

## ORIGINAL ARTICLE

# Predicting the cut-off point for interface pressure in pressure injury according to the standard hospital mattress and polyurethane foam mattress as support surfaces

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## Abstract

This study aimed to investigate the interface pressure (IP) of patients using a standard hospital mattress and polyurethane foam mattress as support surfaces and present cut-off points for IP in patients who exhibited skin changes. A total of 189 inpatients enrolled from six general wards and three intensive care units at a Korean University Hospital. Skin changes were classified, and peak IP at the sacral and occipital regions was measured using a pressure scanner. Differences in IPs according to mattress type were analysed using independent *t*-tests. The receiver operating characteristic curve was constructed to determine the cut-off point, and the area under the curve with a 95% confidence interval was obtained using the Stata 15.1 program. The IP for a standard hospital mattress was significantly higher than that of a polyurethane foam mattress. The cut-off points for IP at the sacral region were 52.90 and 30.15 mm Hg for a standard hospital mattress and polyurethane foam mattress, respectively. The cut-off point for IP at the occipital region was 36.40 mm Hg for a polyurethane foam mattress. Using IP measurements to prevent pressure injuries is important and employ individualised interventions based on the cut-off points for different support surfaces.

## KEYWORDS

mattresses, nursing, pressure ulcer

## Key Messages

- pressure injuries are caused by internal and external factors. The level of interface pressure recommended for preventing pressure injuries differs and varies according to the support surfaces and the body part
- the purpose of this study was to investigate the interface pressure for patients' body parts while using a standard hospital mattress and polyurethane foam mattress as support surfaces. Additionally, it aimed to identify cut-off points for interface pressure in patients who exhibited skin changes related to pressure injuries

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- the cut-off points for interface pressure at the sacral region were 52.90 and 30.15 mm Hg for a standard hospital mattress and polyurethane foam mattress, respectively. The cut-off point at the occipital region was 36.40 mm Hg for a polyurethane foam mattress

## 1 | INTRODUCTION

Pressure injuries (PIs) are prevalent problems that require both nursing and a multidisciplinary approach in inpatients and are caused by internal and external factors.<sup>1</sup> External factors include physical forces such as pressure and shearing force when a pressure greater than the peripheral vascular blood pressure is applied to a certain part of the body for an extended time, it can cause stasis of the capillary blood flow and formation of thrombi in small vessels, which in turn results in ischaemic necrosis of the tissue.<sup>2</sup>

In this regard, repositioning the patient or using a supporting surface is recommended to redistribute pressure.<sup>3</sup> Support surfaces made of various materials and substances (overlays, cushions, polyurethane foam, air, and gel mattresses) are used.<sup>1</sup> Mattresses used in hospitals are made from regenerated sponges with a strong compressive force.<sup>4</sup> These can easily cause PIs because of their low elasticity and inappropriate body pressure distribution.<sup>5</sup> However, polyurethane foam mattresses (PFMs) are relatively effective in preventing PIs<sup>1</sup> because their good breathability and porosity prevent protruding body parts from making contact with the floor, which increases the surface area in contact with the patient's body, thus significantly reducing pressure on the contact surface.<sup>6</sup> A systematic literature review<sup>7</sup> confirmed that foam alternatives to standard hospital mattresses (SHMs) reduce the incidence of PIs in people at risk (relative risk 0.40, 95% confidence interval [CI] 0.21-0.74).

With reference to the pressure that causes PIs, Lee et al<sup>8</sup> reported that histologic changes occur when a pressure of 100 mm Hg or higher is applied for 30 minutes, or that of 45-80 mm Hg is applied for 1 hour or more. Furthermore, mild histologic changes occurred when the applied pressure was 45-60 mm Hg, while moderate to severe histologic changes occurred when the pressure was 80 mm Hg. Therefore, Lee and Cho<sup>9</sup> recommended reducing the interface pressure (IP) of the supporting surface to 45 mm Hg or less to prevent PIs. PIs can also be prevented by applying an external pressure greater than the capillary closing pressure, which is 32 mm Hg because blood can be resupplied to the depressed area by repositioning the patient in bed or from other arteries as a result of the compensatory action.<sup>4</sup> However, the level of IP recommended for preventing PIs differs.<sup>10</sup> It varies according to the support surfaces used by the patient or

the body part at which the pressure occurs.<sup>11</sup> Moreover, no previous study has reported objective criteria for the cut-off point of IP required to prevent PIs.<sup>12</sup>

Thus, this study aimed to investigate the IP for patients' body parts while using an SHM and PFM as support surfaces. Additionally, it aimed to identify cut-off points for IP in patients who exhibited skin changes related to PIs.

## 2 | MATERIAL AND METHODS

### 2.1 | Setting and participants

A non-randomised, quasi-experimental research design (comparison cohort) was used for data collection. The participants were inpatients in six general wards (surgery, neurosurgery, infectious diseases, haemato-oncology, pulmonology, and nephrology) and three intensive care units (ICUs; surgery, internal medicine, and emergency ICUs) at a university hospital in J city, Korea. The inclusion criteria were age > 19 years and willingness to participate in the study. The exclusion criteria were as follows: spinal injury; pathological skin condition, skin damage, or loss due to burns; haemodynamically unstable conditions (eg, no repositioning or head-up and cardiac pacemaker implantation), or discharge during data collection. Participants who met the inclusion criteria were selected in the order of admission. Participants in the general wards and ICUs were assigned to the SHM and PFM groups, respectively. The sample size was calculated using a two-tailed *t*-test and the G\*Power 3.1.3 program.<sup>13</sup> We used a significance level of .05, power of 0.90, and an effect size of 0.50 (medium effect) for the calculation. A sample size of 172 participants was calculated to be sufficient for this study. To account for a possible dropout rate of approximately 5%, 97 and 92 participants were recruited from the general wards and ICUs, respectively (Figure 1).

### 2.2 | Measures

Participants' general information was collected using direct measurement and electronic medical records. Skin conditions related to PIs were assessed and classified by adding intact skin and blanching erythema to the following six categories: stage 1, 2, 3, or 4 PI, unstageable, and suspected

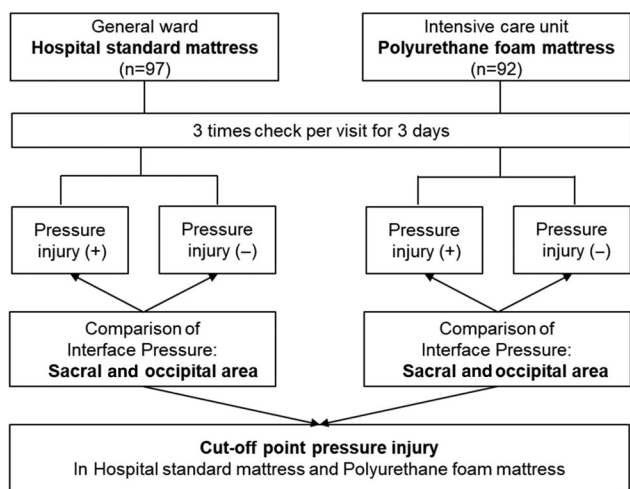


FIGURE 1 Research flow

deep tissue PI.<sup>14</sup> All categories listed above, except for 'intact skin', were considered skin changes.

IP refers to the pressure at the point where the body touches the supporting surface.<sup>15</sup> It was measured using a pressure scanner (Palm Q CR-490; CAPE CO., LTD, Yokisuka-shi, Japan), an airbag-pressure pad with five sensors and a wider area (130 × 130 mm). The scanner was applied at the contact point between the supporting surface and the prominent bony area of the patient. The IP measurement ranged from 0 to 200 mm Hg, and the measurement accuracy was ±3 mm Hg. The pressure was measured at the sacral and occipital regions in the PFM (viscoelastic foam mattress, head and middle zone 20 interlayer density, 7-in. thickness, Versa Care Bed System, Np 100 prevention surface, Hill-Rom Services Inc., USA) and SHM (a regenerated compressed general sponge mattress, 2.36-in. thickness) groups. Measurements were conducted three times at the head of the bed (HOB) elevated to a 30° angle, and the highest pressure value was used.

## 2.3 | Data collection

Data were collected from 20 January 2019 to 15 December 2019. To establish the reliability of IP measurement using a pressure scanner and skin assessment, one certified wound, ostomy, and continence nurse (WOCN) (master's degree, 13 years of experience as WOCN); one nurse who completed a wound and ostomy advanced practice course with 6 years of experience (master's degree); and two WOCNs (bachelor's degree, 6- to 9-month experience) conducted assessments three times in five patients; the intraclass correlation (ICC) coefficients for inter-rater reliability were  $r = .93$  and  $1.00$  ( $P < .001$ ) for IP and skin assessments, respectively. The assessors visited patients for three consecutive days, and the IP was measured three times per visit. The total execution

time for the daily visit and measurement was 15 minutes. Data on mean blood pressure, BT (body temperature), and SpO<sub>2</sub> (saturation of percutaneous oxygen), and skin condition were obtained on the day of each visit.

## 2.4 | Data analysis

Data were analysed using SPSS WIN 25.0 (IBM, Armonk, NY) and Stata 15.1. Descriptive analysis was used to summarise the general characteristics and study variables using frequencies, percentages, means, and standard deviations. Differences in IPs according to mattress type were analysed using independent *t*-tests. The receiver operating characteristics (ROC) curve and area under the curve (AUC) were used to predict the cut-off point of the peak IP for the occurrence of PIs. An AUC with a 95% CI was obtained. Additionally, the sensitivity and specificity were calculated for each estimated cut-off point.

## 2.5 | Ethical approval

The study was approved by the hospital institutional review board. All participants or guardians provided written informed consent after being informed of the study's purpose. Participants with disorientation or sedation in ICUs provided consent via a legal representative before data collection. They were also informed that their confidentiality and anonymity would be maintained and that they could withdraw from the study at any time.

## 3 | RESULTS

### 3.1 | General characteristics and skin changes

The participants' general and PI-related characteristics are summarised in Table 1. The mean age of the participants was  $72.20 \pm 10.06$  years, and the mean Braden scale scores were  $19.13 \pm 3.43$  and  $12.40 \pm 2.61$  in the SHM and PFM groups, respectively. The distribution of the Braden scale score according to the supportive surface is as follows: 49 (50.1%) participants in the no-risk group had a score of 19 or higher, 34 (35.1%) participants in the low-risk group had a score of 15-18, 11 (11.3%) participants in the moderate-risk group had a score of 13-14, and 3 (3.1%) participants in the high-risk group had a score of 12 or less in the SHM group. In the PFM group, 1 (1.1%), 15 (16.3%), 25 (27.2%), and 51 (55.4%) participants were present in the no-risk, low-risk, moderate-risk, and high-risk groups, respectively. In terms of skin changes at the sacral region in the SHM group,

TABLE 1 General characteristics and variables related to pressure injury (N = 189)

| Variables   | Characteristics            | n   | %     | Mean ± SD     | Range      |
|---|----------------------------|-----|-------|---------------|------------|
| Inpatient ward                                    | General ward               | 97  | 51.3  |               |            |
|   | Intensive care unit        | 92  | 48.7  |               |            |
| Support surface                                   | Standard hospital mattress | 97  | 51.3  |               |            |
|   | Polyurethane foam mattress | 92  | 48.7  |               |            |
| Gender  | Male                       | 112 | 59.3  |               |            |
|   | Female                     | 77  | 40.7  |               |            |
| Age (y)   | ≤65                        | 48  | 25.5  | 72.20 ± 10.06 | 51-90      |
|   | 66~79                      | 87  | 46.3  |               |            |
|   | ≥80                        | 53  | 28.2  |               |            |
| Hospitalisation period (d)                        | ≤1                         | 81  | 43.3  | 7.63 ± 28.31  | 0-365      |
|   | 2-6                        | 52  | 27.8  |               |            |
|   | ≥7                         | 54  | 28.9  |               |            |
| Major disease                                     | Pulmonary                  | 40  | 21.2  |               |            |
|   | Cardiovascular             | 13  | 6.9   |               |            |
|   | Cancers                    | 24  | 12.7  |               |            |
|   | Others                     | 112 | 59.2  |               |            |
| PI at admission                                   | Yes                        | 0   | 0.0   |               |            |
|   | No                         | 188 | 100.0 |               |            |
| History of PI                                     | Yes                        | 3   | 1.6   |               |            |
|   | No                         | 186 | 98.4  |               |            |
| Body mass index (kg/m <sup>2</sup> ) <sup>a</sup> | ≤18.4                      | 19  | 13.1  | 22.80 ± 4.50  | 12.4-42.4  |
|   | 18.5~25.4                  | 97  | 66.9  |               |            |
|   | ≥25.5                      | 29  | 20.0  |               |            |
| Mean blood pressure (mm Hg) <sup>a</sup>          | ≤80                        | 47  | 26.0  | 88.64 ± 12.79 | 51.3-133.0 |
|   | 81~99                      | 98  | 54.1  |               |            |
|   | ≥100                       | 36  | 19.9  |               |            |
| BT (°C) <sup>a</sup>                              | ≤36.4                      | 95  | 50.8  | 36.51 ± 0.42  | 35.4-39.1  |
|   | ≥36.5                      | 92  | 49.2  |               |            |
| SpO <sub>2</sub> (%)                              | ≤96                        | 43  | 23.0  | 97.17 ± 6.91  | 86.0-100.0 |
|   | ≥97                        | 144 | 77.0  |               |            |
| Braden scale score_ SHM                           | No risk (≥19)              | 49  | 50.1  | 19.13 ± 3.43  | 11.0-23.0  |
|   | Low risk (15~18)           | 34  | 35.1  |               |            |
|   | Moderate risk (13~14)      | 11  | 11.3  |               |            |
|   | High~severe risk (≤12)     | 3   | 3.1   |               |            |
| Braden scale score_ PFM                           | No risk (≥19)              | 1   | 1.1   | 12.40 ± 2.61  | 7.0-23.0   |
|   | Low risk (15~18)           | 15  | 16.3  |               |            |
|   | Moderate risk (13~14)      | 25  | 27.2  |               |            |
|   | High~severe risk (≤12)     | 51  | 55.4  |               |            |

<sup>a</sup>Missing data excluded.

Abbreviations: General wards = surgery, neurosurgery, infectious diseases, hematooncology, pulmonology, and nephrology; Intensive care unit = surgery, internal medicine, and emergency; PFM, polyurethane foam mattress; PI, pressure injury; SHM, standard hospital mattress.

20 (20.6%) patients had skin changes, and 7 (7.2%) developed skin changes in the occipital region. Skin changes in the sacral region in the PFM group included 47 (51.1%) patients and 19 (20.7%) patients in the occipital region.

### 3.2 | Regional peak IP according to the support surfaces

The IP was  $56.78 \pm 18.96$  and  $35.49 \pm 14.31$  mm Hg for the SHM and PFM groups at the sacral region, respectively. This finding indicated a significantly higher IP for the SHM group ( $t = 8.74, P < .001$ ). The IP was  $53.79 \pm 21.14$  and  $37.42 \pm 10.92$  mm Hg for the SHM and PFM groups at the occipital region, respectively. This finding indicated a significantly higher IP for the SHM group ( $t = 6.74, P < .001$ ; Table 2).

### 3.3 | Regional peak IP according to skin changes based on support surfaces

In the SHM group, no statistically significant differences were found in the IP for the sacral and occipital regions in patients who showed skin changes ( $63.58 \pm 15.49, t = -1.82, P = .072$ ;  $49.89 \pm 15.66$  mm Hg,  $t = 0.51, P = .614$ , respectively) when compared with those with no skin changes ( $55.01 \pm 19.46$  and  $54.09 \pm 21.54$  mm Hg, respectively). In the PFM group, patients with skin changes showed significantly higher IP in the sacral and occipital regions ( $40.86 \pm 14.64$  and  $43.39 \pm 13.83$  mm Hg, respectively) when compared with those without any skin changes ( $28.87 \pm 11.67$  and  $35.87 \pm 9.54$  mm Hg, respectively;  $t = -3.97, P < .001$ ;  $t = -2.77, P = .007$ , respectively; Table 2).

### 3.4 | Cut-off point for interface pressure

In the SHM group, the cut-off point for IP at the sacral region was 52.90 mm Hg (95% CI: 41.78-64.01), with 75.0% sensitivity and 55.0% specificity. The AUC of the ROC curve was .65 (95% CI: 0.52-0.77). The cut-off point for IP at the occipital region was 56.60 mm Hg (95% CI: 37.06-76.13), with 44.2% sensitivity and 68.0% specificity. The AUC of the ROC curve was .55 (95% CI: 0.21-0.67). In the PFM group, the cut-off point for IP at the sacral region was 30.15 mm Hg (95% CI: 21.98-38.26), with 79.0% sensitivity and 60.0% specificity. The AUC of the ROC curve was .73 (95% CI 0.63-0.83). The cut-off point for IP at the occipital region was 36.40 mm Hg (95% CI: 29.45-43.24), with 74.0% sensitivity and 60.0% specificity.

TABLE 2 Differences in regional interface pressure according to skin changes and support surfaces (N = 189)

| Support surface            | Skin change | Sacral region |               |                       | Occipital region       |            |               |                       |                        |
|----------------------------|-------------|---------------|---------------|-----------------------|------------------------|------------|---------------|-----------------------|------------------------|
|                            |             | n (%)         | Mean ± SD     | Within mattress t (P) | Between mattress t (P) | n (%)      | Mean ± SD     | Within mattress t (P) | Between mattress t (P) |
| Standard hospital mattress | No          | 77 (79.4)     | 55.01 ± 19.46 | -1.82 (.072)          | 8.74 (<.001)           | 90 (92.8)  | 54.09 ± 21.54 | 0.51 (.614)           | 6.74 (<.001)           |
|                            | Yes         | 20 (20.6)     | 63.58 ± 15.49 |                       |                        | 7 (7.2)    | 49.89 ± 15.66 |                       |                        |
|                            | Overall     | 97 (100.0)    | 56.78 ± 18.96 |                       |                        | 97 (100.0) | 53.79 ± 21.14 |                       |                        |
| Polyurethane foam mattress | No          | 45 (48.9)     | 29.87 ± 11.67 | -3.97 (<.001)         |                        | 73 (79.3)  | 35.87 ± 9.54  | -2.77 (.007)          |                        |
|                            | Yes         | 47 (51.1)     | 40.86 ± 14.64 |                       |                        | 19 (20.7)  | 43.39 ± 13.83 |                       |                        |
|                            | Overall     | 92 (100.0)    | 35.49 ± 14.31 |                       |                        | 92 (100.0) | 37.42 ± 10.92 |                       |                        |

The AUC of the ROC curve was .68 (95% CI: 0.54-0.83; Table 3; Figures 2 and 3).

## 4 | DISCUSSION

The present findings revealed that in patients using the SHM group, 20.6% and 7.2% of patients had skin changes in the sacral and occipital regions, respectively. In contrast, in the PFM group, 51.1% and 20.7% of patients had skin changes in the sacral and occipital regions, respectively. Evidently, in both groups, skin changes were more prevalent in the sacral region than in the occipital region, supporting the findings of a previous study that reported a higher incidence of PIs in the sacral region.<sup>16</sup>

Furthermore, a higher incidence of skin changes was found in ICU patients using PFM. This result supports the notion that the incidence rate of PIs among medical and surgical ICU patients was 14%-56%.<sup>17,18</sup> In contrast, these rates are higher than those reported in 11 cases with PIs out of 87 (12.6%) ICU patients,<sup>11</sup> including blanching erythema, a pre-pressure sore stage, as a skin change. As in this study, seven stages of skin changes in surgical ICU patients have been observed, including

cases of blanching erythema,<sup>10</sup> which yielded an incidence rate of 28% for skin changes. Although it is difficult to make an accurate comparison due to the different study populations, the participants of this study included internal medicine and emergency ICU patients; therefore, it is presumed that the patient's condition was related to skin changes. The incidence of PI is proportional to the pressure and time under the same conditions.<sup>1</sup> In this study, patients in the general wards who were SHM users had better general conditions than those in ICUs, and it is considered that the occurrence of PI is minor because participants change their posture spontaneously and apply pressure for less time. However, considering that 44% and 7% of the body weight are exerted on the sacral and occipital regions of the head, respectively,<sup>19</sup> skin changes in the sacral region were more prevalent in both SHM and PFM groups in the present study. This emphasises the need for frequent observation of the sacral region among patients and implementing necessary interventions. In particular, additional nursing interventions such as more frequent position changes are required in ICU patients because skin changes can occur under low pressure, even when using a polyurethane foam mattress.

TABLE 3 Cut-off point of regional interface pressure related to skin changes (N = 93)

| Support surface            | Region    | n  | Cut-off point (mm Hg) | 95% CI      | Z (P)         |
|----------------------------|-----------|----|-----------------------|-------------|---------------|
| Hospital standard mattress | Sacral    | 20 | 52.90                 | 41.78-64.01 | 9.33 (<.001)  |
|                            | Occipital | 7  | 56.60                 | 37.06-76.13 | 5.67 (<.001)  |
| Polyurethane foam mattress | Sacral    | 47 | 30.15                 | 21.98-38.26 | 7.23 (<.001)  |
|                            | Occipital | 19 | 36.40                 | 29.45-43.24 | 10.34 (<.001) |

Abbreviations: CI, confidence interval; n, number of skin changes.

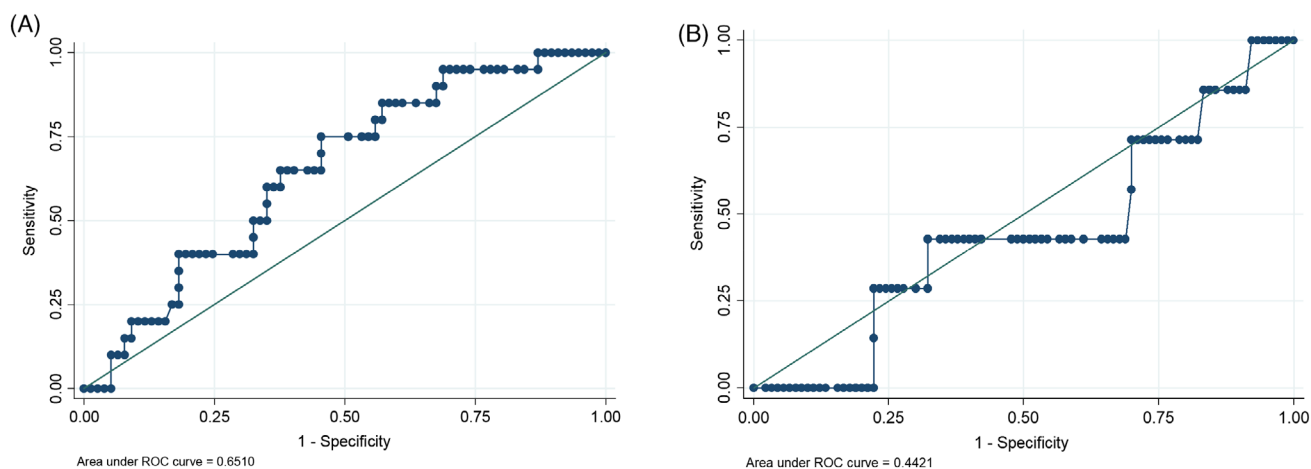
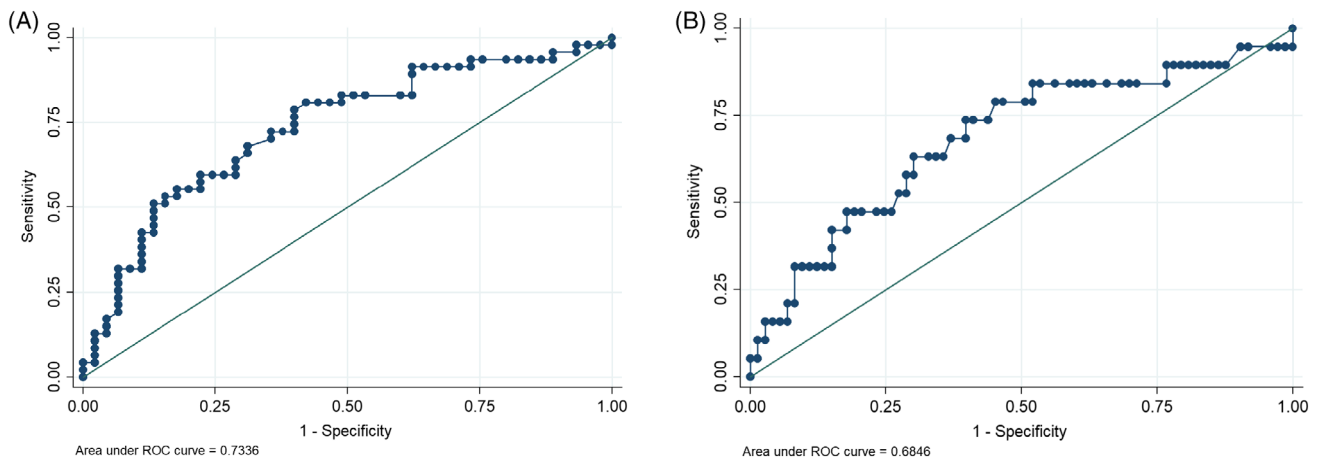


FIGURE 2 (A) Sacral area's interface pressure ROC curve in hospital standard mattress. Sensitivity .75, 1 - Specificity .55. AUC .65 (95% CI 0.52-0.77). (B) Occipital area's interface pressure ROC curve in hospital standard mattress. Sensitivity .44, 1 - Specificity .68. AUC .55 (95% CI 0.21-0.67). AUC, area under the curve; ROC, receiver operating characteristics



**FIGURE 3** (A) Sacral area's interface pressure ROC curve in foam mattress. Sensitivity .79, 1 - Specificity .60. AUC .73 (95% CI 0.63–0.83). (B) Occipital area's interface pressure ROC curve in foam mattress. Sensitivity .74, 1 - Specificity .60. AUC .68 (95% CI 0.54–0.83). AUC, area under the curve; ROC, receiver operating characteristics

The IP for an SHM was significantly higher than that for a PFM. As such, the IP at the sacral and occipital regions was 56.78 ( $\pm 18.96$ ) and 53.79 ( $\pm 21.14$ ) mm Hg, respectively, in the SHM group, and it was 35.49 ( $\pm 14.31$ ) and 37.42 ( $\pm 10.92$ ) mm Hg, respectively in the PFM group. Cho and colleagues<sup>20</sup> found a mean IP of 29.64  $\pm$  2.96 mm Hg for SHMs, and Källman and colleagues<sup>21</sup> reported an IP of 44.7  $\pm$  11.7 mm Hg at the sacral region. Previous findings were lower than those in the present study. This difference may be attributed to the fact that, while the present study measured peak IP in hospitalised patients, previous studies<sup>9,20</sup> measured either the mean IP or included healthy adults without any neurological or musculoskeletal problems. Even if the same pressure scanner is used for assessments, the IP of subjects with underlying diseases tends to be higher than that of healthy adults with an average BMI of 22.7 kg/m<sup>2.5</sup> This can be attributed to the higher IP of the supporting surface due to the reduced soft tissue and elasticity of the skin in the sacral region.<sup>5</sup> The IP in the sacral region using the same pressure scanner was 72.48  $\pm$  29.80 mm Hg for SHM and 42.21  $\pm$  13.78 mm Hg for PFM.<sup>15</sup> These findings were slightly higher but similar to the present study. Therefore, the present study confirmed differences in IP depending on the support surfaces, with significantly lower pressure for PFM than SHM. This confirms the effective pressure distribution of polyurethane foam mattresses, supporting the findings of previous studies.<sup>3,6,15</sup>

The comparison of differences in IP between groups with and without skin changes showed that, when PFMs were used, the IP for the sacral and occipital regions was significantly higher among the skin change group than

the other group. Despite using the same PFM, differences in skin change in critical patients could be attributed to patient characteristics. However, for SHM, no significant difference was found in IP regardless of skin changes. This means that the IP of SHM does not affect skin changes. These results support the previous findings that SHM could be used for patients at low risk of PIs<sup>15</sup> and using a mattress with superior pressure redistribution for patients at a high risk of PIs was recommended.<sup>1,11,22</sup>

Supriadi and colleagues<sup>11</sup> reported that a higher IP for the PIs group (66.2  $\pm$  42.0 mm Hg) than for the no PIs group (42.7  $\pm$  14.8 mm Hg). However, these results cannot be directly compared with those of the present study, because Supriadi et al<sup>11</sup> measured IP in a prospective cohort study. The support surfaces were not distinguished. Thus, the relative IP found in each study should be considered a matter of interpretation rather than the absolute IP of the support surface because of the varied support surfaces, subjects, and measuring devices.<sup>23</sup>

The peak IP in the SHM group with no skin changes in the sacral region was high (54.09 mm Hg), exceeding the capillary closing pressure of 32 mm Hg. These results are assumed to be the better health condition in general wards and collateral circulation in the pressed area.<sup>4</sup> However, skin changes occurred at low pressure (40.86  $\pm$  14.64 mm Hg) in the sacral region for the PFM group. It could be attributed to participants' underlying diseases or health conditions needed to use vasopressors, sedative medications, and ventilators. Accordingly, this result supports the findings of previous studies that suggested the need to reduce IP among patients at high risk of PIs owing to their poor health condition, specifically by using PFM with higher specifications.<sup>7,15,24</sup>

Regarding the significant differences in IP according to skin changes in the PFM group, IP in the sacral region was lower than that in the occipital region. This could be attributed to the more effective pressure distribution in the sacral region than in the occipital region when using a PFM. It can be inferred that the sacral region is anatomically rich in subcutaneous tissues and muscles, which play the role of a cushion in the body. However, most critically ill patients cannot remain in a supine position because of respiratory or enteral feeding problems. Thus, many are positioned with HOB elevated to a 30° angle, which increases the incidence of PIs in the sacral region.<sup>16</sup> Therefore, caution should be paid, as skin changes occur even at low pressure in the position with the upper body raised because the sacral region is pressed with higher pressure due to body weight.<sup>19</sup>

The IP cut-off point at which skin change can occur when using both mattresses varied depending on the region, and SHM had a higher cut-off point than PFM. First, the results showed that IP, except that in the occipital region for SHM, which had a specificity of less than 50%, was appropriate<sup>25</sup> for predicting skin changes related to PIs. Therefore, IP should be reduced to less than 52.90 and 30.15 mm Hg in the sacral region to prevent skin change when using SHM and PFM, respectively. Furthermore, the IP of PFM in the occipital region should be maintained under 36.40 mm Hg. As IP was measured at a 30° angle position, the cut-off point is expected to be lower in the flat position.<sup>4</sup>

Second, the cut-off point that predicts skin change was lower for PFM than for SHM. The higher incidence of skin change despite lower IP may be that the participants in the PFM group were all ICU patients. Consequently, IP must be reduced by using a high-performance supporting surface that can effectively distribute pressure or through more frequent position changes for high-risk critical patients, even if PFMs are used. For patients at low risk of PIs, SHM can be used, but if the patient is at high risk, the use of PFM rather than SHM is recommended.

This study has significant implications for nursing practices. In a previous study,<sup>10</sup> similar to this study, the IP of ICU patients in various regions where PIs were prevalent and identified factors that affect IP. However, the types of mattresses and the cut-off points of IP for skin change were not considered. Thus, it is noteworthy that the present study compared IP related to PIs according to the type of mattress and presented the pressure cut-off points for different parts of the body.

This study had some limitations. First, IP was measured only in the HOB elevated at a 30° angle, because it was necessary to maintain head elevation depending on the state of breathing and consciousness. Second, the homogeneity of the two groups was not obtained. Third,

only critical patients were included in the PFM group, whereas the SHM comprised general ward patients. Therefore, the results should be interpreted with caution. Fourth, the cut-off point for each subgroup of the Braden scale could not be calculated. This is because the number of participants in each subgroup is small, so the accuracy of the score is low. Thus, it is necessary to measure the cut-off point for IP in various positions and to calculate the cut-off point according to the Braden scale subgroup with a larger sample.

However, this study provides scientific evidence based on the direct measurement of IP to examine the effects of physical environmental factors, such as mattresses, in preventing PIs. Thus, the findings of this study could be used as basic data to establish effective PI prevention strategies in clinical practice. Further, we suggest the importance of using IP measurements to prevent PI and use individualised interventions based on the cut-off points for different support surfaces. Follow-up studies should focus on estimating the variables affecting IP, considering patients' health conditions.

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#### CONFLICT OF INTEREST

The authors declare no conflicts of interest.

#### DATA AVAILABILITY STATEMENT

The data that support the findings of this study are openly available in [repository name e.g. "figshare"] at [http://doi.org/\[doi\]](http://doi.org/[doi]), reference number [reference number].

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