J. Phys. Ther. Sci. 28: 460–466, 2016

The Journal of Physical Therapy Science

Original Article

Effects of a continuous lateral turning device on pressure relief

Nam Ho Do[1)], Deog Young Kim[2)], Jung-Hoon Kim[3)], Jong Hyun Choi[1)], So Young Joo[2)], Na Kyung Kang[4)], Yoon Su Baek[1)*]

[1)] *Department of Mechanical Engineering, Yonsei University: 50 Yonsei-ro, Seodaemun-gu, Seoul 120-749, Republic of Korea*
[2)] *Department and Research Institute of Rehabilitation Medicine, Yonsei University College of Medicine, Republic of Korea*
[3)] *Construction Robot and Automation Laboratory, School of Civil and Environmental Engineering, Yonsei University, Republic of Korea*
[4)] *Research Institute of Rehabilitation Medicine, Yonsei University College of Medicine, Republic of Korea*

Abstract. [Purpose] The purpose of this study was to examine the pressure-relieving effects of a continuous lateral turning device on common pressure ulcer sites. [Subjects] Twenty-four healthy adults participated. [Methods] The design of our continuous lateral turning device was motivated by the need for an adequate pressure-relieving device for immobile and/or elderly people. The procedure of manual repositioning is embodied in our continuous lateral turning device. The interface pressure and time were measured, and comfort grade was evaluated during sessions of continuous lateral turning at 0°, 15°, 30°, and 45°. We quantified the pressure-relieving effect using peak pressure, mean pressure, and pressure time integration. [Results] Participants demonstrated pressure time integration values below the pressure-time threshold at 15°, 30°, and 45° at all the common pressure ulcer sites. Moreover, the most effective angles for pressure relief at the common pressure ulcer sites were 30° at the occiput, 15° at the left scapula, 45° at the right scapula, 45° at the sacrum, 15° at the right heel, and 30° at the left heel. However, angles greater than 30° induced discomfort. [Conclusion] Continuous lateral turning with our specially designed device effectively relieved the pressure of targeted sites. Moreover, the suggested angles of continuous lateral turning can be used to relieve pressure at targeted sites.

Key words: Continuous lateral turning, Pressure time integration, Pressure ulcer

(This article was submitted Sep. 14, 2015, and was accepted Oct. 31, 2015)

INTRODUCTION

Pressure ulcers are a common problem seen in patients who are immobile and/or elderly, and a serious national health concern impacting cost of care, reimbursement, and quality of life[1–3)]. For instance, physical inactivity after stroke may contribute to immobile everyday lives of stroke survivors[4)]. In addition, stroke survivors are at risk of developing pressure ulcers[5)]. It is estimated that 2.5 million pressure ulcers are treated each year in US acute care facilities. The pressure ulcer incidence rate has been reported to be 0.4% to 38.0% in acute care, 2.2% to 23.9% in long-term care, and 0% to 17% in home care. The estimated cost of managing a single, full-thickness pressure ulcer can be as high as $70,000. Furthermore, the estimated cost of treating pressure ulcers has been estimated to be $11 billion per year in the USA[6)].

There has been little improvement in the effectiveness of prevention methods[6)]. Effective repositioning methods for pressure ulcer prevention are crucial, because manual repositioning by caregivers is expensive and can result in loss of productive

*Corresponding author. Yoon Su Baek (E-mail: ysbaek@yonsei.ac.kr)

time. Manual repositioning is one of the most expensive interventions, accounting for 75% of the total cost of pressure ulcer prevention[7)] and 40% of all nursing time on day shifts[8)]. In addition, traditional repositioning is one of the highest occupational risks experienced by caregivers[9)].

Manual lateral turning by caregivers has been a standard method of pressure ulcer prevention. Some clinical practice guidelines recommend repositioning at least every two hours for immobile patients and elderly people, but these guidelines are based on a small number of epidemiological studies, with inconsistent findings.

Manual repositioning every two hours and other additional pressure ulcer prevention strategies, such as lateral turning, are used extensively for pressure ulcer prevention. However, the optimal turning angles to prevent pressure ulcers remain unclear. In general, pressure ulcers occur due to pressure distributed through soft tissue located under bony prominences. Thus, common pressure ulcer sites include the occiput, scapula, sacrum, greater trochanter, and heel. The major factors of pressure ulcer development are duration and magnitude of pressure, because a single pressure level is not enough to represent the threshold of pressure ulcer development[10, 11)].

Continuous lateral turning has been used in the care of critically ill patients receiving mechanical ventilation in order to prevent and treat respiratory complications[12)], but few studies have examined the effect of pressure relief in continuous lateral turning. The design of our continuous lateral turning device was motivated by the need for adequate pressure-relieving devices or beds for immobile and/or elderly people. The typical steps involved in the manual repositioning of patients, specifically turning the patients and translating them to the center of the bed, were embodied in our continuous lateral turning device. After initial development, this device was tested to evaluate the pressure-relieving effect of continuous lateral turning on common pressure ulcer sites.

In this study, the pressure-relieving effect of the continuous lateral turning device on common pressure ulcer sites was investigated, and the pressure relief effect was quantified using peak pressure, mean pressure, and pressure time integration. The effects of pressure relief and comfort grades at different turning angles of continuous lateral turning were also investigated and compared.

SUBJECTS AND METHODS

Twenty-four healthy adults (12 men and 12 women) were recruited for this study. The mean (SD) age, weight, height, and body mass index of the participants were 28.2 (4.3) years, 63.6 (16.7) kg, 1.7 (0.1) m, and 22.2 (4.2) kg/m^2, respectively (Table 1). All the participants were free of neck and back pain for a minimum of two years before this study, as well as skin disorders such as chronic pressure ulcers. None of participants reported having diabetes, significant musculoskeletal or neurological disorders. Each participant served as his or her own control. The study protocol followed the principles of the Declaration of Helsinki and was approved by the Institutional Review Board of Yonsei University. Written informed consent was obtained from all of the participants. We did not try to include or exclude any participants based on gender or ethnicity. Confirmation of eligibility was obtained by face-to-face interviews with potential participants. Participation in the study was voluntary, and the participants were free to withdraw at any time. All data were treated confidentially and processed anonymously.

This study used a one-group, repeated-measures design. Before the experiments, the head, shoulders, hips, upper extremities, and lower extremities of all the participants were positioned supine on the bed, and the positions of the eight common pressure ulcer sites, the occiput, both scapulas, sacrum, both greater trochanters, and both heels on the bed, were respectively identified and specified with 68.0 mm × 68.0 mm sensing areas. The interface pressure sensors were attached to the surface of the bed and calibrated. After that, the bed turned each participant to the right from 0° to 0°, 15°, 30°, or 45° for 15 minutes, and returned the participant to the supine position in the following 15 minutes at a constant angular speed. The experiment

Table 1. Demographic characteristics of the study participants

Characteristic	All Participants (N = 24)
	N (%)
Gender	
Male	12 (50)
Female	12 (50)
Asian ethnicity	24 (100)
	Mean (standard deviation)
Age (years)	28.2 (4.3)
Weight (kg)	63.6 (16.7)
Height (m)	1.7 (0.1)
BMI (weight[kg]/height[m^2])	22.2 (4.2)

BMI: body mass index

was simplified by assuming a nearly symmetric pressure distribution between a right and left turn, e.g. pressure distribution for the left scapula when a right turn was applied was similar to the pressure distribution for the right scapula when a left turn was applied. Therefore, only right turns were included in the experimental design. The interface pressure and time values were recorded simultaneously for each test. Each participant's comfort grade on the bed at each angle of continuous lateral turning was also evaluated. Participants were instructed to maintain their posture during the measurement period and allowed to rest for five minutes between tests. The test order of the four conditions was selected randomly.

The newly developed continuous lateral turning device consists of a sliding part able to translate in the x-axis (left shoulder to right shoulder axis), two lateral tilting parts able to rotate around each axis parallel to the y-axis (head to feet axis), and back panels, seat panels, thigh panels, and calf panels. A standard mattress was attached on the panels. The mattress referred to as the standard mattress was made of 80-mm-thick polyurethane with 60 kg/m^3 density and a polyurethane-ethylene cover.

Our continuous lateral turning device was developed for repositioning patients who are immobile and/or elderly. The person's location, including position in the x-axis and orientation in the xz-plane was controlled under no-slip conditions. The typical steps involved in the manual repositioning of patients, specifically turning the patients and translating them to the center of the bed, were embodied in our continuous lateral turning device. The specially designed device was used to induce a change of orientation of the person by continuously turning the person around the axis parallel to the y-axis at a constant angular speed. The device is capable of accurate continuous lateral turning with a range of from 0° to 45° within a set time period at a constant turning speed.

The interface pressure and time values were measured using the Body Pressure Measurement System (Tekscan, South Boston, MA, USA). This system consists of four thin and flexible film sensors. The sensing area of each sensor is 578.0 mm × 884.0 mm. The number of sensing elements per sensor is 1768 (= 34 by 52). The element size of each sensing element is 17.0 mm × 17.0 mm. The thinness and flexibility of the sensors allow precise measurement of the pressure at the bed-skin interface. The sensors were calibrated to measure pressures ranging from 0 to 200 mmHg. The sampling rate for data acquisition was set to 1 Hz.

Matlab (Mathworks, Inc., Natick, MA, USA) was used to sort pressure and time value data at common pressure ulcer sites from the whole data set. To describe the effect of pressure relief, pressure and time at eight common pressure ulcer sites were measured. The peak pressure and mean pressure (mmHg) at the bed-skin interface during turning were obtained. Inspired by studies in which tissue injury is closely related to not only pressure but also exposure time[10)], pressure time integration (mmHg × sec) was calculated. Pressure × time can be used as a tissue tolerance guideline for allowable pressure versus exposure time[11)]. The pressure-time threshold for 2-hour repositioning in this study was defined as 460,800 mmHg × sec on the basis of the results of Linder-Ganz et al.[13)]. For comparisons of pressure time integration values and the pressure-time threshold, we repeated each 30-minute measurement session four times.

Each participant's comfort grade on the bed at each angle of continuous lateral turning was evaluated using a subscale of the comfort and quality of sleep questionnaire developed by Yinnon et al.[14)] which encompasses duration of sleep, number of wakenings, and quality of sleep. This subscale was adapted primarily to include a question relating to the comfort of the mattresses as follows: 1 (extremely comfortable), 2 (very comfortable), 3 (comfortable), 4 (fairly comfortable), 5 (uncomfortable), 6 (very uncomfortable), and 7 (extremely uncomfortable)[14)].

The Statistical Package for the Social Sciences (SPSS; IBM, Armonk, NY) version 18.0 was used to analyze the data. The overall analysis design was a one-way repeated measures analysis of variance (ANOVA) with one factor, turning angle, followed by Bonferroni's significance level adjustment for multiple comparisons. A p-value of 0.05 was accepted as the nominal significance level. The characteristics of the participants are expressed as counts, proportions, or means with standard deviations. The pressure and time parameters are expressed as means with standard deviations (i.e., mean (standard deviation)).

RESULTS

The peak pressures of almost all sites were significantly reduced at turning angles of 15°, 30°, and 45° compared to 0°, except the right scapula at 15°. The peak pressure of the right greater trochanter was significantly increased at 30° and 45° compared with 0° ($p < 0.05$) (Table 2).

The peak pressures at 15°, 30°, and 45° were compared to those at 0°, 15°, and 30°, respectively. The peak pressures of the occiput and right heel significantly decreased at 15°and 30° ($p < 0.05$), but not at 45°. The peak pressures of the left scapula and left heel showed significant decreases only at 15° ($p < 0.05$). The peak pressure of the right scapula significantly decreased at 30° and 45° ($p < 0.05$), but not at 15°. The peak pressure of the sacrum significantly decreased at all the angles ($p < 0.05$). The peak pressure of the right greater trochanter significantly increased at 30° and 45° ($p < 0.05$), but not at 15° (Table 2).

The mean pressures of almost all sites were significantly reduced at turning angles of 15°, 30°, and 45° compared to 0°, except for the right heel at 15°. The mean pressures of the right greater trochanter were significantly increased at 30° and 45° compared to 0° ($p < 0.05$) (Table 3).

The mean pressures at 15°, 30°, and 45° were compared to those at 0°, 15°, and 30°, respectively. The mean pressure of the occiput significantly decreased at 15° and 30° ($p < 0.05$), but not at 45°. The mean pressure of the left scapula significantly decreased at 15° and 45° ($p < 0.05$), but not at 30°. The mean pressures of the right scapula and sacrum significantly decreased at all the angles ($p < 0.05$). The mean pressure of the right heel significantly decreased only at 30° ($p < 0.05$). The mean pressure of the left heel showed a significant decrease only at 15° ($p < 0.05$). The mean pressure of the right greater trochanter significantly increased at 30° and 45° ($p < 0.05$), but not at 15° (Table 3).

The values of pressure time integration of almost all sites were significantly reduced at turning angles of 15°, 30°, and 45° compared to 0° except for the right scapula at 15° and 30°, but the pressure time integration of the right greater trochanter was significantly increased at 45° compared to 0° ($p < 0.05$) (Table 4).

Table 2. Peak pressure at common pressure ulcer sites

	Peak pressure (mmHg)			
	0°	15°	30°	45°
	Mean (standard deviation)			
Occiput	58.8 (10.0)	43.0 (15.2)*†	26.3 (15.3)*†	24.3 (11.6)*
Left Scapula	37.4 (4.7)	32.0 (5.1)*†	29.2 (4.2)*	25.2 (8.0)*
Right Scapula	36.8 (6.7)	33.6 (10.1)	24.4 (12.3)*†	16.8 (13.1)*†
Sacrum	70.5 (24.9)	47.9 (10.1)*†	38.0 (7.9)*†	27.1 (8.5)*†
Left Greater Trochanter	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Right Greater Trochanter	0.0 (0.0)	0.5 (1.4)	8.3 (12.4)*†	35.5 (17.8)*†
Right Heel	77.3 (26.3)	54.7 (24.6)*†	32.9 (21.6)*†	27.3 (20.3)*
Left Heel	86.6 (24.3)	70.3 (27.0)*†	57.3 (38.7)*	46.9 (40.5)*

*p < 0.05 compared with 0°.
†p < 0.05 compared with peak pressures at an angle that is 15° lower

Table 3. Mean pressure at common pressure ulcer sites

	Mean pressure (mmHg)			
	0°	15°	30°	45°
	Mean (standard deviation)			
Occiput	34.9 (5.8)	23.0 (8.6)*†	14.3 (7.3)*†	12.1 (4.6)*
Left Scapula	25.9 (3.3)	20.4 (4.1)*†	18.2 (2.4)*	15.7 (3.2)*†
Right Scapula	24.8 (3.2)	19.2 (4.5)*†	12.9 (5.9)*†	8.9 (5.3)*†
Sacrum	43.7 (7.8)	32.7 (5.1)*†	25.5 (4.9)*†	16.2 (5.2)*†
Left Greater Trochanter	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Right Greater Trochanter	0.0 (0.0)	0.5 (1.3)	5.4 (7.8)*†	20.7 (10.9)*†
Right Heel	27.8 (6.9)	23.1 (10.8)	14.8 (8.2)*†	13.8 (8.5)*
Left Heel	31.6 (6.3)	26.0 (7.6)*†	21.2 (11.0)*	17.1 (12.7)*

*p < 0.05 compared with 0°.
†p < 0.05 compared with mean pressures at an angle that is 15° lower

Table 4. Pressure time integration at common pressure ulcer sites

	Pressure time integration (mmHg × sec)			
	0°	15°	30°	45°
	Mean (standard deviation)			
Occiput	471,318 (45,935)	334,074*†§ (58,340)	260,866*†§ (86,104)	227,919*§ (78,836)
Left Scapula	266,277§ (32,635)	231,091*†§ (28,370)	218,148*§ (32,480)	199,957*§ (41,047)
Right Scapula	259,803§ (36,376)	249,667§ (55,267)	225,394§ (68,862)	194,361*†§ (65,994)
Sacrum	504,298 (170,112)	386,950*†§ (89,928)	366,383*§ (106,445)	295,585*†§ (68,478)
Left Greater Trochanter	0§ (0)	0§ (0)	0§ (0)	0§ (0)
Right Greater Trochanter	292§ (1,429)	978§ (2,678)	10,327§ (17,545)	45,857*†§ (38,050)
Right Heel	549,528 (191,596)	442,565*†§ (172,656)	378,888*§ (137,788)	347,725*§ (127,868)
Left Heel	609,617 (171,748)	451,360*†§ (119,789)	352,407*†§ (158,300)	293,906*§ (131,612)

*p < 0.05 compared with 0°.
†p < 0.05 compared with pressure time integration values at an angle that is 15° lower.
§Values below the pressure-time threshold 460,800 mmHg × sec

The values of pressure time integration at 15°, 30°, and 45° were compared to those at 0°, 15°, and 30°, respectively. The values of pressure time integration of the occiput and left heel significantly decreased at 15° and 30° ($p < 0.05$), but not at 45°. The values of pressure time integration of the left scapula and right heel significantly decreased only at 15° ($p < 0.05$). The pressure time integration of the sacrum significantly decreased at 15° and 45° ($p < 0.05$), but not at 30°. The pressure time integration of the right scapula significantly decreased only at 45° ($p < 0.05$). The pressure time integration of the right greater trochanter significantly increased only at 45° ($p < 0.05$) (Table 4).

The mean comfort grades at the different turning angles were 2.1 at 0°, 2.9 at 15°, 4.0 at 30°, and 5.2 at 45°. The degree of discomfort increased with the elevation of the angle of continuous lateral turning. The comfort grades were significantly higher at 15°, 30°, and 45° than at 0° ($p < 0.05$), and also significantly higher at 15°, 30°, and 45° than at 0°, 15°, and 30°, respectively ($p < 0.05$) (Table 5), indicating greater discomfort with increasing angle.

DISCUSSION

In this study, we verified and quantified the pressure relief effect of our continuous lateral turning device. Our participants showed pressure time integration values below the pressure-time threshold at 15°, 30°, and 45° at all the common pressure ulcer sites due to pressure relief induced by the continuous lateral turning device. Our observations about the different effects of pressure relief according to various angles of continuous lateral turning at common pressure ulcer sites have implications for the repositioning of patients and pressure relief using continuous lateral turning. In particular, we tried to examine which angles of continuous lateral turning were the most effective for pressure relief at each targeted site. The pressure time integration values at almost all sites, with the exception of the right scapula and right greater trochanter, were significantly lower at 15°, 30°, and 45° than at 0°, indicating a decreased risk of developing pressure ulcers.

With respect to common pressure ulcer sites, we conclude that the most effective angles of continuous lateral turning satisfy several conditions. First, the most effective angles have significantly lower pressure time integration values than that of 0°. Second, the most effective angles have significantly lower pressure time integration values than the pressure time integration values at angles that are 15° lower. Third, among the angles satisfying the two previous conditions, the one with the lowest pressure time integration value is the most effective angle. Overall, the most effective angles of continuous lateral turning were 15° for the left scapula and right heel, 30° for the occiput and left heel, and 45° for the right scapula and sacrum. However, at 45° continuous lateral turning, increasing pressure was applied to the right greater trochanter as a side-effect. Table 6 compares the tested maximum interface pressure of our continuous lateral turning device with the results of previous studies that measured pressure-relief.

Various attempts have been made to develop effective methods for preventing pressure ulcers and relieving pressure, but none have reported uniformly successful results. In one study, no significant differences in interface pressure were observed when comparing turning intervals of 60 min, 90 min, and 120 min[18]. The incidence of pressure ulcers decreased when repositioning alternated between 2 hr in the lateral position and 4 hr in a supine position compared to repositioning every 4 hr, but no significant difference was found between the two protocols[19]. One investigation found that rotating beds resulted in nearly the same incidence of pressure ulcers as common hospital beds[20]. Some authors have investigated manual lateral

Table 5. Comfort grade with angle of continuous lateral turning

Angle	Comfort grade
	Mean (standard deviation)
0°	2.1 (1.1)*†
15°	2.9 (1.1)*†
30°	4.0 (1.2)*†
45°	5.2 (1.2)*†

*$p < 0.05$ compared with 0°.
†$p < 0.05$ compared with comfort grade at an angle that is 15° lower

Table 6. Comparison of maximum interface pressure (mmHg) from four studies

Study	Participants position	
	Supine	Laterally turned position (turning angle)
Present study (sacrum)	70.5	47.9 (15°), 38.0 (30°), 27.1 (45°)
Peterson et al. (peri-sacrum)[15]	68.6	69.2 (30°)
Turpin et al. (sacrum)[16]	≤31	100.0 (50°)
Woodhouse et al. (sacrum)[17]	46	48.0 (14°)

turning, specifically 30° lateral turning. These studies suggest that 30° lateral turning induces a lower interface pressure than 90° lateral turning and might be sufficient to prevent pressure ulcers[21, 22]. However, another study found that the incidence of pressure ulcers between a 30° tilt position and 90° lateral position was not significantly different[23]. Overall, while limited interventions are important components of methods for pressure ulcer prevention and pressure relief, there has been little significant improvement in the effectiveness of methods for pressure ulcer prevention and pressure relief[6].

One of the limitations of this study was the small number of study participants. Furthermore, the cost of the position conversion bed or mattress might be expensive. In addition, we only studied healthy adults. Generally, healthy adults are likely to have muscle characteristics different from those of immobile patients or the elderly. Different muscle characteristics would cause different pressure distributions. Additional considerations and clinical studies may be needed to investigate whether the same pressure-relieving effect is found for patients or the elderly, as well as the impact of covariates such as age and gender. Further studies are needed to investigate the pressure-relieving effect of our continuous lateral turning device, considering interface pressure and shear force together[24].

In conclusion, continuous lateral turning with our specially designed device effectively relieved the pressure at targeted sites, potentially reducing the risk of developing pressure ulcers. Moreover, the optimal angles of continuous lateral turning vary by site, and should be applied in a targeted way. The continuous lateral turning device can be employed for pressure ulcer prevention and care with the goal of assisting caregivers providing bedside care and improving pressure ulcer prevention and quality of care.

ACKNOWLEDGEMENT

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MEST) (No. 2012-0000155).

REFERENCES

1) Kim MH, Yoo WG: Effects of an inclining seat support on gluteal pressure. J Phys Ther Sci, 2012, 24: 849–850. [CrossRef]
2) Murata J, Murata S, Ohyama M, et al.: Effect of a dynamic air cushion on the development of leg edema during wheelchair sitting. J Phys Ther Sci, 2014, 26: 911–913. [Medline] [CrossRef]
3) Kuhn BA, Coulter SJ: Balancing the pressure ulcer cost and quality equation. Nurs Econ, 1992, 10: 353–359. [Medline]
4) Lee IH, Park SY: Assistive cushions for symmetric wheelchair sitting by stroke patients. J Phys Ther Sci, 2011, 23: 837–840. [CrossRef]
5) Kobara K, Takahashi H, Fujita D, et al.: Investigation of effect of leg support elevation timing on the horizontal force acting on the buttocks in a reclining wheelchair. J Phys Ther Sci, 2015, 27: 2605–2610. [Medline] [CrossRef]
6) Reddy M, Gill SS, Rochon PA: Preventing pressure ulcers: a systematic review. JAMA, 2006, 296: 974–984. [Medline] [CrossRef]
7) Xakellis GC, Frantz R, Lewis A: Cost of pressure ulcer prevention in long-term care. J Am Geriatr Soc, 1995, 43: 496–501. [Medline] [CrossRef]
8) Versluysen M: Pressure sores in elderly patients. The epidemiology related to hip operations. J Bone Joint Surg Br, 1985, 67: 10–13. [Medline]
9) Marras WS, Davis KG, Kirking BC, et al.: A comprehensive analysis of low-back disorder risk and spinal loading during the transferring and repositioning of patients using different techniques. Ergonomics, 1999, 42: 904–926. [Medline] [CrossRef]
10) Kosiak M: Etiology and pathology of ischemic ulcers. Arch Phys Med Rehabil, 1959, 40: 62–69. [Medline]
11) Reswick JB, Rogers JE: Experience at Rancho Los Amigos Hospital with devices and techniques to prevent pressure sores. In: Kenedi RM, Cowden JM, Scales JT, editors. Bedsore Biomechanics. Baltimore: University Park Press, 1976, pp 301–310.
12) Goldhill DR, Imhoff M, McLean B, et al.: Rotational bed therapy to prevent and treat respiratory complications: a review and meta-analysis. Am J Crit Care, 2007, 16: 50–61, quiz 62. [Medline]
13) Linder-Ganz E, Gefen A: Stress analyses coupled with damage laws to determine biomechanical risk factors for deep tissue injury during sitting. J Biomech Eng, 2009, 131: 011003. [Medline] [CrossRef]
14) Yinnon AM, Ilan Y, Tadmor B, et al.: Quality of sleep in the medical department. Br J Clin Pract, 1992, 46: 88–91.

[Medline]
15) Peterson MJ, Schwab W, van Oostrom JH, et al.: Effects of turning on skin-bed interface pressures in healthy adults. J Adv Nurs, 2010, 66: 1556–1564. [Medline] [CrossRef]
16) Turpin PG, Pemberton V: Prevention of pressure ulcers in patients being managed on CLRT: is supplemental repositioning needed? J Wound Ostomy Continence Nurs, 2006, 33: 381–388. [Medline] [CrossRef]
17) Woodhouse M, Worsley PR, Voegeli D, et al.: The physiological response of soft tissue to periodic repositioning as a strategy for pressure ulcer prevention. Clin Biomech (Bristol, Avon), 2015, 30: 166–174. [Medline] [CrossRef]
18) Knox DM, Anderson TM, Anderson PS: Effects of different turn intervals on skin of healthy older adults. Adv Wound Care, 1994, 7: 48–52, 54–56. [Medline]
19) Vanderwee K, Grypdonck MH, De Bacquer D, et al.: Effectiveness of turning with unequal time intervals on the incidence of pressure ulcer lesions. J Adv Nurs, 2007, 57: 59–68. [Medline] [CrossRef]
20) Gentilello L, Thompson DA, Tonnesen AS, et al.: Effect of a rotating bed on the incidence of pulmonary complications in critically ill patients. Crit Care Med, 1988, 16: 783–786. [Medline] [CrossRef]
21) Colin D, Abraham P, Preault L, et al.: Comparison of 90 degrees and 30 degrees laterally inclined positions in the prevention of pressure ulcers using transcutaneous oxygen and carbon dioxide pressures. Adv Wound Care, 1996, 9: 35–38. [Medline]
22) Defloor T: The effect of position and mattress on interface pressure. Appl Nurs Res, 2000, 13: 2–11. [Medline] [CrossRef]
23) Young T: The 30 degree tilt position vs the 90 degree lateral and supine positions in reducing the incidence of non-blanching erythema in a hospital inpatient population: a randomised controlled trial. J Tissue Viability, 2004, 14: 88, 90, 92–96. [Medline] [CrossRef]
24) Kobara K, Eguchi A, Watanabe S, et al.: Investigation of the validity of an experimental model for the estimated shear force on buttocks in a comfortable sitting posture. J Phys Ther Sci, 2008, 20: 157–162. [CrossRef]