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Design and Development of Lateral Tilting Mechanical bed for rural bedridden patients in Thailand

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Abstract: Tissue injury is a complication that causes excessive interface pressure on a bony prominence and usually occurs in immobilized patients, especially the bedridden ones in home-based care. Objective: To investigate the efficacy of a lateral tilting mechanical bed in decreasing interface pressure over bony prominences in bedridden patients who use these beds. Design: Repeated-measures, intervention, and outcomes measure research design. The sample consisted of 40 home-based bedridden people from September 2017 to December 2018. Data from personal information and interface pressure records were analyzed using descriptive statistics, *t*-test, and Mann–Whitney *U* test. The lateral tilting mechanical bed was created by a multidisciplinary team to develop a patient bed model that can adjust the head and knee and turn to the left and right using electrical systems. The results showed that the experimental group's interface pressure was significantly lower compared to the control group ($p < .01$). The findings revealed that this health care innovation improved the quality of care for bedridden people and reduced workloads and the risk of danger for caregivers.

Keywords: Lateral Tilting Mechanical Bed, Home-Based Care, Bedridden, Pressure Injury, Pressure Ulcer

泰國農村臥床患者側傾式機械床的設計與開發

摘要：組織損傷是一種並發症，會導致骨突出處的界面壓力過大，通常發生在固定的患者中，尤其是臥床不起的家庭護理患者。目的：研究臥床側臥機械床在臥床患者中降低界面壓力，使其比骨突起突出的效果。設計：重複測量，干預和結果測量研究設計。該樣本由 2017 年 9 月至 2018 年 12 月的 40 位在家臥床不起的人組成。使用描述性統計，t 檢驗和 Mann-Whitney U 檢驗對來自個人信息和界面壓力記錄的數據進行了分析。橫向傾斜機械床是由一個多學科團隊創建的，用於開發患者床模型，該模型可以調整頭部和膝蓋，並使用電氣系統向左和向右旋轉。結果表明，與對照組相比，實驗組的界面壓力明顯更低（p <.01）。研究結果表明，這項醫療保健創新提高了臥床人員的護理質量，減少了工作量，並降低了照顧者的危險。

关键词：側傾式機械床，家庭護理，臥床不起，壓力傷害，壓瘡。

Introduction

Tissue injuries (Tis) and pressure injuries [PIs], pressure sores, and pressure ulcers [PUs]) are vital health care problem throughout the world [1], [2], [3], [4]. They affect both patients suffering from pain, infection, and anxiety and their families burdened with an increased workload, rising costs, and higher health care system cost [1], [2], [3], [4] [5], [6], [7]. Mamom et al. [8] found that the incidence of TIs in the urban community was 53.6%. In contrast, Corbett, Funk, Fortunato, and O'Sullivan [9] found that 6.8% – 9.1% of PUs occurred in adults receiving home-based care in the rural community [3], [4]. Home-acquired TIs are often a severe issue responsible for increased morbidity and mortality among patients receiving home-based care [4], [5], [6], [7]. In recent studies on TIs, the risk factors among immobilized patients indicate that intrinsic and extrinsic factors contribute to the development of TIs, mainly seen in systematic reviews and

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randomized controlled trials [5], [6], [10], [11]. However, much evidence indicates that immobility and mechanical loadings — such as interface pressure, friction and shearing force, and deformed cell and tissue ischemia—are the main causative factors directly linked to the occurrence of TIs [5], [6], [10], [11].

Turning/Repositioning was a significant and necessary intervention to reduce mechanical loading to prevent TIs in bedridden people [6], [7]. A previous study on optimal turning that most effectively reduced mechanical loading included head elevation not greater than 60 degrees and 30-degree tilts that can decrease mechanical loading on bony prominences [6], [7]. Patients need to reposition 12 times a day, meaning 4,380 times per patient per year. If each reposition takes 5 minutes, this consumes 21,900 minutes per patient per year [12]. The turning process usually requires at least two caregivers, which doubles the cost of turning intervention [12]. Because turning is difficult, relatives may not turn the patient correctly and over time, which is why there are increased TIs in patients, especially bedridden ones receiving home-based care.

In this study, a lateral tilting mechanical bed (LTMB) was used, based on the best turning principle, involving 30 degrees of head-bed level, knee level, and 30 degrees lateral tilt to distribute mechanical loading on bony prominences. The prototyping began in 2017 by a research team consisting of nursing and engineering faculty. The team worked together to develop innovative solutions to solve the country's core problems through engineering prototypes' design and development. LTMB was devised to emphasize health innovation and developing innovations that can lead to practical use to create value and public health benefits. This innovation would help transform the country's public health system.

1 Objective

This study aimed to examine the efficacy of an LTMB in decreasing the interface pressure over bony prominences in bedridden patients who use these beds.

2 Methods

For studying this new innovative bed's effect, a repeated-measures, intervention, and outcomes measure research design was used.

2.1 Participants

Bedridden participants (N = 40; mean age = 54.48 years [standard deviation, SD = 5.12], range = 43–63 years) with the average body weight 48.83 kg (range 40–60 kg [SD = 5.39]), mean body height 1.56 ± 0.07 cm (range = 142–171 cm), mean body mass index 16.81 ± 1.72 kg/m^2 (range = 13.51–20.47 kg/m^2), and mean Braden scores 9.00 ± 1.01 kg/m^2 (range = 7–11 kg/m^2) were enrolled in this study. They were recruited through a referral from clinicians in the community hospital. The inclusion criteria included being bedridden or with at least three months after a medical condition, such as a stroke or spinal injury. The exclusion criteria included diagnosed skeletal deformities and active PUs. All the participants provided informed consent to the study. The Institutional Review Board approved the study at Thammasat University. The 40 bedridden participants included 24 women and 16 men. Twenty-five participants had a very high-risk level (Braden Scale = 7–9), and 15 participants had a high-risk level (Braden Scale = 10-12).

2.2 Lateral Tilting Mechanical Bed

LTMB, an innovative structural steel bed, has 30 degrees of head-bed level, knee level, and 30 degrees lateral tilt to distribute mechanical loading on the skin (as shown in Figure 1). This innovation has been designed by the researcher and created by the Faculty of Engineering staff, Thammasat University. The bed-strength structure calculation is performed along the horizontal and vertical axes during loading with the quality guarantee. The material's yield strength is generally more significant than the standard yield strength (factor of safety = 2) and is certified to be 150 kg or 330 lb. The result of the safety factor of LTMB is 2.0–3.6.

Fig. 1 Features of established LTMB model

The engineering design in the movement mechanism of various parts of the bed started from selecting the power source for driving the movement. In this study, four linear actuators with an output voltage of 6,000 N and a stroke of 150 mm were used. Three actuators were used for left-side, right-side, and knee lifting. One actuator with a stroke of 200 mm was used for back lifting. All linear actuators used for the LTMB are medical-grade only. The bed floor was newly designed for left- and right-side bed lifting. The floor was divided into eight compartments (as shown in Figure 2).

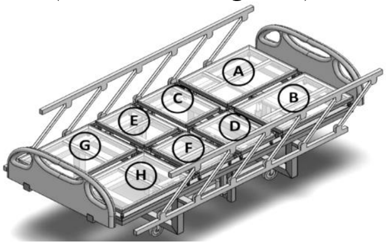

Fig. 2 The design of the bed floor (eight compartments)

Mechanism of head lifting: The head part's linear actuator is fixed to the middle-lower bed frame, and its vertical axis joined to the horizontal axis lies across A and B. When the linear actuator extends to the vertical axis, the bed's head part is raised (Figure 3).

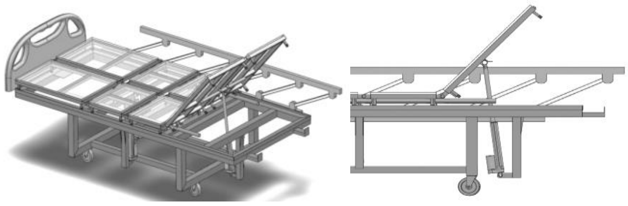

Fig. 3 Mechanism of head lifting

Mechanism of knee lifting: The linear actuator of the knee part is fixed to the middle-lower bed frame, and its vertical axis joined to the horizontal axis lies across E and F. When the linear actuator extends to the vertical axis, the knee part of the bed is raised (Figure 4).

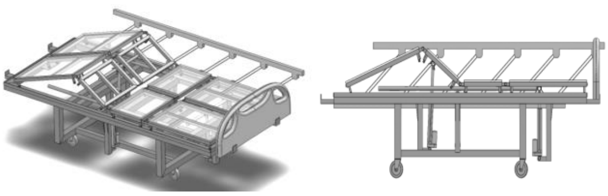

Fig. 4 Mechanism of knee lifting

Mechanism of left- and right-side lifting: The linear actuators of the left- and right-side lifting parts are fixed to both sides of the lateral lower bed frame, and their vertical axis joined to the horizontal axis lies across the left side (B, D, F, and H) and the right side (A, C, E, and G). When the left and right sides' linear actuators extend to the vertical axis, the left and right parts, respectively, of the bed are raised (Figure 5).

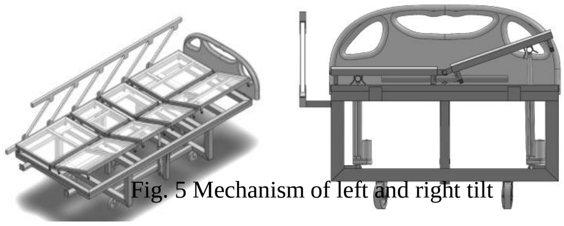

Fig. 5 Mechanism of left and right tilt

After designing the movement mechanism, it is necessary to calculate the material strength of various parts of the bed to meet the desired 100 kg weight-bearing ability of the LTMB. The finite element method was applied for calculation through a three-dimensional design program. The calculation of material strength was performed along the different axes of the bed frame. The material stress was then predicted. The predicted stress value must be less than twofold of the material yield stress (factor of safety $\geq$ 2). The factor of safety of the LTMB was more than 2 in all parts tested: in left- and right-side lifting = 3.1, x-axis = 3.6, and y-axis = 2.

The MyoTrac Infiniti electromyography (MyoTrac Infiniti EMG) device assessed tissue stress to detect the skin's different stress levels. TI or skin integrity was documented weekly over the seven sites for three weeks.

Calibration of the MyoTrac Infiniti EMG biofeedback instrument: The device was recalibrated by the manufacturer Thought Technology Ltd. according to the product protocol of biofeedback specialists for resetting and by a default factory calibration. The researcher and research assistant were trained to use biofeedback training, including practice biofeedback training and instructions on the biofeedback instrument by a specialist.

3 Data collection procedure

Statistical analysis of the interface pressure over seven bony prominences was measured weekly throughout this study. The interface pressure level during the position-induced tissue injury period was estimated to establish the baseline pervade value. The change in pressure in response to changes in body position caused by the LTMB was normalized to each participant’s TIs. To diminish the effect of innovation on TIs, we selected a 2-hourly period because this duration was the turning standard. In this study, a reduction in the interface pressure during the turning period was considered useful for weight-bearing tissues surrounding bony prominences. The Friedman test with a repeated-measures design was used to examine the effectiveness of LTMB in redistributing loading over bony prominences in bedridden patients. Then, the researcher evaluated interface pressure that caused the incidence of TIs, using the MyoTrac Infiniti EMG device, and it was documented weekly in the evening over the seven sites for four weeks. All statistical tests were performed at a level of .05. All data were analyzed using SPSS (Version 22).

The LTMB with a 30-degree lateral tilt resulted in a significant decrease in TIs compared with the conventional bed with manual turning ($p < .05$). Combined with the first, second, and third weeks, the use of LTMB showed a significant difference in TIs compared with a conventional bed with manual repositioning ($p < .05$), as shown in Table 1.

Table 1 The comparison of interface pressure of experimental group and control group in each week

	Gr	N	Mean	S.D.
1st week	experiment	20	20.63	2.04
	control	20	22.25	2.44
2nd week	experiment	20	20.26	2.18
	control	20	22.18	2.51
3rd week	experiment	20	20.16	2.16
	control	20	22.41	2.46

A comparison of the experimental and control groups' interface pressure showed that the interface pressure of all three times of the experimental group was a p-value equal to 0.002, indicating the interface pressure of different groups with statistical significance ($p < .05$). All three times, the control group received a p-value equal to .084, showing that the interface pressure of the control group was not significantly different ($p > .05$). Next, the Wilcoxon signed-rank test was used to compare. The results of the comparison of the experimental group's interface pressure and the mean of the experimental group's interface pressure each week showed a significant difference ($p < .001$ both), indicating the statistically significant differences in the interface pressure ($p < .05$), as shown in Table 2.

Table 2 The comparison of interface pressure of experimental group and control group (Friedman Test)

Mean of Interface pressure	Chi-Square	df	p-value
Experimental group	12.835	2	.002*
Control group	11.165	2	.084

5 Discussion

This study's main finding established the use of LTMB in sufficient magnitude to reduce the interface pressure-related TIs over bony prominences in bedridden users. Our results indicate that the 30-degree lateral tilt bed resulted in a more considerable reduction in interface pressure-related TIs. In contrast, the conventional bed with manual turning may not be adequate for effective pressure distribution in enhancing tissue perfusion to prevent Tis/PUs.

Although the evidence has indicated that LTMB decreases interface pressure in bedridden patients, its effectiveness in enhancing skin integrity has not been investigated. The current practice guideline assumed that a decrease in interface pressure is associated with increases in microcirculation, thus decreasing the risk of TIs or PUs. This study showed the first evidence that LTMB in adequate angles decreases interface pressure-related TIs. This evidence would help promote the use of LTMB in reducing the risk of TIs in bedridden patients. The interface pressure between the bony prominence and the support surface has been used widely to assess the effectiveness of various pressure decreasing strategies, such as alpha beds. In this study, we showed that the semi-prone position (e.g., the 30-degree lateral tilt) of the LTMB did not increase the incidence of TIs.

However, Moore et al. [13] established that the 30-degree lateral tilt with 3-hourly repositioning was a more effective strategy than the 90-degree lateral tilt with a 6-hourly repositioning in reducing the incidence of TIs. They also established that the 30-degree lateral tilt with 2-hourly repositioning was more effective than the 90-degree lateral tilt with a 6-hourly repositioning in reducing the incidence of TIs. Furthermore, in terms of improving the repositioning technique's efficacy, the 30-degree lateral position revealed more usefulness than did others, such as lying positioning. Based on results, decreased loading was present over bony prominences, which improved blood circulation to the high-risk area, especially to the sacrum, and cumulative transcutaneous oxygen ranks to the human skin [13], [14]. This finding coincides with the literature results, which indicates that the 30-degree tilt is the most effective methodology in decreasing the incidence of TIs.

Furthermore, 30-degree lateral repositioning has been shown to diminish workload and is consequently cost-saving than other methods [8], [13], [14]. When linked with the prior studies of Moore et al. [13] and Bergstrom et al. [12], it was found that 3-hourly repositioning with a 30-degree lateral tilt made a statistically significant difference in the occurrence rate of TIs compared with conventional care. These findings show that the LTMB represents the product's anti-mechanical loading, repositioning capabilities, and microclimate ability. The concept of microclimate ability has been gaining increased consideration in the prevention of TIs over the past few years [10], [16], [17]. The particularities of the functions of LTMB and those of conventional beds are in the design of the repositioning bed, which features less than 30 degrees of head-bed elevation, less than 45 degrees of knee step, and 30 degrees of lateral tilt to reduce mechanical loading on bony prominences [10], [16], [17], [18]. In practice, to prevent TIs, there is always an inevitable combination of alterations to microclimate and soft-tissue deformations. The mechanical loading minimization is the mainstream of effective strategies to avoid TIs while certifying that microcirculation is encouraged to improve the skin and tissue function.

The results reveal that the essential factor in reducing the shearing force of repositioning frequently leads to an increased risk of tissue and skin injury when the patient is immobilized. LTMB would be a welcome addition to caregivers who often struggle with common strains related to patients' repositioning. This safe patient-handling system has been specifically designed to help caregivers turn and reposition their patients more efficiently. The researchers offer unique accessories that work in conjunction with LTMB to make it significantly easier for caregivers in the lateral tilting and turning of patients.

Furthermore, first, we assumed that a decrease in interface pressure could increase skin perfusion accompanied by an increase in oxygenation level. Second, we used a rubber cushion from Thailand. Future studies need to consider the use of different cushions to examine their pressure-relieving performance. At this stage, our research should be applied to only foam-based cushions. Third, we studied interface pressure, and we plan to study the effect of LTMB in preventing TIs/PIs.

6. Conclusions

Our results indicate that the turning method should involve at least a 30-degree tilt for a significant decrease in interface pressure over bony prominences in bedridden patients. Our findings may help health care teams recommend more specific 30-degree tilt strategies to prevent TIs or PUs.

References

[1] AL MUTAIRI K. B. and HENDRIE D. Global incidence and prevalence of pressure injuries in public hospitals: a systematic review. *Wound Medicine*. 2018, 1(22):23-31.

[2] JOCELYN CHEW H. S., THIARA E., LOPEZ V., and SHOREY S. Turning frequency in adult bedridden patients to prevent hospital-acquired pressure ulcer: A scoping review. *International Wound Journal*, 2018, 15(2):225-36.

[3] COURVOISIER D. S., RIGHI L., BENE N., RAE A. C., and CHOPARD P. Variation in pressure ulcer prevalence and prevention in nursing homes: *A multicenter study. Applied Nursing Research*, 2018, 1(42):45-50.

[4] LAVALLEE J. F., GRAY T. A., DUMVILLE J., CULLUM N. Barriers and facilitators to preventing pressure ulcers in nursing home residents: A qualitative analysis informed by the Theoretical Domains Framework. *International Journal of Nursing Studies*, 2018, 1(82):79-89.

[5] AMIR Y., LOHRMANN C., HALFENS R. J., and SCHOLS J. M. Pressure ulcers in four Indonesian hospitals: prevalence, patient characteristics, ulcer characteristics, prevention and treatment. *International Wound Journal*, 2017, 14(1):184-93.

[6] BOYKO T. V., LONGAKER M. T., and YANG G. P. Review of the current management of pressure ulcers. *Advances in Wound Care*, 2018, 7(2):57-67.

[7] KAUR S., SINGH A., TEWARI M. K., and KAUR T. Comparison of two intervention strategies on prevention of bedsores among the bedridden patients: A quasi experimental community-based trial. *Indian Journal of Palliative Care*, 2018, 24(1):28.

[8] MAMOM J., RUCHIWIT M., and HAIN D. Strategies of repositioning for effective pressure ulcer prevention in immobilized patients in home-based palliative care: An integrative literature reviews. *Journal of Medical Association of Thailand*, 2020, 103(4):111.

[9] CORBETT L. Q., FUNK M., FORTUNATO G., O'SULLIVAN D. M. Pressure injury in a community population. *Journal of Wound, Ostomy and Continence Nursing*, 2017, 44(3): 221-227. doi: 10.1097/WON.0000000000000320

[10] PREVENTION AND TREATMENT OF PRESSURE ULCERS/INJURIES: Clinical practice guideline Prague: The European Pressure Ulcer Advisory Panel [Online] http://www.internationalguideline.com/guideline

[11] YAP T., KENNERLY S., HORN S., BERSTROM N., COLON-EMERIC C. Team-up clinical trial: investigating repositioning intervals for nursing home pressure ulcer/injury prevention *Innovation in Aging*, 2018, 2(Suppl. 1):567.

[12] BERGSTROM N., HORN S. D., RAPP M., STERN A., BARRETT R., WATKISS M., and KRAHN M. Preventing pressure ulcers: a multisite randomized controlled trial in nursing homes. *Ontario Health Technology Assessment Series*. 2014, 14(11):1.

[13] MOORE Z. and VAN ETTEN M. Repositioning and pressure ulcer prevention in the seated individual. *Wounds UK*, 2011, 7(3):34-40.

[14] MOORE Z., COWMAN S. Pressure ulcer prevalence

and prevention practices in care of the older person in the Republic of Ireland. *Journal of Clinical Nursing*, 2012, 21(3-4):362-71.

[15] GILL E. C. and MOORE Z. An exploration of fourth-year undergraduate nurses' knowledge of and attitude towards pressure ulcer prevention. *Journal of Wound Care*, 2013, 22(11):618-27.

[16] CHAI C. Y., SADOU O., WORSLEY P., and BADER D. L. Pressure signatures can influence tissue response for individuals supported on an alternating pressure mattress. *Journal of Tissue Viability*. 2017, 26(3):180-188.

[17] MAMOM J. The effects of a community-based discharge-planning model for continuing pressure ulcer care on wound healing rates, nutritional status, and infection rates of elderly patients in Thailand. *Songklanakarin Journal of Science and Technology*, 2017, 39(3):341-346.

[18] MAMOM J., CHANSAWAT P., NIEMRIT S. B. Effect of wound care skills model to promote wound healing in patients with pressure ulcers. *Thai Science and Technology Journal*, 2013, 20:609-619.

参考文:

[1] AL MUTAIRI K. B. 和 HENDRIE D. 公立醫院壓力損傷的全球發生率和患病率：系統評價。傷口藥。2018，1（22）：23-31。

[2] JOCELYN CHEW H. S.，THIAA E.，LOPEZ V.和 SHOREY S.成年臥床患者的轉診頻率以預防醫院獲得性壓瘡：一項範圍界定性綜述。國際傷口雜誌，2018，15（2）：225-36。

[3] COURVOISIER D. S.，RIGHI L.，BENE N.，RAE A.C. 和 CHOPARDP。療養院壓力性潰瘍患病率的變化和預防：一項多中心研究。應用護理研究，2018，1（42）：45-50。

[4] LAVALLEE J. F.，GRAY T. A.，DUMVILLE J.，CULLUM N.防止養老院居民壓瘡的障礙和促進者：理論領域框架提供的定性分析。國際護理研究雜誌，2018，1（82）：79-89。

[5] AMIR Y.，LOHRMANN C.，HALFENS R. J. 和 SCHOLS J. M.印度尼西亞四家醫院的壓瘡：患病率，患者特徵，潰瘍特徵，預防和治療。國際傷口雜誌，2017，14（1）：184-93。

[6] BOYKO T. V.，LONGAKER M. T. 和 YANG G. P. 對當前壓力性潰瘍的治療方法的綜述。傷口護理進展，2018，7（2）：57-67。

[7] KAUR S.，SINGH A.，TEWARI M. K. 和 KAUR T. 兩種在臥床患者中預防褥瘡的干預策略的比較：一項基於社區的實驗性試驗。印度姑息治療雜誌，2018，24（1）：28。

[8] MAMOM J.，RUCHIWIT M. 和 HAIN D.在以家庭為基礎的姑息治療中固定患者的有效預防壓瘡的重新定位策略：綜述性文獻。泰國醫學會雜誌，2020，103（4）：111。

[9] CORBETT L. Q.，FUNK M.，FORTUNATO G.，O'SULLIVAN D. M.社區人口的壓力傷害。傷口，造口術和輕便護理雜誌，2017，44（3）：221-227。 doi：10.1097 / WON.0000000000000320

[10] 預防和治療壓力性潰瘍/傷害：臨床實踐指南布拉格：歐洲壓力性潰瘍諮詢小組[在線] http://www.internationalguideline.com/ guideline

[11] YAP T.，KENNERLY S.，HORN S.，BERSTROM N.，COLON-EMERIC C. 團隊合作臨床試驗：研究重新定位療養院壓力性潰瘍/預防傷害的間隔時間衰老創新，2018，2（增刊 1）：567。

[12] BERGSTROM N.，HORN S. D.，RAPP M.，STERN A.，BARRETT R.，WATKISS M. 和 KRAHNM。預防壓瘡：在療養院進行的多站點隨機對照試驗。安大略省衛生技術評估叢書。 2014，14（11）：1。

[13] MOORE Z. 和 VAN ETTEN M.坐著者的重新安置和預防壓瘡。英國傷口，2011，7（3）：34-40。

[14] MOORE Z.，COWMAN S. 愛爾蘭共和國老年人的壓瘡患病率和預防措施。臨床護理雜誌，2012，21（3-4）：362-71。

[15] GILL E. C. 和 MOOREZ。四年級本科護士對預防壓瘡的知識和態度的探討。傷口護理雜誌，2013，22（11）：618-27。

[16] CHAI C. Y.，SADOU O.，WORSLEY P. 和 BADER D. L.壓力信號可以影響交替壓力床墊上支撐的個體的組織反應。組織活力雜誌。 2017，26（3）：180-188。

[17] MAMOM J. 基於社區的持續性潰瘍治療的出院計劃模型對泰國老年患者的傷口癒合率，營養狀況和感染率的影響。 Songklanakarin 科技雜誌，2017，39（3）：341-346。

[18] MAMOM J.，CHANSAWAT P.，NIEMRIT S. B.傷口護理技能模型對壓瘡患者促進傷口癒合的作用。泰國科技雜誌，2013，20：609-619。