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A knowledge test on pressure injury in adult intensive care patients: Development, validation, and item analysis

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ABSTRACT

Background: Pressure injuries are a major problem in critically ill patients, but both students' and intensive care nurses' knowledge about these injuries leaves room for improvement. As no knowledge test is currently available that focuses on pressure injuries in adult intensive care patients, we aimed to develop such tool, establish the content validity, and perform item analysis using Classical test theory.

Methods: Test development followed established multiple-choice question-writing guidelines. Content validation used a Delphi procedure including eight international experts. Item analysis (question difficulty and discrimination power, and quality of the distractors) was based on the test results of a convenience sample who completed the test online, based on ready knowledge.

Results: Four Delphi validation rounds resulted in a 24-item multiple-choice test within seven categories: Epidemiology, Aetiology, Prevention, Classification, Risk factors and risk assessment, Wound care, and Skin care. The content validity index was 0.96. The median score of 12 students and 38 qualified nurses was 12.5/24 (interquartile range 11–14.25; range 4–17; 52%). Least correct answers were in the categories Classification and Wound care. Item analysis revealed several knowledge gaps and misconceptions.

Conclusions: The test has excellent content validity. The sample's overall score was low. Item analysis identified various training needs. Future users are recommended to further validate the test and establish its reliability, and to tailor it to their individual context and evaluation requirements.

1. Introduction

Pressure injuries (PI) are localised damage to the skin and/or underlying tissue, resulting from pressure or pressure combined with shear. They are classified according to their severity in Categories/Stages I-IV, Unstageable PI, and Suspected Deep Tissue Injury [1]. Patients in the Intensive Care Unit (ICU) have up to 3.8 times the risk of developing PI of patients hospitalised in other wards [2]. Their increased susceptibility has mainly been attributed to their state of immobility, weakened condition, severity of disease, haemodynamic instability, and poor tissue perfusion [3,4]. Additionally, they are extremely prone to developing medical device-related PI due the multiple devices used for diagnosis and therapy [5].

Within the multidisciplinary team, PI prevention is primarily entrusted to the nurses, who provide 24-h care. Consequently, (future) ICU nurses need good knowledge of PI risk factors, aetiology, classification, risk assessment, and evidence-informed prevention strategies. Several tools for assessing PI knowledge are available. The *Pressure Ulcer Knowledge Assessment Tool* (PUKAT) 2.0 [6] is a revised update of the PUKAT [7], containing 25 multiple choice questions within six categories: Aetiology, Classification and observation, Risk assessment, Nutrition, Prevention, and Specific patient groups. The *Pressure Injuries Prevention Knowledge Questionnaire* consists of 31 correct/false questions [8]; and the revised *Pieper-Zulkowski Pressure Ulcer Knowledge Test* (PZ-PUKT) holds the answer options 'yes', 'no', and 'don't know' for 72 items in the categories Prevention/risk, Staging, and Wound description [9]. The latter was adapted for use in Australian acute care hospitals, holding 49 true/false questions in three categories: Prevention (33 items), Staging (eight items), and Wound description (eight items) [10].

Adequate and tailored knowledge assessment seems important, as

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illustrated by both students' and ICU nurses' scores on PI knowledge tests. Both in Italy [11] and Australia [12], 742 and 2949 nursing students, respectively, obtained a mean score of 51.1% on the PUKAT [7]. In Turkey [13], 390 ICU nurses achieved a mean score of 44.4% on the Turkish version of the PUKAT 2.0 [14] and in Australia [15], nearly one-fifth of statements of an adapted 49-item Modified Pieper Pressure Injury Knowledge Test [10] were answered correctly by less than half of 46 ICU nurses [9]. From the United States [16] PZ-PUKT scores reported were 51.66 ± 5.97 (72%) but the sample was limited to 32 ICU nurses who, moreover, had a mean age of 44.8 (±10.37) years, and therefore do not represent the population [10].

None of the knowledge tests that are currently available specifically target the utmost susceptible population of ICU patients. Critically ill patients have however a considerably different PI risk profile than non-critically ill populations. Therefore, the aim of this study was to develop a multiple-choice test specifically dedicated to assess knowledge of PI in adult ICU patients; to establish the content validity; and to perform item analysis.

2. Methods

2.1. Test development

We developed a test consisting of 22 questions in six categories following established multiple-choice item-writing guidelines [17]. Questions in the categories *Aetiology*, *Prevention*, *Classification*, *Risk factors and risk assessment*, and *Wound care* were derived from the most recent Clinical practice guideline [1]. Questions in the category *Epidemiology* were based on the most recent information on PI occurrence in ICUs [18]. Each question had one single correct answer and two distractors, and held the answer option 'I am not sure' to distinguish gaps in knowledge from randomly guessed correct or incorrect responses [17].

2.2. Face and content validation

Validity refers to how accurately a test measures the concept it is supposed to measure. Face validity is a subjective measure, concerned with how suitable the content of a test seems to be on the surface [19]. Content validity concerns the degree to which a sample of items, taken together, constitute an adequate operational definition of a construct [20].

To evaluate face and content validity of the test, we invited ten internationally recognised PI experts to join a Delphi panel, eight of whom agreed. Membership required at least a master's degree in nursing or medico-social sciences, and proven clinical and/or academic expertise in the domain of PI. The experts were asked to evaluate the test and provide comments on four domains:

(a) ***clarity***, i.e. whether all questions and answer options would be correctly understood. Clarity was rated as *clear* or *needs rewording*;
(b) ***completeness***, i.e. whether the domain of content for the construct was adequately represented by the test items. Completeness was rated as *yes* or *no*;
(b) ***correctness***, i.e. whether all answer options indicated as correct answers were indeed correct. Correctness was rated as *yes* or *no*;
(d) ***relevance***, i.e. the extent to which each question was relevant for the ICU context. Relevance was rated as *1=not relevant; 2=somewhat relevant; 3=quite relevant;* or *4=highly relevant.* The ratings were used to calculate a content validity index (CVI), which reflects the degree to which an instrument has an appropriate sample of items for the construct being measured [20]. At item-level (I-CVI), content validity is calculated from the proportion of experts giving an item a relevance rating 3 or 4. Scale-level content validity was calculated as the average of the I-CVIs for all items (S-CVI/Ave). In a validation process involving at least 6 experts, an instrument is considered to have excellent content validity if all items have a minimum I-CVI of 0.78 and the S-CVI/Ave is ≥ 0.90 [20–22].

2.3. Item analysis

Item analysis was based on the Classical test theory, implying quantification of the difficulty and the discrimination power of each question, and the quality of the distractors [23,24].

2.3.1. Question difficulty

Question difficulty is calculated as the proportion of respondents who answered the question correctly; values range from 0.0 to 1.0. Questions with value > 0.9 are considered too easy; questions with value < 0.1 are considered too difficult [24]. For tests using three-response multiple-choice questions, 0.77 has been proposed as ideal difficulty level [25].

2.3.2. Quality of the distractors

A distractor is considered functional when it is plausible for respondents with low achievement. The quality of a distractor is defined by the proportion of respondents who choose the distractor. Values range from 0.0 to 1.0. Distractors with value 0 are considered unattractive, while value 1 indicates that the distractor is too attractive [24]. Distractors are functional if they are selected by ≥ 5% of the participants [23].

2.3.3. Discrimination power

Item discrimination power indicates the extent to which success on an test item matches success on the entire test. Item discrimination is computed for each question from equal-sized (27%) high and low scoring groups by subtracting the number of correct answers by the low group from the number of correct answers by the high group, and dividing this difference by the size of the total group [26]. The range of values is 0.00–1.00; values > 0.35 are (very) good values; >0.25–0.35 satisfying to good; 0.15–0.25 mediocre to satisfying; and values < 0.15 indicate bad to mediocre item discrimination [24].

2.4. Sampling

We recruited a convenience sample of bachelor nursing students and ICU nurses to voluntarily take the test based on ready knowledge. Due to time constraints to complete the study, quota sampling was not feasible and thus no a priori size estimation was made. As a knowledge test can be used either in educational or clinical settings, inclusion criteria were: a degree in critical care nursing or being a degree student in a bachelor critical care nursing course; and at least three months work experience in an ICU.

2.5. Data collection

The validated test, preceded by a number of sociodemographic questions, was drawn up in Qualtrics® software for conducting online surveys. The participants were urged to complete the test individually, and were given 3 min for each question. When that time expired, they were automatically taken to the next question with no option to return to previous questions.

The eleven programme coordinators of the eight Universities of Applied Sciences in Flanders, Belgium, that organise an advanced bachelor course in critical care nursing were invited to distribute a call for participation among their students. The call included the Qualtrics® link to the questionnaire. Additionally, we launched a one-time call for participation via a private Facebook® group to bachelor students who had completed ICU internship for at least 12 weeks. Finally, we invited ICU nurses from our network. Participants could take the test online between 19 November 2020 and 10 March 2021.

2.6. Ethics

The research was approved by the institutional review board of the nursing faculty of HOGENT University of Applied Sciences and Arts. Potential respondents were informed that study participation was voluntary and could be terminated at any time; that anonymity and privacy were guaranteed; that test results would only be used in the context of the current research; and that individual scores would not be shared with any third parties. Participants provided informed consent before completing the test.

2.7. Data analysis

The data was imported in IBM® SPSS® Statistics® version 25. Only fully completed tests were analysed. Normality of data was assessed using the Kolmogorov-Smirnov test; Mann-Whitney U and Kruskal-Wallis tests were consequently used, as appropriate. Categorical variables are reported as numbers (percentages); continuous variables as median (interquartile range [IQR]). For the test questions, a sum score was calculated by rating a correct answer as 1 point, and an incorrect answer or the answer option *I am not sure* as 0 points. As such, minimal and maximal scores that could be achieved were 0 and 24, respectively. Two-tailed $p < 0.05$ was considered statistically significant.

3. Results

3.1. Face and content validation

Throughout four Delphi rounds, several questions were reworded, deleted, or added. The category *Skin care* was added for completeness and included questions derived from the 2019 Clinical practice guideline [1]. The final test was given the name DecubICUs-test and consists of 24 multiple choice questions in seven categories: *Epidemiology*, *Aetiology*, *Prevention*, *Classification*, *Risk factors and risk assessment*, *Wound care*, and *Skin care* (Table 1). The S-CVI/Ave was 0.96 (Table 2). All eight panel members completed the first and second Delphi rounds; the third and four rounds were completed by six experts.

3.2. Sample and questionnaire completion time

Sixty respondents attempted the test, 50 of whom completed it. The sample consisted of 12 students and 38 qualified nurses, whose characteristics are presented in Table 3. The average time to complete the questionnaire was 10.5 min (minimal 4.5; maximal 32 min).

3.3. Test results

The sample's ($n = 50$) median test score was 12.5 out of 24 (IQR 11–14.25; range 4–17; 52%). For none of the sociodemographic characteristics test scores differed among subgroups (Table 3). Median (IQR) scores according to test categories were: *Epidemiology*, 3 questions, 2 (1–2); *Aetiology*, 3 questions, 2 (1–2); *Prevention*, 3 questions, 1 (1-1); *Classification*, 5 questions, 1 (1–2); *Risk factors and risk assessment*, 6 questions, 4 (3–5); *Wound care*, 2 questions, 0 (0–1); and *Skin care*, 2 questions, 2 (1–2).

3.4. Item analysis

The complete results are in Table 1.

3.4.1. Question difficulty

Values ranged between 0.02 and 0.94. A difficulty level >0.9 was found for 3 questions (questions 1, 9, and 15), and 2 questions (questions 8 and 16) had a value < 0.10.

3.4.2. Attractiveness of the distractors

Values ranged between 0.00 and 0.88. In eight questions, all distractors (questions 7, 8, and 16) or at least one (questions 10, 13, 14, 21 and 22) were chosen more frequently than the correct answer.

3.4.3. Discrimination power

Eight questions scored ≥0.35, indicating good to very good discrimination power (questions 2, 3, 5, 6, 10, 11, 12, and 14); four questions >0.25–0.35 (sufficient to good; questions 7, 13, 21, and 24); five questions 0.15–0.25: (mediocre to sufficient; questions 4, 17, 18, 20, and 27); and eight questions scored <0.15 (bad to mediocre; questions 1, 7, 8, 9, 15, 16, 19, and 22).

4. Discussion and conclusions

The DecubICUs-test has excellent content validity, obtained after four Delphi rounds by a panel of internationally recognised PI experts. Item analysis, based on test results that reflect ready knowledge of a small and heterogeneous sample of students and qualified nurses, revealed important general misconceptions and knowledge gaps. The overall test score (52%) was low.

High question difficulty was observed for questions 8 (recommended mattress for PI prevention in high-risk patients; value, 0.02) and 16 (soft multilayer silicone foam dressing application to areas at risk of developing PI; value, 0.08). In tests aimed at assessing post-training knowledge, questions with such values are considered too difficult and should be deleted [24]. Contrarily, in our sample who did not prepare for the test, they showed to be indispensable to reveal specific training needs. For example, question 8 identified the general misconception that alternating pressure mattresses are the recommended type of mattress for critically ill patients (88% of respondents). The remaining 2% answered the question correctly, and not one single respondent indicated to be unsure about the answer. In turn, the distribution of answers on question 16 illustrates a knowledge gap: only 8% of respondents knew that applying soft multilayer silicone foam dressings is recommended as soon as a patient is admitted to the ICU; 46% falsely thought that it is recommended to apply them as soon as non-blanchable erythema is detected; and 26% wrongly answered that soft multilayer silicone foam dressings are not recommended for exerting extra pressure. The remaining 20% of respondents indicated to be unsure about the correct answer.

Also questions answered correctly by ≥ 90% of respondents are recommended to be deleted from a test, provided the latter aims to assess knowledge of respondents who adequately prepared for taking it [24]. In our unprepared sample, 94% of respondents knew that offloading of the heels is always recommended to prevent PI, suggesting that question 9 (recommended measure to prevent PI at the heels) might be futile in any assessment scenario. However, Simonetti et al. [11] found that only 32.4% of Italian nursing students who completed a test on PI prevention were aware that elevation of the heels remains important when a patient is lying on a pressure reducing foam mattress. Deleting question 9 from the test merely based on findings from our small sample would prevent future users in other settings to detect potential gaps in knowledge about this topic.

Revising tests on the basis of their scores is an essential part of improving instruction [17]. It is however key that the way and extent to which outcomes of item analysis are applied to modify a test, take into account the specific context in which a test will be used in order to achieve the desired detection power. Identification of ICU nurses' training needs in a clinical setting places different requirements on a test than a formative or summative classroom exam. Therefore we here present the complete DecubICUs-test as validated for content (CVI, 0.96) by our expert panel. Future users can adapt it according to their individual evaluation requirements by performing item analysis that is based on the test results of a sample that adequately represents their population of test takers [23].

Table 1
DecubICUs-test and item analysis results (n = 50).

Question	Answer options	Question difficulty	Discrimination power	Distractor attractiveness
Epidemiology				
1. Which parts of the body are most affected by pressure injuries in ICU patients?	**Sacrum, buttocks, and heels.**	0.92	0.00	
	Sacrum, buttocks, and shoulder blades.			0.02
	Sacrum, buttocks, and ears.			0.06
	I am not sure.			0.00
2. Internationally, what percentage of patients in ICU have at least one pressure injury, including Stage I?	5–15%		0.45	0.20
	16–25%	0.39		
	>25%			0.20
	I am not sure.			0.22
3. Internationally, what percentage of all pressure injuries are located at the sacral region in ICU patients?	1%–24%		0.45	0.16
	25% - 50%	0.36		
	51%–75%			0.30
	I am not sure.			0.18
Aetiology				
4. Pressure injury is defined as damage to the skin and/or underlying tissues due to …	**pressure or pressure in combination with shear.**	0.86	0.17	
	pressure or pressure in combination with friction.			0.10
	pressure or pressure in combination with chronic exposure to moisture.			0.02
	I am not sure.			0.02
5. A direct cause of pressure injuries is …	skin maceration.		0.50	0.16
	oxygen deficiency in the tissues.	0.64		
	protein deficiency.			0.12
	I am not sure.			0.08
6. A mechanically ventilated patient is positioned with the head of bed elevated to 45°. Forces of gravity pull the patient down the bed, but the patient's skin adheres to the supporting surface. Which statement is correct?	Pressure increases.		0.38	0.18
	Friction increases.			0.28
	Shear increases.	0.52		
	I am not sure.			0.02
Prevention				
7. How often should ICU patients be repositioned to prevent pressure injuries?	Every 2 h.		0.00	0.52
	Every 3 h.			0.32
	As required.	0.16		
	I am not sure.			0.00
8. Which mattress is recommended for pressure injury prevention in high-risk patients?	Alternating pressure mattress.		0.00	0.88
	Low air loss mattress.			0.10
	As required.	0.02		
	I am not sure.			0.00
9. What measure is recommended to prevent pressure injuries at the heels?	Specific heel prevention is unnecessary in case of adequate repositioning.		0.08	0.06
	A foam cushion under the heels.			0.00
	Offloading of the heels.	0.94		
	I am not sure.			0.00
Classification				
10. What is this? 	Stage I pressure injury.		1.00	0.10
	Stage II pressure injury.			0.26
	Stage III pressure injury.	0.18		
	Stage IV pressure injury.			0.00
	Unstageable pressure injury.			0.12
	Suspected Deep Tissue Injury.			0.02
	This is not a pressure injury.			0.18
	I am not sure.			0.14
11. What is this? 	Stage I pressure injury.		0.50	0.14
	Stage II pressure injury.	0.36		
	Stage III pressure injury.			0.24
	Stage IV pressure injury.			0.02
	Unstageable pressure injury.			0.08
	Suspected Deep Tissue Injury.			0.00
	This is not a pressure injury.			0.06
	I am not sure.			0.10
12. What is this? 	Stage I pressure injury.		0.67	0.02
	Stage II pressure injury.			0.16
	Stage III pressure injury.			0.12
	Stage IV pressure injury.	0.28		
	Unstageable pressure injury.			0.08
	Suspected Deep Tissue Injury.			0.12
	This is not a pressure injury.			0.16
	I am not sure.			0.06
13. What is this? 	Stage I pressure injury.		0.33	0.50
	Stage II pressure injury.			0.02
	Stage III pressure injury.			0.00
	Stage IV pressure injury.			0.00
	Unstageable pressure injury.			0.04
	Suspected Deep Tissue Injury.			0.00
	This is not a pressure injury.	0.40		
	I am not sure.			0.04

(*continued on next page*)

Table 1 (*continued*)

Question	Answer options	Question difficulty	Discrimination power	Distractor attractiveness
14. Pressure injuries limited to the dermis are classified as …	Stage I pressure injury.		0.64	0.44
	Stage II pressure injury.	0.32		
	Stage III pressure injury.			0.02
	Stage IV pressure injury.			0.00
	Unstageable pressure injury.			0.02
	Suspected Deep Tissue Injury.			0.04
	I am not sure.			0.14
Risk factors and risk assessment				
15. There is a strong association between the presence of non-blanchable erythema and the development of new pressure injuries.	**This is correct for all patients.**	0.92	0.00	
	This is only correct for patients on vasopressors.			0.04
	This is not correct.			0.00
	I am not sure.			0.04
16. For patients at high risk of pressure injury, the application of soft multilayer silicone foam dressings to areas at risk of developing a pressure injury is …	**recommended as soon as a patient is admitted to the ICU.**	0.08	0.00	
	recommended as soon as non-blanchable erythema is detected.			0.46
	not recommended because these dressings exert extra pressure.			0.26
	I am not sure.			0.20
17. In decisions about appropriate preventive measures, a pressure injury risk assessment score is …	decisive; the score determines the choice of the measures.		0.24	0.12
	indicative; the score together with the clinical context determine the choice of the measures.	0.74		
	noncommittal; the score is purely informative.			0.04
	I am not sure.			0.10
18. Compared to fair-skinned patients, the literature reports fewer Stage I pressure injuries in dark-skinned patients because in dark-skinned patients these injuries …	occur less easily.		0.22	0.02
	are less easily detected.	0.84		
	progress more easily to a deeper injury.			0.00
	I am not sure.			0.14
19. Which of the following risk factors for developing pressure injuries are specific for ICU patients?	Mechanical ventilation, increased body temperature, low haemoglobin.		0.14	0.02
	Use of vasopressors, elevated C-reactive protein, severity of illness.			0.16
	Duration of ICU stay, mechanical ventilation, use of vasopressors.	0.72		
	I am not sure.			0.10
20. Which is the most important risk factor for developing pressure injuries?	Poor nutritional status.		0.24	0.24
	Limited mobility.	0.74		
	Incontinence.			0.02
	I am not sure.			0.00
Wound care				
21. Debriding a hard, black necrotic crust on the heel is …	always recommended.		0.33	0.50
	recommended if local infection is suspected.	0.22		
	never recommended.			0.02
	I am not sure.			0.26
22. In Stage II pressure injuries with delayed healing, use of a local antiseptic is …	**always recommended.**	0.16	0.00	
	recommended in case of clinical signs of infection.			0.62
	never recommended.			0.04
	I am not sure.			0.18
Skin care				
23. What type of skin cleanser is recommended to maintain skin integrity?	Alkaline cleansers.		0.17	0.02
	pH-neutral cleansers.	0.86		
	Acidic cleansers.			0.02
	I am not sure.			0.10
24. Vigorously rubbing skin at risk for pressure injury after applying a moisturizer is …	recommended as it enhances blood flow.		0.24	0.08
	recommended as it enhances infiltration of the product in the skin.			0.04
	not recommended as it has the potential to damage tissue.	0.72		
	I am not sure.			0.16

Correct answers are in bold letter type.

Table 2
Content validity index.

Question	Relevance scores: 1 = not relevant; 2 = somewhat relevant; 3 = quite relevant; 4 = highly relevant								# experts in agreement	I-CVI
	EXPERT1	EXPERT2	EXPERT3	EXPERT4	EXPERT5	EXPERT6	EXPERT7	EXPERT8		
1	4	4	4	4	4	4	3	4	8	1.00
2	4	3	4	3	3	4	2	2	6	0.75
3	4	3	4	3	3	4	2	2	6	0.75
4	3	4	4	4	4	4	4	4	8	1.00
5	4	3	4	4	4	4	3	4	8	1.00
6	4	4	4	3	4	4	3	4	8	1.00
7	4	4	4	4	4	4	4	4	8	1.00
8	4	4	4	4	4	4	3	4	8	1.00
9	4	4	4	4	4	4	4	4	8	1.00
10	4	3	4	4	4	4	3	4	8	1.00
11	4	3	4	4	4	4	3	4	8	1.00
12	4	3	4	4	4	4	3	4	8	1.00
13	4	3	4	4	4	4	3	4	8	1.00
14	4	3	4	4	4	4	3	3	8	1.00
15	3	4	4	4	4	4	4	4	8	1.00
16	4	4	4	3	4	4	4	2	7	0.875
17	4	4	4	3	4	4	4	3	8	1.00
18	4	4	4	4	4	4	3	3	8	1.00
19	4	4	4	4	4	4	3	2	7	0.875
20	4	4	4	4	4	4	4	4	8	1.00
21	3	4	4	4	4	4	3	2	7	0.875
22	4	4	4	4	4	4	2	3	7	0.875
23	3	4	4	4	4	4	3	3	8	1.00
24	3	4	4	4	4	4	3	4	8	1.00
Proportion relevant	1.00	1.00	1.00	1.00	1.00	1.00	0.88	0.79		
Mean I-CVI: 0.96										
S-CVI/Ave: 0.96										

I-CVI, item-level content validity index; S-CVI/Ave: scale-level content validity index.

Table 3
Sociodemographic characteristics and median test scores of the respondents.

Characteristic		Number (%)	Median score out of 24[a](IQR)	p-value
Gender	Male	11 (22)	12 (12–14)	0.71
	Female	39 (78)	13 (11–15)	
Age (years)	21–30	37 (74)	13 (11–15)	0.25
	31–40	4 (8)	12 (11.25–12)	
	41–50	3 (6)	12 (11–12)	
	>50	6 (12)	11 (7.75–12.75)	
Work experience as a nurse (years)	None (student)	12 (24)	14.5 (11.5–15)	0.18
	<1	11 (22)	13 (11–15)	
	1–5	14 (28)	11.5 (10.25–13.25)	
	6–10	3 (6)	14 (13–14)	
	>10	10 (20)	12 (10.75–12.5)	
Degree in critical care nursing	Yes	23 (46)	12 (11–14)	0.66
	No	27 (54)	13 (11–15)	
Work environment	Intensive Care Unit	29 (58)	12 (11–14)	0.19
	[b]Other critical care unit	9 (18)	12 (9.5–13.5)	
	Not applicable (student)	12 (24)	14.5 (11.5–15)	
Most recent pressure injury course	<6 months ago	4 (8)	11.5 (10.25–14.25)	0.56
	6 months–1 year ago	4 (8)	11.5 (10.25–14.25)	
	1–5 years ago	12 (24)	13.5 (11.25–14.75)	
	>5 years ago	4 (8)	12 (10.5–12)	
	Never attended	26 (52)	13 (11–15)	

[a] IQR, interquartile range.
[b] Emergency department (n = 7) and Mobile team Critical Care (n = 2).

Our sample's overall score (52%) was far below the calculated 80% Angoff-threshold to pass this test [27], with the least correct answers in the categories *Wound care* and *Classification*. As correctly classifying PI is important to ensure appropriate treatment, our sample's median score of 1 out of 5 (IQR 1–2) for the latter category is disturbing. The low scores may be associated with the fact that PI had to be classified on the sole basis of photographs. This approach had first been shown to have a high degree of validity [28] but was refuted by Jesada et al. [29], who found a moderate interrater reliability (κ = 0.39–0.58) for staging of PI when comparing 100 digital photographs with bedside assessment. Notably, in both studies the assessments were performed by wound experts. Although the photographs used in our test were taken from a validated educational tool [30], the lack of clinical context may have negatively influenced the scores, as well as the absence of specific wound care expertise among our respondents. The latter may also account for the low test scores in the category *Wound care* (2 questions, median score 0; IQR 0–1).

Our results reinforce previous findings about gaps in knowledge of PI among nursing students and ICU nurses [11–16]. While solid knowledge does not necessarily translate into good practice, it is certainly a sine qua non for good practice. Our findings thus support a call for educators, researchers, and hospital and unit managers to regularly assess knowledge of PI using validated instruments that are tailored to the setting; and to provide timely courses and training that are based on the identified needs.

4.1. Strengths and limitations

The DecubICUs-test is the first test that was specifically developed to assess knowledge of PI in ICU patients. Its development and content validation followed rigorous processes. The current results for either test scores or item analysis are however not to be extrapolated.

Classical test theory, used in this study, assumes that a test-taker's observed score represents the score which he or she would obtain if there were no errors in measurement. Measuring instruments are however imperfect, and thereby a score may not adequately represent the test-taker's true ability. Item Response Theory (IRT) is an alternative approach to analysing test results, based on the assumption that a test-taker's response to a question is a function of the difference between both his or her abilities and the characteristics of the item [31].

Although IRT appears to provide better outcomes in terms of reliability and generalizability compared to Classical test theory, it requires large sample sizes (preferably ≥1000) in order to obtain accurate item-parameter estimates [32] and could therefore not be used in this study.

Participation of our convenience sample was voluntary, implying that respondents may have been more interested in PI than non-respondents. Thereby, non-response bias and sampling bias may have influenced our results. Consequently, however, a random sample might have generated even lower test scores. Also, the sample was small and not representative of the entire population of ICU nurses, and thereby did not allow to draw strong conclusions about the overall level of knowledge. This was however not the aim of this study, but rather the assessment of the questionnaire's content validity.

As previously mentioned, the use of photographs of wounds without further clinical information may have negatively impacted the scores in the *Classification* category. Also, although the respondents were explicitly urged to complete the test individually, this could not be verified. Since they had only 3 min to answer each question and no option to return to or revise previous questions, it seems unlikely that they have looked up the answers, but this cannot be ruled out. We only assessed face and content validity; reliability (internal consistency and stability) and additional aspects of validity (construct validity and convergent validity) must be tested in future studies with larger samples before this new questionnaire can be recommended as robust enough to be used. Larger samples would moreover allow the use of IRT for item analysis.

Finally, guidelines change over time. Adaptation and revaluation of the test will be needed as soon as new evidence for preventing and managing PI in critically ill patients is available.

In conclusion, the DecubICUs-test is a knowledge test on PI in adult critically ill patients that was developed following rigorous methods. It has excellent content validity as established by a panel of internationally recognised experts. Future users are recommended to adapt it to their individual evaluation needs through context-specific item analysis, and to establish additional types of validity using larger samples. The overall test score in our mixed sample of nurses and nursing students who took the test based on ready knowledge was low. Various general misconceptions and knowledge gaps were identified. Our findings support a call to regularly assess students' and nurses' knowledge of PI using validated instruments that are tailored to the setting, and to provide timely courses and training that are based on the identified needs.

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Declaration of competing interest

None of the authors has conflicts of interest in relation to this research.

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