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Pressure Mapping in Elderly Care

A Tool to Increase Pressure Injury Knowledge and Awareness Among Staff

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ABSTRACT

PURPOSE: The purpose of this study was to evaluate the use of a pressure mapping system with real-time feedback of pressure points in elderly care, with specific focus on pressure injury (PI) knowledge/attitudes (staff), interface pressure, and PI prevention activities (residents).

DESIGN: Descriptive, 1-group pretest/posttest study.

SUBJECTS AND SETTING: A convenience sample of 40 assistant nurses and aides participated in the study; staff members were recruited at daytime, and 1 nighttime meeting was held at the facility. A convenience sample of 12 residents with risk for PI were recruited, 4 from each ward. Inclusion criteria were participants older than 65 years, Modified Norton Scale score 20 or less, and in need of help with turning in order to prevent PI. The study setting was a care facility for the elderly in Uppsala, Sweden.

METHODS: A descriptive, comparative pretest/posttest study design was used. The intervention consisted of the use of a pressure mapping system, combined with theoretical and practical teaching. Theoretical and practical information related to PI prevention and the pressure mapping system was presented to the staff. The staff (n = 40) completed the Pressure Ulcer Knowledge and Assessment Tool (PUKAT) and Attitudes towards Pressure Ulcer (APuP) before and following study intervention. Residents' beds were equipped with a pressure mapping system during 7 consecutive days. Peak pressures and preventive interventions were registered 3 times a day by trained study nurses, assistant nurses, and aides.

RESULTS: Staff members' PUKAT scores increased significantly ($P = .002$), while their attitude scores, which were high pretest, remained unchanged. Peak interface pressures were significantly reduced ($P = .016$), and more preventive interventions (n = 0.012) were implemented when the staff repositioned residents after feedback from the pressure mapping system.

CONCLUSIONS: A limited educational intervention, combined with the use of a pressure mapping system, was successful as it improved staff members' knowledge about PI prevention, reduced interface pressure, and increased PI prevention activities. As many of the staff members lacked formal education in PI prevention and management, opportunities for teaching sessions and reflection upon PI prevention should be incorporated into the workplace. More research is needed to evaluate the effect of continuous pressure mapping on the incidence of PI.

KEY WORDS: elderly care, knowledge and attitudes, pressure mapping, pressure ulcer/injury, prevention.

INTRODUCTION

Frail and elderly individuals are vulnerable to developing pressure injuries (PIs). Significant risk factors for the development of PIs such as declining general and mental health, sensory perception, nutritional status, and mobility, as well as increased skin fragility and exposure to moisture (eg, due to incontinence), are positively correlated with increasing age and frailty.[1] Pressure injuries cause not only physical suffering but may also have a negative impact on social, psychological, and/or financial aspects of life and, consequently, health-related quality of life.[2]

Pressure injuries are common in aged care settings; reported prevalence rates vary from 4.1% to 32.2%.[1] National prevalence studies in Swedish aged care facilities report prevalence rates between 11.8% and 14.5%.[3] Pressure redistribution via repositioning, use of pressure-redistribution mattresses, chair cushions, and heel cushions, etc, are the mainstay of preventive interventions.[1,4] Despite evidence-based PI prevention guidelines,[1] not all who are at risk receive adequate prevention.[3,5] Studies show that nursing staff's knowledge of PI prevention could be improved both in hospitals and in aged care facilities.[5-8]

Continuous Pressure Mapping Systems

There are several commercially available pressure mapping systems that can measure interface pressure in different positions and on various types of pressure-redistribution surfaces.[9-11] Continuous pressure mapping can provide nursing staff real-time feedback of pressure points in those at risk for PIs.

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The utility of such a pressure mapping system has been investigated in the Clinical Training Center at one Swedish university hospital.[12,13] Regardless of nursing category (RN, assistant, or student nurse), nurses achieved lower interface pressure for both their male and female volunteers patients when using feedback from the monitor as compared with no feedback. The conclusion from these 2 studies was that feedback from a pressure mapping system increased nurses' knowledge and skills related to repositioning for PI prevention. Behrendt and colleagues[14] also found that a continuous pressure mapping system significantly reduced the incidence of PIs in a medical intensive care unit.

Whether the usefulness and acceptance of pressure mapping seen among nurses in the hospital setting are generalizable[12,13] (ie, would be the same, in care settings for the frail and elderly) has not been studied. The educational level of staff working in elderly care varies considerably in Sweden, with some staff members having no formal nursing education or education in elderly care. A pressure mapping system with visual real-time feedback could be an effective and pedagogic tool for educating staff in the care of the elderly to increase their commitment to PI prevention activities. The purpose of this study was to evaluate the effectiveness of a PI prevention program comprised of staff education regarding PI prevention and the use of a pressure mapping system with real-time feedback of pressure points in elderly care. Specific research questions were: (1) how does the use of a pressure mapping system, combined with theoretical and practical teaching, affect staff's knowledge and attitudes about PI and PI prevention; (2) is there any difference in interface pressures when the pressure mapping system is used in the care of the elderly compared to when it is not; (3) is there any difference in PI prevention activities when the pressure mapping system is used in the care of the elderly compared with when it is not; and (4) how does care facility staff evaluate the pressure mapping system?

METHODS

A descriptive, 1-group comparative pretest/posttest study design guided data collection (Figure 1). Following education regarding PI prevention and pressure mapping, the pressure mapping systems were used by the staff to monitor residents over 7 consecutive days during the 6-week study period. Two instruments were used to measure staff PI knowledge and attitude toward before and on implementation of the study intervention.

Sample and Setting

A convenience sample of assistant nurses and aides was recruited from the facility at 2 workplace meetings held during daytime hours and 1 meeting held at night; staff members who were on sick leave or on vacation were excluded. The assistant nurses have 2 to 3 years of education from community colleges, and the aides typically complete a brief period of on-the-job training to learn about their specific employer's policies and procedures.

A convenience sample of residents deemed at risk for PI were recruited, 4 from each of 3 wards. The first author (L.H.) worked as an RN at 1 ward at the time for the study. To avoid bias, that ward was not included in the study. All staff members (N = 40) working during the study period participated. Inclusion criteria for residents receiving care were older than 65 years, Modified Norton Scale score of 20 or less,[15] and in need of help with turning in order to prevent PIs. Exclusion criteria were residents in the end-of-life phase or with existing stage 4 PIs.[1]

The study was conducted at a care facility for the elderly in Uppsala, Sweden. The facility has a total of 80 residents living on 4 different wards; all residents have their own studio apartment. Resident acuity varied from requiring little staff input to total care as required for those in the end-of-life phase. The staff on each ward consists of 17 to 19 assistant nurses or aides and 1 RN (daytime). No advanced medical equipment was available at the facility. Three of the 4 wards were included in the study.

The principles set out in the Declaration of Helsinki as well as in national and local guidelines for research were followed (CODEX).[16] The director of the care facility approved the study. Both the nursing staff and residents were informed about the purpose and procedure of the study, that participation was completely voluntary and that they were free to withdraw from the study at any time. Signed, informed consent was obtained from the residents or from a family member if a resident was unable to sign. The nursing staff and residents were assured confidentiality.

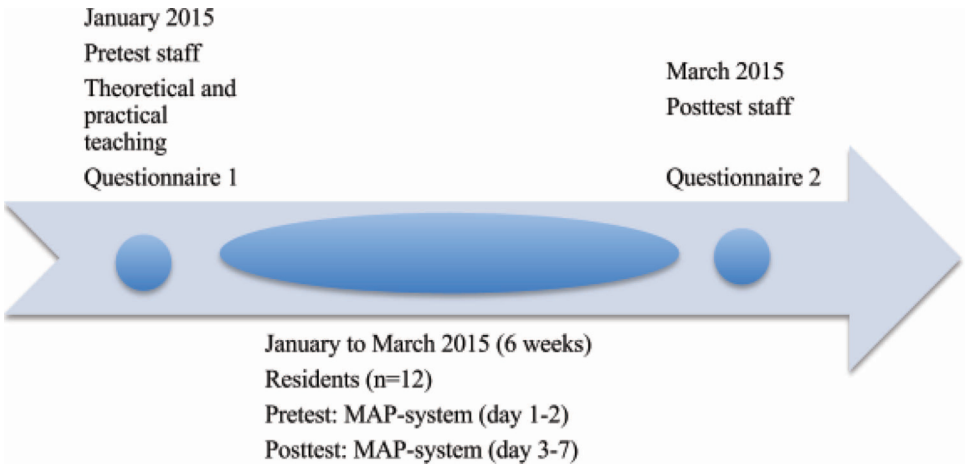

Figure 1. Study flowchart.

Instruments

A questionnaire consisting of the Pressure Ulcer Knowledge and Assessment Tool (PUKAT) and Attitudes towards Pressure Ulcer (APuP) was used to assess the staff's knowledge about and attitudes to PI prevention.[17,18] Both instruments have showed acceptable psychometric properties, with Cronbach's α of 0.77 and 0.79, respectively. The questionnaire comprised 26 knowledge questions and 13 attitude questions. The questions about attitudes were answered on a 4-point Likert scale (1 = strongly agree to 4 = strongly disagree). Both Knowledge and Attitude scores were calculated as a percentage of the possible total score. A mean knowledge score over 60% and a mean attitude score over 75% were deemed satisfactory.[19] Another set of demographic questions regarding the nursing staff's gender, age, education, and working experience was included, as well as 4 study-specific questions to evaluate the nursing staff's experience of using the continuous bedside pressure mapping (CBPM) system as a preventive tool. The questions were answered using a 4-point Likert scale (1 = strongly disagree to 4 = strongly agree).

A CBPM system (MAP System; Wellsense USA, Inc, Nashville, Tennessee) was used to measure tissue interface pressures in participating residents and provide feedback for the staff delivering preventive interventions. The CBPM system is a pressure-sensing mat and a control unit that incorporates a small computer and a monitor. The control unit, which for this intervention was placed at the foot of the resident's bed, receives pressure data continuously from the pressure-sensing mat. These data are displayed in real-time as color imagery and depict how pressure at the body-mat interface is distributed and redistributed when the body is repositioned. Red signifies areas of high pressure, defined in this study to be 60 mm Hg or more. The colors from blue to dark orange signify increasing pressure from 10 mm Hg to less than 60 mm Hg.

Study Procedures

We collected selected demographic information from the nursing assistants and aides and measured knowledge and attitudes to PIs and PI prevention before and 6 weeks after the CBPM system was implemented. Thereafter, 2 investigators (L.H., E.O.) led discussions and provided opportunities for nursing assistants and aides to learn the correct answers, reflect upon their own responses to the questionnaires, and gain a better understanding of the theoretical aspects of PIs and their own attitudes regarding PIs and PI prevention; these sessions lasted approximately 20 minutes. In addition, the nursing assistants and aides received training in use of the CBPM system; training required approximately 15 minutes. Following the training on the device, the CBPM system was placed on an empty bed for 1 week and members of the staff were welcome to come individually or in groups to practice using it under the supervision of the study nurses.

After completion of the training and practice sessions, the CBPM systems were incorporated into the beds of the participating residents and the facility staff could then use the monitor when positioning the resident in bed. A CBPM mat was placed over each resident's mattress (pressure reducing foam for all residents plus static air mattress for 6 residents). After that, the bed was made as usual. The CBPM monitors, which were placed on the footboard of the bed and covered during 2 days (pretest) so that only the study nurses (L.H., E.O.) could register the data. During the following 5 days, the CBPM monitors were uncovered (posttest) and the assistant nurses or aides were encouraged to use the monitor when caring for the resident. The assistant nurses and aides also registered the peak pressures and type of PI preventive intervention that was used.

During data collection, a specific protocol was used to register peak pressures (measured in mm Hg) from the CBPM monitor, and PI preventive interventions (mattress, heel protection, pillow, wedge, sheepskin, elevated head of bed, lowered foot of bed) were recorded. These data were registered 3 times a day (08:00, 14:00, and 20:00) for each resident in the study protocol. Staff members were instructed to reposition the resident if the monitor showed warm colors (red and orange). The goal was to reduce the interface pressure so that no red and orange colors, only blue and green, showed on the screen. Three CBPM systems were used during data collection. Data were collected during 6 weeks in the spring of 2015 (Figure 1).

DATA ANALYSIS

The answer to each PUKAT question was dichotomized (correct-incorrect). Negatively worded attitude questions were reversed so that a higher score indicated more positive attitudes.[18] Categorical data were presented as numbers and percentage, whereas continuous and ordinal data were presented as means, minimums, and maximums. Comparisons between pre- and posttest knowledge and attitude scores, peak pressures, and the number of preventive interventions were conducted using the Wilcoxon signed-rank test (related sample). The first day in the posttest intervention was considered as a learning phase, and these data were not included in the analyses. A P value of .05 or less was considered statistically significant. All statistical analyses were performed using SPSS 22.0 (Statistical Package for the Social Sciences Inc, Chicago, Illinois).

RESULTS

Forty of 55 staff members from the facility participated in the research; 15 staff members who were on vacation or on sick leave during data collection were excluded from participation. The majority of participating staff members were female (90%). The mean age for the total group was 41.3 (range, 20-63) years (Table 1). Twelve residents participated in the study; their mean age was 86 years, and their mean Modified Norton Scale score was 17.3. Seven of the 12 residents were female.

The nursing staff showed a significant improvement (z = 3.1, N-Ties = 38, P = .002) in their knowledge about PIs after theoretical and practical teaching and after using the CBPM system. The mean knowledge score increased from 49% in the pretest participants to 59% in the posttest participants (Table 2). There were 7 pretest and 23 posttest participants who scored over 60%. The mean attitude score was 85% in both the pretest and posttest participants. The question with the highest score was "I personally have an important task in pressure injury prevention" (95%) and the lowest score was "I am well trained to prevent pressure injuries" (68%).

Pressure Injury Prevention and Tissue Interface Pressures

The mean peak pressure was significantly lower (z = 2.4, N-Ties = 11, P = .016) when the CBPM system was used compared with when it was not. The mean peak pressure was reduced from 54.4 mm Hg (pretest) to 48.0 mm Hg (posttest) (Table 3).

TABLE 1.
Demographic Data for Staff (N = 40)

	n	%
Gender		
Female	36	90
Male	4	10
Assistant nurse	38	95
Nursing aide	2	2
Work experience within elderly care		
<1 y	1	2
1-3 y	9	23
3-5 y	4	10
>5 y	26	65
Course regarding pressure injuries, wounds, or wound care	12	30

The number of preventive interventions was significantly higher ($z = 2.5$, N-Ties = 12, $P = .012$) when the CBPM system was used compared with when it was not. The mean number of preventive intervention per day increased from 1.2 (pretest) to 1.7 (posttest) (Table 4). The majority of preventive interventions were small and large cushions, heel protection, and wedges.

The staff considered the CBPM system as a valuable tool to be used in clinical practice (Table 5). They commented that the system was practical, enabling rapid identification of pressure points for a particular resident, and they noted the system enhanced identification of individualized management of pressure relief. They also stated that they could learn a lot more about PI prevention and that they would like to continue to use the CBPM system.

DISCUSSION

The intervention implemented in our study (use of the CBPM system, combined with theoretical and practical teaching) significantly improved the staff members' knowledge about PI prevention. Staff attitudes to PI prevention were found to be positive and did not change over the 6-week study period. Tissue interface pressures decreased significantly, and significantly more preventive interventions were given to the elderly when the electronic pressure mapping system was used compared with when it was not. The staff gave the CBPM system high scores (good preventive tool, easy to understand the information on the monitor, want to continue to use the tool, and would recommend it to others).

TABLE 2.
Staff Members' Pressure Injury Knowledge and Attitude Scores (%)

	Pretest Mean Score	Posttest Mean Score	
Knowledge	**n = 40**	**n = 40**	***P***
Etiology and causes	51.0	66.3	
Classification and observation	38.5	57.0	
Risk assessment	51.3	56.3	
Nutrition	62.5	57.7	
Reduction in the amount of pressure and shear	46.4	58.5	
Reduction in the duration of pressure and shear	52.5	52.0	
Total score[a]	49.0	59.0	.002
Attitude	**n = 24**	**n = 24**	
Total score[b]	85.0	85.0	ns

Abbreviation: ns, not significant.
[a]Satisfactory Knowledge score more than 60%.
[b]Satisfactory Attitude score more than 75%.

The mean knowledge score for the total sample increased from 49% (pretest) to 59% (posttest). These results are similar to those of Sving and colleagues,[5] who found that the assistant nurses in a hospital setting attained a knowledge score of 51% at baseline and 59% after a comprehensive intervention (1-day educational program facilitated by a multidisciplinary team, monthly prevalence measures over 6 months, timely feedback of results, and the support of an external facilitator in PI prevention). In our study, 23 of 40 staff members achieved a satisfactory knowledge score of 60%. A study from Belgium, using the same questionnaire in nursing homes, found much lower knowledge scores, that is, 28.7% for assistant nurses and 29.3% for RNs.[6] Thus, even a limited educational intervention using visual real-time feedback of pressure points can improve PI knowledge.

We found that use of the CBPM system made the nursing staff more aware of PI prevention. The results show that more preventive interventions were used and the residents were lying in a position with lower peak pressure when the nursing staff used the feedback from the monitor. The frequency of turning was not registered, but our results suggest that the nursing staff used a variety of preventive activities such as micro positioning to reduce pressure. A large multisite randomized controlled trial in American nursing homes, investigating the effect of different turning intervals on PI incidence, found that turning at 3- and 4-hour intervals is no worse than turning every 2 hours.[20] The authors postulated that less frequent turning might increase sleep, improve health-related quality of life, reduce staff injury, and provide wider time frames for other activities such as meals, walking, and toileting. Another cost-effectiveness study argues that despite being marginally more clinically effective to prevent PIs, alternating 2 and 4 hourly repositioning is not a cost-effective use of resources (compared with 4 hourly repositioning) for the high-risk group in nursing homes.[21] A pressure mapping system, such as the CBPM system, could be a useful tool to monitor pressure points and to alert staff about when to reposition. At night, or when the person sleeps, it might assist staff to engage in micro repositioning that are less likely to interfere with sleep. Källman[22] described pressure-induced vasodilation in nursing home residents during 1-hour periods. One important finding was that the number of spontaneous movements by the resident was not related to the total risk score (RAPS-scale), indicating that residents assessed to be at low risk for PI might need to be repositioned as often as residents assessed to be at high risk.

Although cost was not an outcome measured in our study, it is an important consideration. A recent systematic review found that the cost of PI prevention per patient per day varied between €2.65 and €87.57 (between US $2.92 and US $96.58) across settings.[23] Corresponding figures for PI treatment ranged from €1.71 to €470.49 (from US $1.88 to US $518.96). Consequently, it is important to identify cost-effective, user-friendly tools to avoid unnecessary suffering from PIs. The staff in the present study used the pressure

TABLE 3.
Peak Pressure Without and With Visual Real-Time Feedback From the CBPM Monitor

				Without Feedback		With Feedback		
Resident	Age	Sex[a]	MNS[b]	Mean	Min-Max, mm Hg	Mean	Min-Max, mm Hg	*P*
1	85	F	20	51.3	38-58	47.1	39-50	
2	92	M	19	40.8	36-50	38.3	37-51	
3	82	F	12	48.8	41-57	33.1	35-65	
4	95	F	15	51.0	48-56	51.0	41-54	
5	87	M	19	52.2	48-58	48.7	50-73	
6	83	M	15	48.7	39-61	37.3	37-53	
7	95	F	18	44.0	39-53	52.0	45-50	
8	86	F	17	51.0	32-66	40.1	34-63	
9	69	M	20	72.5	68-79	59.1	52-88	
10	88	F	16	52.5	43-62	35.5	36-53	
11	71	M	16	73.3	54-105	69.8	52-106	
12	99	F	20	66.3	47-82	64.2	41-84	
Total				54.4		48.0		.016

[a]F, female; M, male.
[b]MNS, Modified Norton Scale score 21 or less identifies patient at risk for pressure injury.

mapping system during the 6-week study period and assessed it as a valuable tool. Further research is needed to evaluate the cost-effectiveness of the system.

We found the educational level related to PI prevention is limited, especially given the risk profile of the frail, elderly individuals living there. Only a third of staff participants indicated completing continuing activities focusing on PIs or wound care, and responses to the attitude questions revealed that they had insight about their lack of knowledge. The intervention in our study was limited both in content and in time. Nevertheless, the intervention positively influenced knowledge of PIs and frequency of preventive interventions. Facility managers and RNs are responsible for educating and supervising staff in quality and safety of care, which includes PI prevention. To uphold knowledge about PI prevention, teaching should be repeated and combined with reflection.[5] Managers and clinical nurse educators have the ability to influence policy and procedures in their facilities. Investing in the specialty of elderly care, as well as gaining academic merits, provides a sound evidence base on which to improve the quality of resident care.[24]

TABLE 4.
Preventive Interventions per Day Without and With Visual Real-Time Feedback From the CBPM Monitor

Resident	Without Feedback, Mean	With Feedback, Mean	*P*
1	0.0	0.4	
2	1.0	0.8	
3	2.0	2.4	
4	1.4	3.0	
5	0.8	1.3	
6	4.5	6.0	
7	1.0	2.0	
8	1.2	0.9	
9	0.0	0.8	
10	0.7	1.1	
11	1.0	1.2	
12	0.3	0.3	
Total	1.2	1.7	.012

Abbreviation: CBPM, continuous bedside pressure mapping.

LIMITATIONS/STRENGTHS

A pre- and posttest design was used in this study; therefore, causal relationships between intervention and effect cannot be inferred. Even though the resident and staff sample sizes were small, a robust response to the intervention was indicated. A strength of this study included use of a research-based, internationally recognized questionnaire.[17,18] However, there was considerable attrition from the APuP (40%). One reason could be that the nursing staff found some questions hard to understand.

Because of the relatively short data collection time, we were unable to measure occurrence rates of PIs. Another limitation was that the relationship between different peak pressures and the risk of each resident to develop a PI was unknown. The intention was to ask the residents to assess their comfort in bed after being positioned by the staff using a visual analog scale.

TABLE 5.
CBPM System Evaluation (N = 35)

	Mean
I think the CBPM system is a good method to prevent pressure injury	3.7
I think it was easy to read and understand the information from the CBPM monitor	3.5
I would like to continue to work with the CBPM system	3.7
I would recommend the CBPM system to other nursing staff	3.7

Abbreviation: CBPM, continuous bedside pressure mapping.

However, the residents included were unable to answer adequately as they had had dysphasia or other speech problems or were too tired to respond to queries during sleep periods. Pressure mapping user error and variability may have occurred; in order to minimize this possible systematic error, a single investigator (L.H.) was responsible for ensuring the pressure mapping system's integrity on each bed.

CONCLUSION

We found that nursing staff's knowledge and awareness of PI prevention increased after a limited intervention using a pressure mapping system, combined with theoretical and practical teaching. As many of the staff members lacked formal education in PI prevention and management, repeated opportunities for teaching sessions and reflection upon PI prevention should be incorporated into the workplace and pressure mapping may augment education strategies. The pressure mapping system was well received by the staff, who used the visual real-time feedback of pressure points from the monitor to reduce peak pressure. However, further studies are needed to evaluate the effect of continuous pressure mapping on the incidence and prevalence of PI and if mapping is clinically practical and relevant to change nursing practice.

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REFERENCES

1. National Pressure Ulcer Advisory Panel, European Pressure Ulcer Advisory Panel, and Pan Pacific Pressure Injury Alliance; Haesler E, ed. *Prevention and Treatment of Pressure Ulcers: Clinical Practice Guideline.* Perth, Australia: Cambridge Media; 2014.
2. Gorecki C, Brown JM, Nelson EA, et al.; European Quality of Life Pressure Ulcer Project group. Impact of pressure ulcers on quality of life in older patients: a systematic review. *J Am Geriatr Soc*. 2009;57:1175-1183.
3. Bååth C, Idvall E, Gunningberg L, Hommel A. Pressure-reducing interventions among persons with pressure ulcers: results from the first three national pressure ulcer prevalence surveys in Sweden. *J Eval Clin Pract*. 2014;20:58-65.
4. McInnes E, Jammali-Blasi A, Bell-Syer SEM, Dumville JC, Middleton V, Cullum N. Support surfaces for pressure ulcer prevention. *Cochrane Database Syst Rev*. 2015;(9):CD001735.
5. Sving E, Högman M, Mamhidir AG, Gunningberg L. Getting evidence-based pressure ulcer prevention into practice: a multi-faceted unit-tailored intervention in a hospital setting. *Int Wound J*. 2016;13(5):645-654.
6. Demarré L, Vanderwee K, Defloor T, Verhaeghe S, Schoonhoven L, Beeckman D. Pressure ulcers: knowledge and attitude of nurses and nursing assistants in Belgian nursing homes. *J Clin Nurs*. 2012;21:1425-1434.
7. Meesterberends E, Wilborn D, Lohrmann C, Schols JM, Halfens RJ. Knowledge and use of pressure ulcer preventive measures in nursing homes: a comparison of Dutch and German nursing staff. *J Clin Nurs*. 2014;23:1948-1958.
8. Gunningberg L, Mårtensson G, Mamhidir AG, Florin J, Muntlin Athlin Å, Bååth C. Pressure ulcer knowledge of registered nurses, assistant nurses and student nurses: a descriptive, comparative multicentre study in Sweden. *Int Wound J*. 2015;12:462-468.
9. Lippoldt J, Pernicka E, Staudinger T. Interface pressure at different degrees of backrest elevation with various types of pressure-redistribution surfaces. *Am J Crit Care*. 2014;23:119-126.
10. Yoshikawa Y, Maeshige N, Sugimoto M, Uemura M, Noguchi M, Terashi H. Positioning bedridden patients to reduce interface pressures over the sacrum and great trochanter. *J Wound Care*. 2015;24:319-325.
11. Bush TR, Leitkam S, Aurino M, Cooper A, Basson MD. A comparison of pressure mapping between two pressure-reducing methods for the sacral region. *J Wound Ostomy Continence Nurs*. 2015;42:338-345.
12. Gunningberg L, Carli C. Reduced pressure for fewer pressure ulcers: can real-time feedback of interface pressure optimise repositioning in bed? *Int Wound J*. 2016;13(5):774-779.
13. Gunningberg L, Pöder U, Carli C. Facilitating student nurses' learning by real time feedback of positioning to avoid pressure ulcers—evaluation of clinical simulation. *J Nurs Educ Pract*. 2016;6(1).
14. Behrendt R, Ghaznavi AM, Mahan M, Craft S, Siddiqui A. Continuous bedside pressure mapping and rates of hospital-associated PUs in a medical intensive care unit. *Am J Crit Care*. 2014;23:127-133.
15. Ek A-C, Unosson M, Bjurulf P. The Modified Norton Scale and the nutritional state. *Scand J Caring Sci*. 1989;3:183-187.
16. CODEX. Rules and guidelines for research. http://www.codex.vr.se. Updated November 3, 2015. Accessed November 6, 2015.
17. Beeckman D, Vanderwee K, Demarré L, Paquay L, Van Hecke A, Defloor T. Pressure ulcer prevention: development and psychometric validation of a knowledge assessment instrument. *Int J Nurs Stud*. 2010;47:399-410.
18. Beeckman D, Defloor T, Demarré L, Van Hecke A, Vanderwee K. Pressure ulcers: development and psychometric evaluation of the Attitude towards Pressure Ulcer Prevention instrument (APuP). *Int J Nurs Stud*. 2010;47:1432-1441.
19. Beeckman D. *Pressure Ulcer Prevention: Evidence-Based Tool Development and Tailored Protocol Implementation to Improve Clinical Practice* [doctoral thesis]. Gent, Belgium: Ghent University; 2011. ISBN:9789078344186.
20. Bergstrom N, Horn SD, Rapp M, et al. Preventing pressure ulcers: a multisite randomized controlled trial in nursing homes. *Ont Health Technol Assess Ser*. 2014;14:1-32.
21. Marsden G, Jones K, Neilson J, Avital L, Collier M, Stansby G. A cost-effectiveness analysis of two different repositioning strategies for the prevention of pressure ulcers. *J Adv Nurs*. 2015;71(12):2879-2885.
22. Källman U. *Evaluation of Repositioning in Pressure Ulcer Prevention*. Linköping, Sweden: Division of Nursing Science, Department of Medical and Health Sciences, Linköping University; 2015. Medical Dissertation No. 1455.
23. Demarré L, Van Lancker A, Van Hecke A, et al. The cost of prevention and treatment of pressure ulcers: a systematic review. *Int J Nurs Stud*. 2015;52:1754-1774.
24. Trinkoff AM, Lerner NB, Storr CL, Han K, Johantgen ME, Gartrell K. Leadership education, certification and resident outcomes in US nursing homes: cross-sectional secondary data analysis. *Int J Nurs Stud*. 2015;52:334-344.