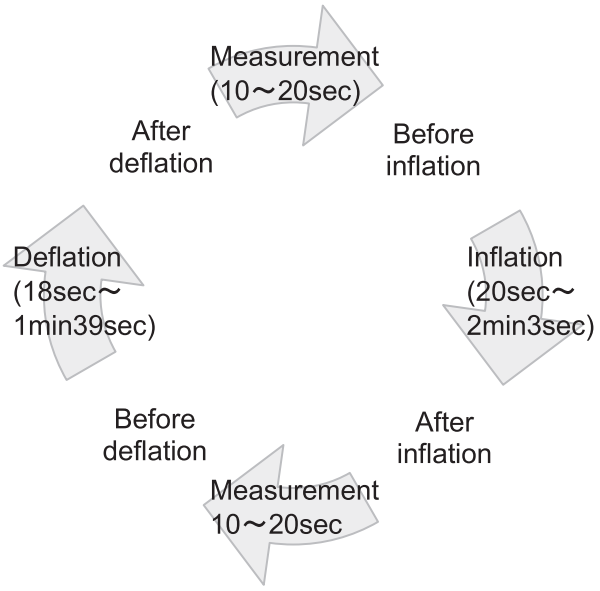
Changes in contact areas of the body and mattress as well as interface pressure before and after SCs were measured using an ErgoCheck system (ABW Co. Ltd., Hamburg, Germany) resembling a 215 × 70-cm sheet with 150 sensor pads (10 × 10 cm).

2.4.3. Alignment

Balanced alignment was defined as all lines connecting the left and right coracoid processes, anterior superior iliac spines, patellae and talus bones being parallel in the anterior view of the body, and the acromion, greater trochanter, apex of the head of fibula, and lateral malleolus being located along a straight line in the lateral view.

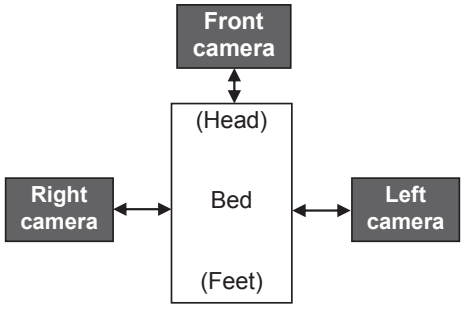
Alignment was measured using DMC-GF2, DMC-GF3 and DMC-FH7 digital cameras (Panasonic Co., Osaka, Japan) positioned using tripods (Fig. 3).

Anterior alignment was measured as follows. Stickers were placed on both right and left coracoid processes, the anterior superior iliac spines, patellae and talus bones, and images were photographed after importing SCs into the computer to draw straight lines connecting the same parts on the right and left sides using Microsoft Paint. Fig. 4 shows a kite string placed perpendicular to the midline as the 0° reference, and the other straight lines were moved in parallel such that the left end of the line (on the participant) joined the kite string. Angles between the kite string and the other straight lines were measured three times each using ImageJ, and the means were calculated. The inter-rater reliability intra-class coefficient correlations for anterior and lateral alignment were 0.948—0.999 and 0.825—0.999, respectively. Differences in angles between the kite string and straight lines connecting the left and right coracoid processes as well as the left and right sides of other parts were summed.



Measurements were taken immediately after cell inflation and immediately after cell deflation for every SC. The numbers onthe arrows means the required time.

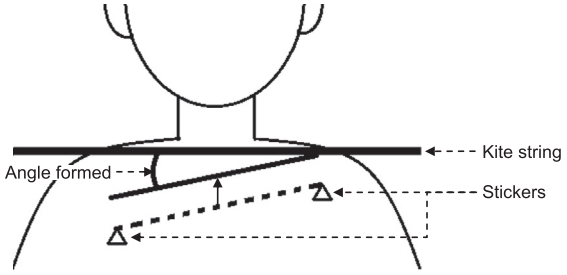
Fig. 2 Experimental flow.



Front camera: We set up for the anterior view, adjusting it at a height and angle such that the subject's shoulders to toes could be pictured. These were 186.5cm and 41degrees, respectively. The distance from the bed was 19cm.

Right camera and Left camera: We set up on each side such that the center of the lens was the same height as the top of the mattress and the subject's entire body was pictured. The height was 75cm, and the distance from the bed was 177cm.

Fig. 3 Camera placements.



A straight line that is drawn between the two stickers is moved in a parallel manner, and the angle formed between this straight line and the kite string is determined.

Fig. 4 Reference line and measurement method of anterior alignment.

Lateral alignment was measured as follows. Stickers were placed on the left and right acromions, greater trochanters, apices of the heads of the fibula, and lateral malleoli, and images photographed after SCs were imported into the computer. Left and right angles, angle of the acromion, greater trochanters, and apices of the heads of the fibula (A) and the angle of greater trochanter, apices of the heads of the fibula, and lateral malleoli (B) were measured three times each using ImageJ and the means were calculated. Differences between 180° for both left and right A and B were summed.

2.4.4. Physical sensation

The participants evaluated the physical sensations experienced during and immediately after inflation and deflation. Responses to the following sensations were scored as 1 (yes) or 0 (no): seasickness, the body being twisted, the skin being tugged, a downward slide and compression. The participants evaluated these sensations at specific sites for all but the first item and yes responses for each site were scored as 1 per person.

2.5. Measurement conditions

Items were measured between mid-August and mid-October, 2013 in a room at 26.1—29.6 °C with humidity 32.1%—68.2%.

2.5.1. Body position

Items were measured with the participants in the supine position. The participants relaxed their arms and placed them with the thumbs lightly touching the sides of the body. The heels were placed at a position equal to 10% of their height from the midline. The shoulders were aligned with the upper ends of Cells A and F, and the midline was aligned with the line connecting the middle of the upper part of the head board and that of the upper part of the foot board. Voluntary movements were avoided during the experiment. The participants wore seamless tank tops and half-length leggings.

2.5.2. Measurement interval

Items were initially measured starting from 10 min after the participants lay on the mattress. Thereafter, values at all SC sites were measured immediately after cell inflation and deflation (Fig. 2). All measurements were completed within 1 h per person.

2.6. Analysis

Maximum pressure and contact areas were analyzed before and after SC using the Wilcoxon signed-rank test. $P < 0.05$ was considered significant.

Overall rank was determined after including values for alignment and physical sensation. Alignment was ranked in order from lowest to highest by adding the sum of differences in anterior and lateral alignment for each combination. Physical sensation was ranked in order from lowest to highest based on the total score of the five items for each combination in all participants.

2.7. Ethical considerations

The Ethics Review Board at Kanazawa University Faculty of Medicine approved the present study (Approval number: HS25-10-1).

3. Results

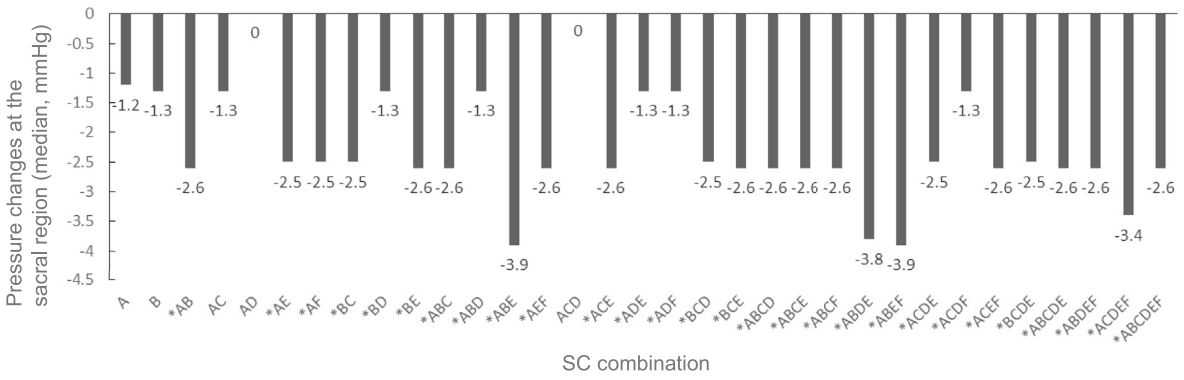
Nine healthy women (age, 21—22 y; height, 152.5—168.5 cm; BMI, 17.7—22.1 kg/m^2) provided written, informed consent to participate in this study.

3.1. Interface pressure before and after SC at regions susceptible to pressure ulcers

Sacral region pressure significantly decreased by 1.3—3.9 mmHg in 28 combinations (Fig. 5).

3.2. Contact area before and after SC

Median contact area significantly increased in 17 combinations of cells (Fig. 6).



*: p<0.05 (Wilcoxon signed-rank test performed using the interface pressure before and after the SCs. N=9)

Fig. 5 Median pressure change at the sacral region before and after SC with each SC combinations.

3.3. Alignment after SC

Differences in anterior alignment were minimal and maximal in the BE and ADE combinations, respectively (4.124° vs. 12.041°). Differences in lateral alignment were minimal and maximal in the ABDE and ACDF combinations, respectively (2.094° vs. 12.323°; Fig. 7).

3.4. Physical sensations

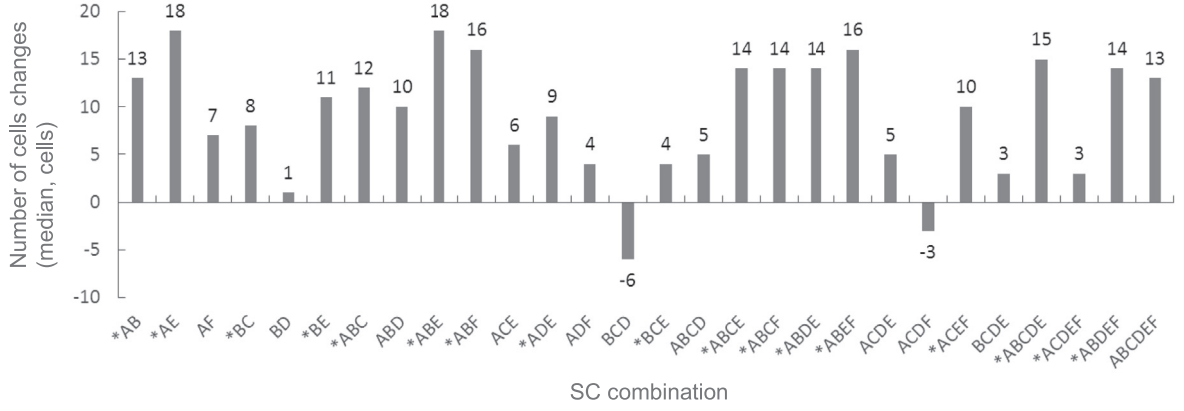
Physical sensations experienced during and immediately after deflation were scored as one point each for tugged skin in the back and arm for the ABE and ABCDE combinations, respectively. Table 1 shows the physical sensations experienced during and immediately after inflation. Combinations that caused the most complaints were in the in order, ACDF, ADF and AF. Specific sites associated with the most complaints comprised the lumbar, followed by the thoracic region.

3.5. Overall rank

The top three ranked combinations were BCE, AE and BD, and the bottom two ranked combinations were ADF and ACDF (Table 2).

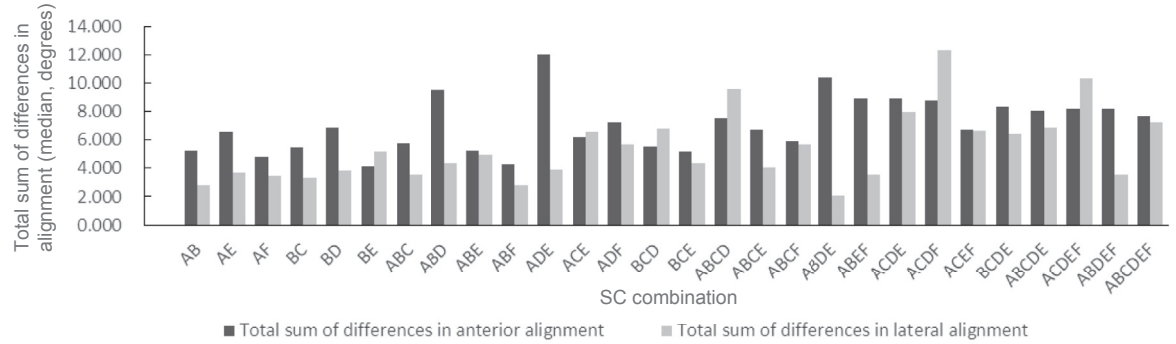
4. Discussion

The present study ranked pressure redistribution effects in the sacral region, to determine the optimal cell combination for SC among 28 that were based on alignment and physical sensation (Table 2). A novel finding was that the pressure redistribution effect was attained through SC at several, rather than one site.



*: p<0.05 (Wilcoxon signed-rank test performed using the number of cells before and after the SCs. N=9)

Fig. 6 Median number of cells change of total contact area before and after SC with each SC combinations.



The total sum of the differences in anterior alignment is the sum of the differences (absolute values) of the angle formed between the kite string and the straight line that connects left and right coracoid processes and the angles formed between the kite string and straight lines that connect each of the left and right anterior superior iliac spines, patellae, and talus bones.
The total sum of the differences in lateral alignment is the sum of the left and right A and B angles each subtracted from 180 degrees.

Fig. 7 Median total sum of differences in anterior or lateral alignments with each SC combinations.

Optimal sites of SC have not been investigated from the perspective of interface pressure, contact area, alignment, and physical sensation as far as we could determine. The present study identified sites that were safe and comfortable for applying SC with a pressure redistribution effect at the sacral region that could maintain natural flow of the body axis and were less likely to cause discomfort. Oertwich et al. [9] positioned a towel directly under the body

Table 1 Physical sensation during inflation to immediately after inflation of cells (score).

Pattern	Total
AB	6
AE	2
AF	9
BC	5
BD	2
BE	7
ABC	7
ABD	6
ABE	5
ABF	6
ACE	2
ADE	3
ADF	10
BCD	2
BCE	2
ABCD	6
ABCE	3
ABCF	7
ABDE	3
ABEF	3
ACDE	3
ACDF	12
ACEF	6
BCDE	3
ABCDE	2
ABDEF	3
ACDEF	5
ABCDEF	4

Table 2 Alignment, physical sensation, and overall rank for the 28 patterns that demonstrated significant decreases in pressure at the sacral region.

Pattern	Alignment rank	Physical sensation rank	Overall rank
BCE	7	1	1
AE	9	1	2
BD	10	1	3
BCD	14	1	4
ACE	17	1	5
ABCE	11	7	5
BC	4	15	7
ABF	1	18	7
AB	2	18	9
ABDE	15	7	10
ABE	8	15	11
ABEF	16	7	11
ABCDE	22	1	11
ABC	5	23	14
BCDE	21	7	14
ACDEF	27	15	14
AF	3	26	17
BE	6	23	17
ADE	24	7	19
ACDE	25	7	20
ABDEF	13	7	21
ABCF	12	23	22
ACEF	19	18	23
ABCDEF	23	14	23
ABD	20	18	25
ABCD	26	18	26
ADF	18	27	27
ACDF	28	28	28

to produce small movements and measured pressure and blood flow at the sacral region. They found that a towel placed under the femoral or thoracic region decreased pressure at the sacral region by about 4 mmHg and increased blood flow by 0.1 mL/min/100 g tissue compared with the supine position without the towel. That study also found that SC in body position has pressure redistribution effects at the sacral region. The present study also identified a significant decrease in pressure at the sacral region in 28 combinations of SC sites, indicating that SC can decompress the sacral region. Of the 28 combinations, those that induced significant differences in sacral region pressure had pressure decreases of 1.3—3.9 mmHg (Fig. 5). Although blood flow was not measured in the present study, our findings of pressure changes were similar to those reported by Oertwich et al. [9], suggesting similar changes in blood flow. The median of pressure changes at the sacral region was within the precision range of the device, but we assessed 17 combinations in which an increase in contact area was likely to decrease interface pressure because these two parameters are inversely related. In addition, SCs do not require a major change in body position, whereas artificially induced changes in body position require effort. Thus, a caregiver burden remains. Indeed, physical fatigue developed when placing a towel under the mattress and applying SC. The mechanical application of SC described herein should further alleviate the burden on caregivers.

Combinations of SC have been applied at a single site [7]. Here, we ranked combinations of SC at multiple sites and found that 28 of them significantly decreased pressure at the sacral region, which is susceptible to the development of pressure ulcers. The common feature among the top three ranked SC combinations was that they involve tilting the buttock region and one other site. Most body weight is concentrated at the buttock region when lying supine [10]. We considered that SC in the buttock region reduced the disruption in alignment caused by the body sinking into the mattress and the impact on physical sensation. Combining SC in which the buttock region and one other site were tilted caused the body to become enveloped, which increased stability. This was considered to explain why the participants were more likely to feel comfortable. The common feature between the bottom two SC combinations was that they were applied at the shoulders and calves and not at the buttock region. Since the shoulders and calves are lighter than the buttock region, they are more likely to be raised by SC, leading to a greater tendency towards disrupted alignment. Moreover, these specific sites become compressed with cell inflation, thereby inducing discomfort.

Small changes can effectively reduce pressure, but large changes such as shifting from the supine to the lateral position are still required because such repositioning not only redistributes pressure but also relieves pain associated with maintaining the same position, which results in benefits such as preventing muscle contracture and the loosening of airway secretions.

The present study has some limitations. One is that all participants were healthy women in their 20s with a low risk of developing pressure ulcers. The results on interface pressure, alignment, and physical sensation by SC may have been quite different had the participants been elderly with marked bone protrusions or decreased tissue strength. Another limitation is that the specific postures after SC were maintained only for 10—20 s. Kawamoto et al. [11] reported that subjective complaints increased at around 60 and 90 min after maintaining supine and lateral positions respectively. The present findings indicated that physical sensation might change over time when the same body position is maintained. Furthermore, sustaining a post-SC posture for a long period might augment disrupted alignment. We did not measure changes in pressure and shear in underlying tissues which might exert a powerful effect on blood flow and oxidation.

5. Conclusion

The present findings indicated that SC at the buttock region can reduce disruptions in alignment as well as the impact on physical sensation caused by the body sinking into the mattress. They can also improve the interface contact area effect due to increased contact with the surface area of the mattress.

Conflict of interest

We occupied the air mattress for SCs from CAPE Inc. at no charge. They lent the air mattress without being particular about our research plan.

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