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Psychometric testing and evaluation of user acceptance of an automatic lateral turning device for the prevention of pressure ulcers

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ABSTRACT

Introduction: Repositioning of patients with reduced or impaired mobility could lessen pressure ulcers (PU). Automated preventive devices can support nurses, but user acceptance must be determined with valid and reliable tools. This study measured user acceptance of an automatic lateral turning device, using a self-developed questionnaire.

Method: The study included 194 nurses in leadership positions from 75 institutions. A two-page user acceptance questionnaire was designed and tested for internal validity (exploratory factor analysis; EFA) and reliability (Cronbach's-α). A linear regression analysis was used to test the model's theoretical framework.

Results: The overall response rate was 74.9%. The EFA revealed five exploratory factors ("pain/well-being", "PU prevention", "handling", "nurse support", and "obese patient support") from the two outcomes ("general satisfaction" and "can replace manual repositioning"). The adjusted r^2 was 0.607 for "general satisfaction", with the maximum standardized β for "PU prevention" (0.476), "pain/well-being" (β = 0.197) and "handling" (β = 0.145). The adjusted r^2 for "can replace manual positioning" was 0.458. The β for "nurse support" was 0.264, followed by "pain-wellbeing" (β = 0.224) and "obese patient support" (β = 0.218).

Conclusion: The psychometric testing results were satisfactory. Overall user acceptance of the automatic lateral turning device was high. A positive evaluation of the system's functionality, regarding the prevention of PU, is essential for patient and staff satisfaction, as well as user recommendation.

1. Introduction

Pressure ulcers (PU) are a serious issue in elderly institutionalized patients [1,2], and are an indicator of the standard of health care [3]. PU cause pain and a reduced quality of life [4]. To identify those at risk, relevant risk factors have been determined [5,6] and a number of preventive interventions have been established [7], with supporting evidence published in clinical practice guidelines for PU prevention [8]. Of these interventions, the repositioning of individuals with impaired mobility, and the use of appropriate support surfaces are the most significant in preventing PU [9–11]. Repositioning of at-risk patients is an essential task in nursing: in bedridden patients, this usually means changing the patient's position, for example, from their left side to their back, or to their right side. A 30° angle for positioning patients has been shown to reduce PU incidence significantly [12]. Although efficient, manual repositioning can be very time-consuming; depending on the patient's condition, this maneuver can take over 15 min [13]. Furthermore, it is a burden for caregivers and may result in work-related musculoskeletal disorders [14,15]. Assistive devices reduce biomechanical loading in the lower back and upper extremities during patient-turning tasks [16]; however, user acceptance is a prerequisite for such technologies [17]. User acceptance is usually validated through the efficacy, effectiveness, and usability of the device [18]. Tools to measure user acceptance must be valid, reliable, and appropriate for the device [19]. In this study, a survey was designed and conducted to measure user acceptance of an automatic lateral turning device to prevent PU. The following research questions were addressed:

- Is the self-designed survey valid and reliable for measuring user acceptance of an automatic lateral turning device?
- If the survey is deemed valid and reliable, what is the user acceptance of the automatic lateral turning device?
- Are there differences in user acceptance, depending on the user and clinical location (i.e., the responder's occupational status or medical discipline)?

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2. Materials and methods

2.1. Study design

A cross-sectional survey was conducted: 260 employees in a leading role (nursing service management, ward management, nursing directorate) or with a corresponding qualification (e.g., wound manager/quality manager) from 85 institutions (hospitals and nursing homes) were invited to participate in the study. The institutions encompassed different funding bodies and bed capacities. A two-page standardized questionnaire was used to gather information between November 2019 and January 2020. The participants had four weeks to complete the questionnaire.

2.2. Automatic lateral turning device

The experimental device is a mattress-sized turning platform (Toto® Lateral Turning System; Frontier Medical Group, Blackwood, Wales, UK). It automatically turns patients at user-defined intervals day and night, by tilting them smoothly and consistently from the left to the right side, using inflatable air cells within the platform. Patients are fully supported from head to toe to avoid the risk of twisting. The system fits most nursing bed frames and can be positioned under any existing mattress (except pocket sprung). The accompanying control unit is placed at the end of the bed and has all the necessary information and settings to fully control and adapt the time intervals and positions, according to the patient's requirements.

2.3. Inclusion criteria

Institutions with a minimum of three months experience in the daily use of the lateral turning device system were included in the study, regardless of whether the system was loaned, rented, or purchased. The target group of participants were from the following medical disciplines: intensive care, geriatrics, internal medicine, surgery, and neurology, as these are the main areas where the system was in use.

2.4. Variables

The questionnaire was comprised of four sections. Apart from a section for personal comments at the end, there were no open questions. Section one included factual information about the responders' occupational status, years of professional experience and institution (number of beds, medical discipline). According to Table 1, section two (light green) had 11 statements on patient comfort and safety characteristics. Section three (light blue) contained 12 statements regarding staff relief/support if the automated lateral turning system is applied. Section four (light orange) comprised five statements about general satisfaction with the device and an evaluation of whether or not the device can replace manual repositioning. The design and selection of the variables were based on the intended functionality of the lateral turning device (i.e., PU prevention) and on the unstructured feedback given by practitioners to the manufacturer regarding their perceptions and experiences with the device (i.e., pain relief for patients). This information was structured and assigned to the different sections of the questionnaire. To evaluate the statements in sections two to four, a five-point Likert Scale was provided, with the following labels and numerical values: strongly agree (1), agree (2), neither agree nor disagree (3), disagree (4), strongly disagree (5). Fig. 1 shows the theoretical framework of the questionnaire, which included statements on patient safety (section two) and nursing staff work relief (section three), intended to be exploratory and to explain the measured outcome (section four). Since the exploratory topics in sections two and three may cover a broad area, an exploratory factor analysis (EFA) was applied to detect any potential underlying,

Table 1
Descriptive results of user acceptance study.

	Strongly agree	Agree	Neither agree or diagree	disagree	Strongly disagree	Total
Section 2. Statements about patient comfort and patient safety	%	%	%	%	%	n
The patient's pain could be reduced by using the system in general.	35.1	37.6	22.7	2.6	0.5	191
Compared to manual positioning, patient's pain could be reduced by using the system.	48.5	36.6	12.4	0.5	0.0	190
The system is particularly suitable for patients at risk of pressure ulcers.	57.7	27.8	10.3	3.6	0.5	194
The use of the system has a positive influence on pressure ulcer management.	49.5	37.6	9.8	1.5	0.5	192
The system can reduce the use of special *anti*-decubitus mattresses.	38.7	30.4	18.0	8.2	3.1	191
With the help of the system, self-mobility and body awareness are preserved even during long-term prophylactic use.	35.1	37.1	21.6	4.1	1.5	193
The system ensures an undisturbed night's sleep and increases sleep quality.	53.1	23.2	20.1	2.6	1.0	194
The system eliminates the need for additional heat-accumulating pillows and/or blankets.	38.1	33.5	19.1	6.2	2.1	192
The system allows positioning more gently and painlessly.	60.3	28.4	9.8	1.0	0.5	194
Patients widely tolerated the system	35.1	40.2	21.1	1.5	1.5	193
Using the system supports pneumonia prophylaxis	33.5	36.1	16.0	11.3	1.0	190
Section 3 statements about staff relief	Strongly agree	Agree	Neither agree or diagree	disagree	Strongly disagree	Total
Lack of human resources can be compensated when using the system	14.4	34.0	33.5	11.3	5.7	192
Nursing staff receive excellent nightly support using the system.	31.4	44.3	17.0	5.2	0.5	191
The use of the system creates free resources for other important care activities.	18.0	42.3	32.5	6.2	1.0	194
The system represents an additional support.	56.2	33.5	6.7	1.5	0.5	191
The installation of the system is quick and easy	64.9	24.7	7.7	2.1	0.5	194
Due to being light, the system is flexible and mobile.	74.2	21.1	4.1	0.0	0.0	194
The system is easy and intuitive to use by using the touchpad.	77.8	17.5	3.6	0.0	0.0	194
The automatic positioning by the system runs reliably.	77.8	16.5	5.7	0.0	0.0	192
The use of the system reduces strain on the back (e.g. with obese patients).	62.4	28.4	7.7	1.5	0.0	194
The system makes it easier to position obese patients.	53.1	29.4	15.5	2.1	0.0	194
The system is very well compatible with in-house foam mattresses.	59.8	28.9	7.7	1.5	1.0	192
The system is very well compatible with special mattresses.	27.8	36.6	24.7	4.6	2.1	186
Section 4 statements about general satisfaction and replacement capability	Strongly agree	Agree	Neither agree or diagree	disagree	Strongly disagree	Total
I am very satisfied with the use of the system and the results.	56.2	32.0	10.8	1.0	0.0	194
The system should be integrated in our pressure ulcer management.	65.5	23.7	6.7	3.1	1.0	194
I would recommend the system to my colleagues.	69.6	20.6	7.7	1.5	0.5	194
The use of the system should be expanded in my institution	58.2	29.9	6.2	2.6	2.1	192
The system can – to a great extent - or completely replace manual repositioning.	22.2	41.8	24.7	8.8	2.1	193

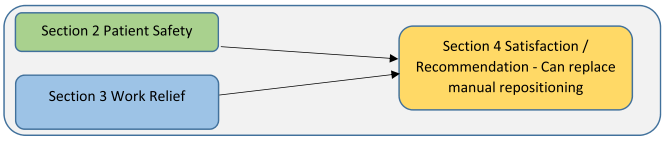

Fig. 1. Theoretical model.

unobserved, latent variables.

3. Methods against bias

To ensure anonymity, personal data such as age or gender of participants were not included in the questionnaire. All questionnaires were conducted confidentially: they were returned anonymously by mail, with a sealed envelope passed to one of the company representatives, or by electronic communication (fax) to the distributor.

3.1. Ethical considerations

No patient data were required for this study. Only the professional opinions of healthcare practitioners were recorded, and this information was confidential. Since neither the collection nor transfer of sensitive data was carried out, ethics approval was not required for this study.

3.2. Data analysis

All data were checked for outliers and inconsistencies, then descriptive data analyses were conducted. For categorical variables, absolute and relative frequencies were calculated. For (pseudo-)metric variables, the means with standard deviations (sd) were calculated. A one-way analysis of variance (ANOVA) and Kruskal Wallis tests ($\alpha = 0.05$, two-sided) were used to compare the differences in means. An EFA was run, with a varimax rotation for testing the validity of the questionnaire design, following a well-established psychometric testing procedure [21]. The Kaiser-Meyer-Olkin (KMO) was calculated if enough data were available to predict each factor. The Bartlett test was conducted to prove sufficient correlation of the variable for the EFA. Commonalities were calculated for all items to determine if they were affected by small sample size. Cronbach's-α was calculated for each factor for reliability. The theoretical construct of the questionnaire design was tested by calculating the variance (adjusted r^2) of the exploratory factors of the two different outcomes. The differences between the exploratory variables and the two outcome variables were analyzed by presenting standardized β coefficients, with 95% confidence intervals and p-values, in multivariate linear regression models. All analyses were made using SPSS v.25 for Windows.

3.3. Sample

Of the 85 facilities in Germany that met the inclusion criteria, 73 took part in the study. Two hundred and sixty questionnaires were distributed to eligible participants; 194 questionnaires were completed and could be evaluated. Most responders (n = 127, 65.5%) were ward charge nurses. The average years of experience was 22.4 (sd 9.3). Responders were from the following institutions: university hospitals (n = 5), confessional hospitals (n = 27), community hospitals (n = 73), nursing homes (n = 30), and other (n = 56). The average number of beds ranged from 177 for nursing homes to 802 for university hospitals.

4. Results

4.1. Descriptives

The responses for each statement (Table 1) varied between n = 186 and n = 194. The response for "strongly agree" ranged between 14.4% and 77.8%, and for "agree" between 16.5% and 44.3%. Regarding general satisfaction statements, 88.2% of users "agreed'' or "strongly agreed". About 66.0% of the users "strongly agreed'' or "agreed'' that such a system is "capable of replacing - to a great extent - or completely replacing manual repositioning".

4.2. Psychometric testing

An EFA with varimax rotation was conducted to assess the variability of the 23 statements on patient safety and staff relief (Table 2). The KMO was 0.83, and the Bartlett test was <0.001. Commonalities ranged

Table 2
Rotated component matrix (coefficients< 0.45 were suppressed).

Rotated Component Matrixa						
	Component					
	1	2	3	4	5	6
1 patient's pain could be reduced	0.714					
2 pain could be reduced compared to manual positioning	0.728					
3 suitable for patients at risk of pressure ulcers				0.751		
4 positive influence on your pressure ulcer management				0.815		
5 reduce the use of special *anti*-decubitus mattresses				0.527		
6 self-mobility and body awareness are preserved	0.825					
7 ensures the patient undisturbed night's sleep	0.659					
8 eliminates the need for additional heat-accumulating pillows						0.788
9 patients can be positioned more gently and painlessly	0.477				0.468	0.467
10 largely tolerated by the patients.	0.668					
11 Pneumonia prophylaxis can be positively influenced						0.498
1 lack of human resources can be compensated			0.818			
2 Nursing staff receive excellent nightly support			0.765			
3 creates free resources for other important care activities			0.790			
4 represents an additional support			0.487			
5 easily and quickly installed		0.720				
6 flexible and mobile.		0.843				
7 intuitive to use using the touchpad		0.735				
8 system runs reliably.		0.488				
9 guarantees a particularly back-friendly work (e.g. with heavy patients)					0.732	
10 makes it easier to position high-weight patients					0.701	
11 well compatible with in-house foam mattresses		0.477				
12 compatible with special mattresses.				0.598		

between 0.51 and 0.78. According to Table 1, six factors were requested with an Eigenvalue >1. The first factor accounted for 34.7% of the variance, the second factor accounted for 8.8%, the third for 7.7%, the fourth for 5.9%, the fifth for 4.9%, and the sixth accounted for 4.2%. For each factor, Cronbach's-α (α) was computed. The first factor is labelled as "pain (relief) and well-being" (yellow, α = 0.883); the second factor describes "(easy) handling" (purple, α = 0.749); the third factor covers "nurse support" (turquoise, α = 0.819); the fourth indicates "PU prevention" (green, α = 0.799); and the fifth factor is labelled as "obese patient support" (grey, α = 0.787). The last factor (#6 according to Table 1) did not allow meaningful labelling and was not considered for further analysis. Table 1 shows the coefficients of the rotated component matrix. Loading of less than 0.45 was omitted to improve clarity.

Four statements from section four ("I am very satisfied with the use of the system and the results", "The system should be integrated into our pressure ulcer management", "I would recommend the system to my colleagues" and "The use of the system should be expanded in my institution") can be labelled as general satisfaction and/or a recommendation. These showed a high internal consistency (Cronbach's-α = 0.901). The fifth statement solely describes replacement capability ("The system can - to a great extent - or completely replace manual repositioning").

4.3. Influence of independent variables on dependent variables

Using multivariate multiple linear regression analysis, the effect of the five exploratory factors on the two outcomes was calculated in two separate analyses. Fig. 2 shows the results of the calculated standardized β coefficient, in case they were statistically significant. According to Fig. 2, arrows to the left show the standardized β of the exploratory factors, regarding the outcome "Satisfaction and recommendation". The adjusted r^2 was 0.607. The highest β was PU prevention (β = 0.476) and the perceived effect on pain and well-being (β = 0.197). Arrows to the right explain the influence of the exploratory factors on evaluating whether or not the device "can replace manual positioning". The adjusted r^2 was 0.458. The standardized β for support of the nursing staff was 0.264, followed by pain and well-being (β = 0.224) and obese patient support (β = 0.218). PU prevention and handling were not statistically significant. Information on the p-values and 95% confidence intervals are found in Suppl. A.

4.4. Evaluation regarding occupation and discipline

Table 3 shows the evaluation of all exploratory and outcome factors. For this purpose, the five-point Likert scale was considered pseudometric. Based on the occupational status of responders, the highest rating was given for "handling" (1.33) and the lowest for "replace manual positioning" (2.27); nursing directors evaluated highest on general satisfaction (1.17) and handling (1.19), and quality/PU managers evaluated highest on obese patient support (1.17) and PU prevention (1.33). Regarding disciplines, general satisfaction with the device was highest for surgery (1.33). Respondends in geriatric care were highly convinces (1.63), that it could replace - to a great extent or completely - manual repositioning.

5. Discussion

The study will be discussed in three parts: first to address the sample quality, second to discuss the psychometric results, and third to outline acceptance of the lateral turning device.

5.1. Sample quality

The sample comprised 194 questionnaires from 73 institutions, including acute hospitals and nursing homes. Participants were very experienced, with an average of more than 20 years of professional practice. The participants have extensive and broad knowledge about PU prevention measures and devices. The response rate was almost 75%, which is considered high. Previous research has shown that increased levels of satisfaction and the intention to participate in a survey positively influence the response [20].

5.2. Psychometric results

The applied statistical analyses indicate that the explained variance of the first five factors was considered sufficient for this purpose. The KMO results showed that there were enough items for the prediction of each factor. The Bartlett test was also highly significant, indicating that the variables correlated adequately for the factor analysis. The lowest communality value was >0.5, indicating that the sample size of the model was sufficient. The internal consistency was between 0.749 and

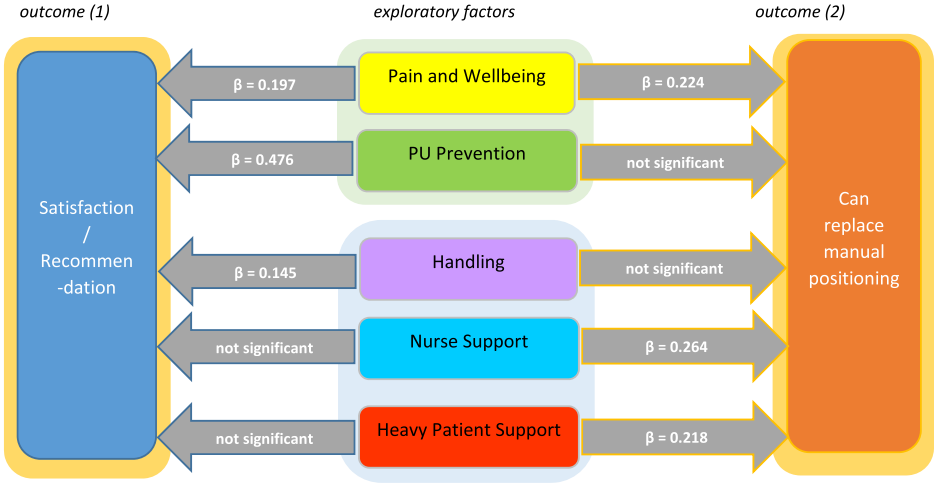

Fig. 2. Standardized β coefficient of the exploratory factors on both outcomes.

Table 3
User acceptance evaluation according to occupation and discipline.

	occupation	n	mean	sd	P[a]	discipline	n	mean	sd	p
pain and wellbeing	charge nurse	122	1.78	0.62	0.121	geriatrics	38	1.44	0.38	0.001
	head charge nurse	23	2.01	0.97	(0.107)	ICU	34	1.80	0.62	(0.007)
	nursing director	12	1.39	0.56		surgery	22	1.92	0.62	
	quality/PU manager	3	1.83	0.00		internal	31	1.77	0.55	
	Other	26	1.91	0.70		other	44	2.06	0.83	
	Total	186	1.80	0.68		total	169	1.80	0.66	
handling	charge nurse	124	1.31	0.44	0.232	geriatrics	38	1.18	0.39	0.047
	head charge nurse	23	1.32	0.53	(0.220)	ICU	36	1.29	0.45	(0.031)
	nursing director	12	1.19	0.39		surgery	23	1.39	0.41	
	quality/PU manager	3	1.83	0.72		internal	31	1.26	0.48	
	other	27	1.40	0.47		other	44	1.47	0.49	
	total	189	1.33	0.46		total	172	1.32	0.46	
nurse support	charge nurse	122	2.07	0.74	0.307	geriatrics	37	1.80	0.46	0.015
	head charge nurse	23	2.29	0.64	(0.180)	ICU	34	2.13	0.69	(0.155)
	nursing director	11	1.75	0.39		surgery	23	1.91	0.58	
	quality/PU manager	3	2.00	0.00		internal	31	2.15	0.81	
	other	26	2.16	0.75		other	44	2.30	0.75	
	total	185	2.09	0.71		total	169	2.08	0.69	
pressure ulcer prevention	charge nurse	123	1.76	0.77	0.121	geriatrics	37	1.53	0.56	0.092
	head charge nurse	23	2.10	0.95	(0.226)	ICU	36	1.75	0.86	(0.194)
	nursing director	12	1.44	0.57		surgery	24	1.85	0.72	
	quality/PU manager	3	1.33	0.00		internal	31	1.80	0.62	
	other	26	1.74	0.69		other	45	2.00	0.88	
	total	187	1.77	0.78		total	173	1.79	0.76	
heavy patient support	charge nurse	127	1.59	0.70	0.035	geriatrics	38	1.37	0.52	0.232
	head charge nurse	23	1.39	0.56	(0.031)	ICU	36	1.61	0.67	(0.380)
	nursing director	12	1.25	0.50		surgery	24	1.48	0.60	
	quality/PU manager	3	1.17	0.29		internal	32	1.58	0.67	
	other	27	1.87	0.74		other	45	1.70	0.81	
	total	192	1.58	0.69		total	175	1.56	0.67	
satisfaction	charge nurse	125	1.55	0.71	0.315	geriatrics	38	1.41	0.53	0.068
	head charge nurse	23	1.68	0.88	(0.234)	ICU	35	1.51	0.70	(0.890)
	nursing director	12	1.17	0.34		surgery	24	1.33	0.45	
	quality/PU manager	3	1.33	0.14		internal	32	1.49	0.58	
	other	27	1.46	0.73		other	44	1.77	0.87	
	total	190	1.53	0.72		total	173	1.53	0.68	
replace manuel repositioning	charge nurse	126	2.34	1.02	0.074	geriatrics	38	1.63	0.67	<0.001
	head charge nurse	23	2.30	0.76	(0.055)	ICU	36	2.42	0.87	(0.001)
	nursing director	12	1.50	0.67		surgery	23	2.35	0.98	
	quality/PU manager	3	2.00	0.00		internal	32	2.16	0.85	
	other	27	2.30	0.95		other	45	2.62	1.01	
	total	191	2.27	0.97		total	174	2.24	0.94	

[a] P values: without brackets F Test, (in brackets Kruskal-Wallis).

0.883, which is sufficient for this purpose [21]. The explained variances were high for both outcomes. The psychometric results were positive and, therefore, the designed questionnaire and theoretical framework are useful and valid for the evaluation of user acceptance of an automatic lateral turning device.

5.3. Acceptance of the lateral turning device

The overall acceptance and satisfaction of most features of the automatic lateral turning device were positively evaluated, although self-administered questionnaires are often biased by social desirability. In this study, most individuals who tested the device provided a "true statement", as no incentive was provided or promised. Interestingly, both outcomes showed almost diametrically different results. Apart from "pain and well-being" and general satisfaction and recommendations, it is essential for practitioners that the device is effective for PU prevention, pain relief and patient well-being. Lateral turning effectively relieves the pressure of specific body sites [22], and it is well-tolerated in older individuals [23]. Other studies have reported no significant differences in patient comfort, regardless of whether the turning has been performed manually (by practitioners) or by an automatic lateral turning device [24].

Participant satisfaction was high; the handling of the device was positively evaluated. Almost all responders confirmed the suitability of the system for the care of obese patients, although relief or support (with obese patients) only plays a minor role. However, this is of high importance if individuals see the device as a supportive tool, which can replace - to a great extent or completely - manual repositioning.

Some patients need to be repositioned at least every two hours, a maneuver that takes up to 15 min on average [13]; the repositioning time for one immobile patient can be 180 min per day. Moreover, depending on the weight, height, and morbidity of a critically ill patient, two or more practitioners must perform this intervention. The device is helpful because there is a global shortage of nursing staff in many healthcare settings, and it can also help preserve the health of nursing staff by reducing the physical burden of turning patients [25].

5.4. Limitations

Based on the high response rate, the application of specific statistical procedures to reduce a non-response bias were not considered necessary. In satisfaction or acceptance studies, the assumption of normality within the data is often violated [26]; however, the plotted residuals of the factors displayed almost normal distribution. Social desirability bias is always an issue when conducting surveys using self-administered questionnaires [27], and this must be considered when interpreting

the results. However, around 90% of all responders evaluated the product positively, regarding aspects of ease of use, patient well-being and PU prevention. The current study design does not enable conclusions regarding the efficacy or effectiveness of the device [28]; however, user acceptance is a prerequisite for successfully using and implementing new products [29]. Important items or aspects may have been neglected when the user acceptance questionnaire was designed, but the amount of explained variance in both outcomes was high, indicating that the main exploratory factors have been identified. Finally, it must be emphasized that the views and perceptions of healthcare practitioners have been demonstrated here, yet for a comprehensive evaluation, the comfort and safety of the device, and the views and opinions of the patient (users) are necessary.

6. Conclusion

The psychometric testing results were satisfactory. Overall user acceptance with the automatic lateral turning device was high. General satisfaction and recommendation is important in evaluating the device for the prevention of PU. Users also stated that the device is easy to handle, and suitable for obese patient support, workload relief, and patient well-being.

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Declaration of competing interest

The author certifies that there are no affiliations with, or involvement in, any organization or entity with any financial or non-financial interest in the subject matter or materials discussed in this manuscript.

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