A risk assessment scale for the prediction of pressure sore development: reliability and validity

Margareta Lindgren MScN PhD RN
Student, Department of Medicine and Care, Division of Nursing Science, Faculty of Health Sciences, Linköping, Sweden

Mitra Unosson PhD RN
Senior Lecturer, Department of Medicine and Care, Division of Nursing Science, Faculty of Health Sciences, Linköping, Sweden

Ann-Margret Krantz MScN RN
Lecturer, Department of Medicine and Care, Division of Nursing Science, Faculty of Health Sciences, Linköping, Sweden

and Anna-Christina Ek PhD RN
Professor, Department of Medicine and Care, Division of Nursing Science, Faculty of Health Sciences, Linköping, Sweden

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Correspondence:
Margareta Lindgren,
Department of Medicine and Care,
Division of Nursing Science,
Faculty of Health Sciences,
Linköpings Universitet,
SE-581 85 Linköping,
Sweden.
E-mail: margareta.lindgren@hul.liu.se

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Background. The ability to assess the risk of a patient developing pressure sores is a major issue in pressure sore prevention. Risk assessment scales should be valid, reliable and easy to use in clinical practice.

Aim. To develop further a risk assessment scale, for predicting pressure sore development and, in addition, to present the validity and reliability of this scale.

Methods. The risk assessment pressure sore (RAPS) scale, includes 12 variables, five from the re-modified Norton scale, three from the Braden scale and three from other research results. Five hundred and thirty patients without pressure sores on admission were included in the study and assessed over a maximum period of 12 weeks. Internal consistency was examined by item analysis and equivalence by interrater reliability. To estimate equivalence, 10 pairs of nurses assessed a total of 116 patients. The underlying dimensions of the scale were examined by factor analysis. The predictive validity was examined by determination of sensitivity, specificity and predictive value.

Results. Two variables were excluded as a result of low item–item and item–total correlations. The average percentage of agreement and the intraclass correlation between raters were 70% and 0·83, respectively. The factor analysis gave three factors, with a total variance explained of 65·1%. Sensitivity, specificity and predictive value were high among patients at medical and infection wards.

Conclusions. The RAPS scale is a reliable scale for predicting pressure sore development. The validity is especially good for patients undergoing treatment in medical wards and wards for infectious diseases. This indicates that the RAPS scale may be useful in clinical practice for these groups of patients. For patients undergoing surgical treatment, further analysis will be performed.

Keywords: pressure sore, risk assessment, prevention, validity, reliability, instrument development

Introduction

Pressure sore development constitutes a major problem, which causes excessive pain and suffering in affected patients. Problems with pressure sores are also associated with significant costs for society (Davies 1994, Smith *et al*. 1995). Studies carried out in various care settings show a prevalence of pressure sores among inpatients ranging between 3·75% and 42% (Barrois 1995, Unosson *et al*. 1995, Lindgren *et al*. 2000).

Identification of patients at risk of pressure sore development is perhaps the most important issue in pressure sore prevention (Davies 1994, Smith *et al*. 1995). Prediction of a health problem should be possible at an early stage and it is essential that preventive methods should be available (Larson 1986), the problem with patients developing pressure sores stresses both these criteria. A useful instrument for the prediction of pressure sore development requires high sensitivity and specificity, good predictive value, and should be easy to use in clinical practice (Edwards 1996, Streiner & Norman 1998).

Research concerning the identification of patients at risk of developing pressure sores has been in progress since the early 1960s when the Norton scale was developed (Norton *et al*. 1979). Assessment scales frequently used in clinical practice and research are the Norton scale (Norton *et al*. 1979) and the Braden scale (Bergstrom *et al*. 1987, Braden & Bergstrom 1987). In the United Kingdom, the Waterlow scale (Waterlow 1987), and in Sweden, a modified and re-modified version of the Norton scale (Ek & Bjurulf 1987, Ek *et al*. 1991) are used.

The Norton scale

In the early 1960s, Norton *et al*. (1979) presented a risk assessment scale for prediction of pressure sore development among elderly patients. The scale was developed from clinical experience and included five variables (Table 1). The maximum score on the scale is 20. A cut-off score of ≤14 (Norton *et al*. 1979) or ≤16 (Norton 1987) has been used for prediction of patients at risk of developing pressure sores. Norton *et al*. (1979) found an almost linear relationship between the initial assessment score and the incidence of pressure sores among 250 geriatric patients (Norton *et al*. 1979). The predictive validity of the scale has been examined in different settings. A sensitivity ranging from 63% to 100%, a specificity from 26% to 89%, a predictive value positive test (PVP) ranging from 9% to 70%, and a predictive value negative test (PVN) from 35% to 93% have been presented in different studies (Goldstone & Goldstone 1982, Bergstrom *et al*. 1987, Dealey 1989, Wardman 1991, Bridel 1993, Wai-Han *et al*. 1997, Mei-che Pang & Kwok-shing Wong 1998) (Table 2). The Norton scale has been criticized both for over prediction and under prediction of patients at risk

Table 1 Variables included in the Norton scale, the re-modified Norton scale, the Braden scale and the RAPS scale

Variable	The Norton scale*	The re-modified Norton scale†	The Braden scale‡	The RAPS scale
General physical condition	+	+		+
Mental state	+	+		
Activity	+	+	+	+
Mobility	+	+	+	+
Incontinence	+	+		
Food intake		+		+
Fluid intake		+		+
Nutritional status			+	
Moisture			+	+
Sensory perception			+	+
Friction and shear			+	+
Skin type				(+)
Bodily constitution				(+)
Body temperature				+
Serum albumin				+

*Norton *et al*. (1979); †Ek *et al*. (1991); ‡Braden and Bergstrom (1987).

Table 2 Validity data of the Norton scale, the modified Norton scale and the Braden scale

Scale/authors	*n*	Type of ward/unit	Cut-off point	Sensitivity (%)	Specificity (%)	PVP (%)	PVN (%)	Patients with sores
The Norton scale (maximum score 20)								
Goldstone and Goldstone (1982)	40	Orthopaedic	≤14	89	64			18
Bergstrom *et al.* (1987)	40	Orthopaedic	≤14	89	36	53	80	18
Retrospective from Goldstone and Goldstone (1982)								
Dealey (1989)	175			88	26	37	81	
Vardman (1991)	32	Nursing home		100	82	66	69	10
At risk patients								
Bridel (1993)	250	Geriatric	≤14	63	70	39	86	59
Retrospective from Norton *et al.* (1962)								
Wai-Han *et al.* (1997)	185	Eldercare	≤14	75				8
Mei-che Pang and Kwok-shing Wong (1998)	106	Medical and orthopaedic	≤16	81	59	33	93	21
The modified Norton scale								
Ek (1987) (maximum score 32)	515	Long-term care	≤25	51	65	13		39
Ek (unpublished data)	501	Long-term care	≤21	69	69	32	91	50
Re-modified (maximum score 28)								
Gunningberg *et al.* (1991)	81	Hip fracture patients	<21	71	44	35	78	24
The Braden scale (maximum score 23)								
Bergstrom *et al.* (1987)	99/100	Medical-surgical	≤16	100/100	90/64			7/9
Barnes and Payton (1993)	361	Acute-care	≤16	73	91			22
Braden and Bergstrom (1994)	102	Nursing-home	≤18	79	74	54	90	28
VandenBosch *et al.* (1996)	103	Tertiary care	≤17	59	69			29
Bergstrom and Braden (1998)	843	Tertiary care	≤16	38	92	31	94	108
		Medical-surgical	≤19	50	82	17	96	
		Long-term care	≤18	74	60	37	88	
Halfens *et al.* (2000)	320	Medical, surgical, neurological, orthopaedic	≤20	73	74			47

of developing pressure sores (Goldstone & Goldstone 1982, Bridel 1993). The reliability of the Norton scale is not considered in these studies.

The modified Norton scale

A modified version of the Norton scale was introduced for the first time in Sweden in 1987. In a study of 515 long-term care patients, additional factors consisting of food and fluid intake, body temperature and social activity were incorporated into the original Norton scale with a maximum score of 32. By multiple regression analysis, s-albumin, mobility, activity and general physical condition emerged as risk factors in this study. The predictive validity of this version, when measured by sensitivity and specificity, was 52% and 65%, respectively, and the PVP was 12% (Ek 1987). The scale was further developed from these results. Variables such as social activity and body temperature were excluded as they did not appear to be specific risk factors, while the variable food and fluid intake was divided into two variables as s-albumin and delayed hypersensitivity tests (Purified Protein Derivate, PPD) both indicated nutrition as a significant risk factor (Table 1). The maximum score for the re-modified version was 28, and patients with a total score of ≤21 were considered to be at risk of developing pressure sores (Ek & Bjurulf 1987, Ek *et al.* 1991). Both sensitivity and specificity for the re-modified version were 69%, and the PVP and PVN were 32% and 91%, respectively (unpublished data).

Gunningberg *et al.* (1999) examined the predictive validity of the re-modified Norton scale among 81 hip fracture patients at time of admission to the acute and emergency

department. The results measured sensitivity at 71%, the-specificity at 44%, the PVP at 35%, and PVN was 78% (Table 2).

The re-modified version of the Norton scale was examined with regard to interrater variability: 110 patients were evaluated by 22 registered nurses and 22 practical nurses. The percentage of agreement between registered nurses ranged from 55% for incontinence to 86% for activity. The corresponding figures for practical nurses ranged from 51% for general physical condition to 87% for food intake. From this analysis it was concluded that only one category of nurses should perform the risk assessment, as there were some differences in assessments between registered nurses and practical nurses (Ek & Bjurulf 1987).

The Braden scale

The Braden scale, based on an overview of the literature, was first presented by Braden and Bergstrom (1987). Two fundamental causes of pressure sores are described: the duration and intensity of the pressure, and the tissue tolerance to pressure. The scale is composed of six subscales (Table 1). The maximum score is 23, and cut-off scores between ≤14 and ≤18 have been used in different studies (Bergstrom *et al*. 1987, 1998, Braden & Bergstrom 1987). The predictive validity of the Braden scale has been examined in different studies with various populations. In these studies the sensitivity ranged between 38% and 100% and the specificity between 60% and 92% (Bergstrom *et al*. 1987, 1998, Bergstrom & Braden 1992, Barnes & Payton 1993, Braden & Bergstrom 1994, VandenBosch *et al*. 1996, Halfens *et al*. 2000). The PVP and the PVN were 54% and 90%, respectively (Braden & Bergstrom 1994) (Table 2).

The interrater reliability has been examined by a comparison of different categories of personnel. The reliability coefficient between registered nurses and graduate students was high ($r = 99$), and the percentage of agreement measuring 88%. It was significantly lower (11–38%) when comparison was applied to less well-educated carers (Bergstrom *et al*. 1987).

Halfens *et al*. (2000) used the Braden scale in a prospective multicentre study, adding several other risk factors to the scale. The original Braden scale was found to be both reliable and valid (Table 2). However, the authors also suggested that the nutrition variable be reformulated so as to take the nutritional condition, and not only the nutritional intake, into consideration (Halfens *et al*. 2000).

The Norton scale, the re-modified Norton scale, and the Braden scale are additive ordinal scales. Each variable is rated from 1 to 4 except for friction and shear, which is rated from 1 to 3. The lower the score, the greater the risk of pressure sore development. The variables activity (ability to move) and mobility (ability to change body position) were included and defined in the same way as in the above-mentioned risk assessment scales. In the Braden scale, the variable nutrition includes both food and fluid intake while in the re-modified Norton scale, food and fluid intake are separated into two variables. Incontinence is included in the three scales, but in the Braden scale, the variable perspiration, here termed moisture, is added. Sensory perception and friction and shear are not included in the Norton scale nor in the re-modified Norton scale (Table 1) (Norton *et al*. 1979, Braden & Bergstrom 1987, Ek *et al*. 1991).

The reliability of risk assessment scales has not been adequately assessed in a Swedish context. The results from validity studies of risk assessment scales are difficult to compare, as definitions of pressure sores, the demographics of the patients included, sample size and data collection vary between studies and the results are not conclusive (Table 2). Some studies are prospective and some retrospective. Thus, there is a need for a further development of risk assessment scales in order to create a scale that is useful in different units or wards.

The study

Aim

The aim of this study was to develop further a risk assessment scale, the re-modified Norton scale, for the prediction of pressure sore development. The aim was also to present the validity and the reliability of this scale.

Method

This prospective study was performed at one university hospital and one county hospital in Sweden from 1996 to 1998. Data for the interrater reliability were collected at the same two hospitals in 1999. The Research Ethical Committee of the Faculty of Health Sciences, Linköping University, approved the study.

Instrument

A pressure sore is defined as a sore or skin damage appearing after a prolonged period of ischameia in the skin (Ek 1987). The pressure sore grading system used in this study was as follows: Stage 1, persistent discoloration, with intact skin surface; Stage 2, epithelial damage (abrasion or blister); Stage 3, damage to the full thickness of the skin without a

deep cavity; and Stage 4, damage to the full thickness of the skin with a deep cavity (Ek *et al.* 1991, AHCPR 1992).

The risk assessment scale used in this study, the risk assessment pressure sore (RAPS) scale, was composed of risk factors included in the Norton scale (Norton *et al.* 1979), the re-modified Norton scale (Ek & Bjurulf 1987, Ek *et al.* 1989, 1991), and the Braden scale (Braden & Bergstrom 1987, Bergstrom & Braden 1992). The variables, bodily constitution and skin type were also added to the scale as they have emerged as risk factors in several studies (Waterlow 1987, Ek 1987, Allman *et al.* 1995). The RAPS scale thus includes the following 12 variables: general physical condition, activity, mobility, moisture, food intake, fluid intake, sensory perception, friction and shear, skin type, bodily constitution, body temperature and serum albumin level. The scale is an additive ordinal scale, in which all but two variables are rated between 1 and 4. Friction and shear, as well as skin type, have a rating of between 1 and 3. The maximum rating score is 46, with the assumption that the lower the scores, the greater the risk of pressure sore development.

Patients

Patients included in the study were newly admitted to acute, medical, surgical, infection, orthopaedic, rehabilitation, or geriatric wards. The inclusion criteria were: 17 years of age or older, an expected hospital stay of at least 5 days and, for patients undergoing surgical treatment, an expected time on the operating table of at least 1 hour. The exclusion criteria were pressure sore on admission. The patients were included in the study on three fixed days per week. These days could differ between the wards depending on the rules of admission on each ward. The calculation of the sample size was based on earlier studies performed in this area (Ek 1987, Ek *et al.* 1991). A total of 588 patients were asked to participate and 530 (90·1%) were included after their informed consent had been obtained. In some of the assessments values are missing, which explains why the analysis was based on a figure less than 530.

Procedure

Information meetings were held in each participating ward. The nurses were informed about the aim of the study, as well as receiving instruction on how to use the RAPS scale and the pressure sore grading system, and how to assess the skin. This information was given both orally and in writing. A member of the scientific team included the patients after informed consent was obtained. This member also supported the nurses during the data collection period. Registered nurses assessed the patients within 24 hours of admission and, after that, once a week until discharged for a maximum period of no more than 12 weeks. Fifty per cent of the patients were monitored for up to 8 days while the reminder were monitored for up to 12 weeks. The patients' skin condition was inspected on admission and once a week during hospital stay.

A separate data collection was performed in 10 wards for the interrater reliability test of the RAPS scale. Ten informed pairs of registered nurses assessed, concurrently and independently of each other, between 9 and 15 patients each for a total of 116 patients. The majority of the nurses were already familiar with the RAPS scale because of their participation in a major study. All nurses were instructed to study the assessment scale and were able to ask questions regarding the scale before making the assessments. A requirement was that the nurses had cared for the patients for at least 2 days prior to the assessment, in order to ensure that they were already familiar with the patients to be assessed.

Data analysis

Statistics

The data were analysed using the Statistical Package for the Social Sciences (SPSS) (SPSS Inc., Chicago, IL, USA) version 10·1.

Reliability

Item-item correlation ($>0{\cdot}30$ and $<0{\cdot}70$), corrected item-total scale correlation ($>0{\cdot}30$) and Cronbach's α coefficient ($>0{\cdot}80$) were used to measure the internal consistency of the RAPS scale (Cronbach 1951, Ferketich 1991, Nunally & Bernstein 1994). In order to estimate equivalence, intraclass correlation (ICC), and percentage of agreement were used (Armitage & Berry 1995, Streiner & Norman 1998).

Validity

To estimate underlying dimensions in the RAPS scale, factor analysis was performed using principal component analysis with oblique rotation. The criterion used for factor selection was an eigenvalue of approximately 1 or above (Gorsuch 1983). The predictive validity was estimated by measuring sensitivity, specificity and predictive value. Sensitivity is defined as the percentage of those classified as risk patients who developed pressure sores. Specificity is the percentage of those classified as not being at risk that did not develop pressure sores. Predictive value positive test is defined as the probability of pressure sore development among those who are classified as risk patients. Predictive value negative test is defined as the probability of not having pressure sores among those who are defined as not being at risk (Fletcher *et al.* 1996).

Table 3 Spearman rank correlation coefficient between items on the RAPS scale

Items	1	2	3	4	5	6	7	8	9	10	11	12
1. General physical condition												
2. Activity	0·51**											
3. Mobility	0·46**	0·67**										
4. Moisture	0·36**	0·49**	0·49**									
5. Food intake	0·51**	0·42**	0·40**	0·33**								
6. Fluid intake	0·25**	0·24**	0·26**	0·18**	0·42**							
7. Sensory perception	0·25**	0·35**	0·41**	0·35**	0·23**	0·11*						
8. Friction and shear	0·42**	0·62**	0·78**	0·48**	0·36**	0·20**	0·39**					
9. Skin type	0·18**	0·18**	0·13**	0·13**	0·20**	0·20**	0·00	0·15**				
10. Bodily constitution	0·14**	0·05	0·09*	0·09	0·17**	0·16**	0·02	0·05	0·12**			
11. Body temperature	0·45**	0·22**	0·20**	0·24**	0·26**	0·10*	0·07	0·22**	−0·02	−0·00		
12. Serum albumin	0·37**	0·25**	0·22**	0·21**	0·34**	0·24**	0·11*	0·21**	0·06	0·20**	0·24**	

*$P < 0·05$; **$P < 0·01$ (two-tailed).

Results

The major study included 530 patients, 265 men and 265 women, of which 62 (11·7%) patients developed pressure sores. The mean age of the group was 69·25 ± 14·39 years. The men were younger than the women, 67·1 ± 13·9 and 71·4 ± 14·6 years, respectively ($P = 0·001$). The patients were admitted to 21 different wards: 286 to surgical wards and 244 to medical wards.

Reliability

For two items, bodily constitution and skin type, the correlation with the remaining items was less than 0·30. For mobility, the correlation with friction and shear was above 0·70 (Table 3). The corrected item–total correlation ranged from 0·21 for bodily constitution and 0·25 for skin type to 0·70 for mobility. All correlations were significant ($P < 0·001$) (Table 4). After exclusion of skin type and bodily constitution, mean item–item correlation increased from 0·28 to 0·34 and Cronbach's α coefficient from 0·82 to 0·83. The maximum score for the RAPS scale, after exclusion of skin type and bodily constitution was 39. The average percentage of agreement and the intraclass correlation (ICC) between raters for the total sample ($n = 116$) were 70% and 0·83, respectively (bodily constitution and skin type excluded).

Table 4 Corrected item–total scale correlation ($n = 488$)

Items	*r*
1. General physical condition	0·66*
2. Activity	0·65*
3. Mobility	0·70*
4. Moisture	0·50*
5. Food intake	0·63*
6. Fluid intake	0·40*
7. Sensory perception	0·39*
8. Friction and shear	0·68*
9. Skin type	0·25*
10. Bodily constitution	0·21*
11. Body temperature	0·34*
12. Serum albumin	0·36*

*$P < 0·001$.

Validity

The factor analysis, with eigenvalue of approximately 1·0 and above, resulted in three factors. Factor one, termed mobility, included: physical activity, mobility, moisture, sensory perception, and friction and shear. Factor two, termed physical condition, included: general physical condition, temperature and s-albumin. Factor three, termed nutrition, included: food and fluid intake (Table 5). The total variance explained was 65·1%.

Sensitivity, specificity, PVP, and PVN for the RAPS scale were performed on data collected on admission ($n = 488$). At a cut-off point of ≤36, sensitivity was 57·4% and specificity, 57·6%, whereas PVP was 14·4% and PVN 91·6% (Table 6). Sensitivity, specificity and predictive values for medical and surgical patients were also calculated. At a cut-off point of ≤36, sensitivity for medical patients was 90·0%, specificity 28·6%, PVP 10·7%, and PVN 96·8%. The corresponding figures for surgical patients were 38·2%, 84·8%, 27·7% and 90·0%, respectively. At a cut-off point of 31, the best balance between sensitivity and specificity was achieved for medical patients; sensitivity was 75%, specificity, 70%, PVP 19·2%, and PVN 96·7% (Table 6). The same analysis was performed with the two largest groups of patients, namely patients from

Table 5 Principal component analysis with oblique rotation for the RAPS scale

Factor Variable	Mobility Loading	Physical condition Loading	Nutrition Loading	Communalities h^2
1. General physical condition	0·40	**0·54**	0·13	0·65
2. Physical activity	**0·74**	0·11	< 0·1	0·66
3. Mobility	**0·87**	< 0·1	< 0·1	0·81
4. Moisture	**0·66**	< 0·1	< 0·1	0·46
5. Food intake	0·25	0·23	**0·60**	0·67
6. Fluid intake	< 0·1	−0·15	**0·92**	0·80
7. Sensory perception	**0·73**	−0·16	< 0·1	0·47
8. Friction and shear	**0·85**	0·11	< 0·1	0·76
9. Body temperature	< 0·1	**0·89**	−0·18	0·74
10. s-Albumin	−0·10	**0·53**	0·38	0·48
Eigenvalue	4·27	1·27	0·96	
Percentage of variance	42·74	12·71	9·62	
Cumulative percentage	42·74	55·46	65·08	
α Coefficient	0·83	0·59	0·57	

The variables finally included in the respective factors are in bold type.

wards for infectious diseases ($n = 76$) and orthopaedic patients ($n = 99$). At a cut-off point ≤36, for patients from wards for infectious diseases, the sensitivity was 90·0%, specificity 28·8%, PVP 16·1%, and PVN 95·0%. For orthopaedic patients, the results at the same cut-off point were 47·8%, 85·5%, 50·0% and 84·4%, respectively. At a lower cut-off point of 31, sensitivity was 80%, whereas specificity, PVP, and PVN were 69·7%, 28·6%, and 95·8%, respectively, for patients from wards for infectious diseases (Table 6). Sensitivity, specificity, PVP and PVN were calculated excluding s-albumin ($n = 508$) as data were missing in 20 cases. The results did not differ from those obtained in the analysis presented above.

Discussion

The RAPS scale is a further development of the modified and re-modified Norton scale (Ek 1987, Ek *et al*. 1991). One of the intentions of adding variables to these scales was to increase the predictive validity. In this study, this has been achieved to some extent, but the result varies a great deal among different categories of patients.

Risk assessment is recommended as the first step in the prevention of pressure sore development in nursing care (AHCPR 1992, EPUAP 1998). Assessment has to be performed on admission, and must be re-assessed whenever there is a significant change in the patients' condition. A risk assessment scale will help the nurses to make a systematic assessment of the patients' condition and risk of pressure sore development. This can become an important foundation for prevention and quality assurance, helping nurses to work more professionally (Ek *et al*. 2001). To improve the prediction and prevention of pressure sore development, risk assessment scales with high degree of sensitivity, specificity and predictive values are needed. The risk assessment scale, the RAPS scale, used in this study includes variables from the Norton scale, the re-modified Norton scale and the Braden scale (Braden & Bergstrom 1987, Ek 1987, Ek *et al*. 1991). These scales have been examined, although not fully and not in Sweden, for validity and reliability in different care settings (Edwards 1994, Ek 1987, Mei-che Pang & Kwok-shing Wong 1998). Thus, risk assessment scales need to be further developed for Swedish conditions in order to improve the prediction of pressure sore development.

In this study, analysis of the reliability of the RAPS scale consists of internal consistency and equivalence. The internal consistency of the scale was measured by item–item correlation and corrected item–total correlation. It is recommended that the items in a scale should be correlated with the total scale above 0·30. The higher the correlation, the better the item (Nunally & Bernstein 1994). The item-item correlation should be moderate, between 0·30 and 0·70. Ferketich (1991) points out that an item–item correlation below 0·30 may indicate that the item does not relate to the problem measured and that an item–item correlation above 0·70 indicates that the item may be unnecessary (Ferketich 1991). As bodily constitution and skin type were weakly correlated with the scale as a whole, and very weakly correlated with the other items, they were excluded. After the exclusion, item–item correlation varied moderately, and the mean item–item correlation increased to a level above 0·30, as recommended (Nunally & Bernstein 1994). The item friction and shear correlated with mobility above 0·70 and may be an unnecessary item. However, this

Table 6 Sensitivity, specificity, predictive value positive test (PVP), and predictive value negative test (PVN). Numbers in brackets are the number of patients with pressure sores

Cut-off point	Sensitivity (%)	Specificity (%)	PVP (%)	PVN (%)
Total sample, $n = 488$ (54)				
≤38	77·8	34·8	12·9	92·6
≤37	70·4	46·5	14·1	92·7
≤36	57·4	57·6	14·4	91·6
≤35	50·0	64·3	14·8	91·2
≤34	46·3	69·4	15·8	91·2
≤33	38·9	75·3	16·4	90·8
≤32	33·3	80·2	17·3	90·6
≤31	31·5	84·6	20·2	90·8
Medical patients, $n = 230$ (20)				
≤38	95·0	8·1	9·0	94·4
≤37	90·0	16·7	9·3	94·6
≤36	90·0	28·6	10·7	96·8
≤35	85·0	38·6	11·6	96·4
≤34	80·0	45·2	12·2	96·0
≤33	75·0	54·8	13·6	95·8
≤32	75·0	62·9	19·2	96·4
≤31	75·0	70·0	19·2	96·7
Surgical patients, $n = 258$ (34)				
≤38	67·6	59·8	20·4	92·4
≤37	58·9	74·6	26·0	92·3
≤36	38·2	84·8	27·7	90·0
≤35	29·4	88·4	27·8	89·2
≤34	26·5	92·0	33·3	89·2
≤33	17·6	95·1	35·3	87·3
≤32	8·8	96·4	27·3	87·4
≤31	5·9	98·2	33·3	87·3
Patients in wards for infectious diseases, $n = 76$ (10)				
≤38	90·0	3·0	12·3	66·7
≤37	90·0	13·5	13·6	90·0
≤36	90·0	28·8	16·1	95·0
≤35	90·0	33·3	17·0	95·7
≤34	90·0	54·5	21·1	95·6
≤33	80·0	54·5	21·1	94·7
≤32	80·0	62·1	24·2	95·3
≤31	80·0	69·7	28·6	95·8
Orthopaedic patients, $n = 99$ (23)				
≤38	82·6	50·0	33·3	90·5
≤37	69·6	69·7	41·0	88·3
≤36	47·8	85·5	50·0	84·4
≤35	39·1	89·5	52·9	82·9
≤34	34·8	93·4	61·5	82·6
≤33	21·7	97·4	71·4	80·4
≤32	13·0	97·4	60·0	78·7
≤31	8·7	100·0	100·0	78·4

item is of major importance from a clinical perspective and was therefore not excluded. A sample size of at least 200–300 subjects is recommended in order to minimize the risk of false results based on chance (Ferketich 1991). In this study, 530 patients were included. Taken together, the results show that the internal consistency of the RAPS scale is sufficient.

The percentage of agreement among nurses was 70%. As this calculation does not consider chance influence, intraclass correlation was calculated (Armitage & Berry 1995). The

intraclass correlation between nurses was high, 0·83, indicating that the equivalence of the RAPS scale is good.

Factor analysis was used to examine underlying dimensions of the RAPS scale, which is an ordinal scale. However, the use of factor analysis is justified, as the analysis is based on correlation, which will not be affected by the scaling (Kim & Mueller 1978). The factor analysis gave three factors, and no cross-linking was found. The variables included in the three factors appear to be coherent, and the factors were designated mobility, physical status and nutrition. The distribution of variables into three factors seems to be logical and indicates that the RAPS scale measures three clusters of variables: mobility, physical condition, and nutrition. The total variance explained was 65·1%, which is satisfactory for a new scale (Gorsuch 1983). The total variance indicates, however, that there are some additional variables to be considered beyond those included in the RAPS scale when measuring the risk of pressure sore development. Future studies need to investigate whether these factors be identified and assessed, or can all changes be related to the body's adjustment to immobility and bed rest, which is clinically more complicated and comprehensive to observe and to measure (Rosseau 1993).

The sample in this study is a very heterogeneous group of patients. According to the results concerning sensitivity, specificity and predictive value, it seems preferable to use the RAPS scale among patients in medical wards and wards for infectious diseases. The sensitivity among medical patients and patients treated in wards for infectious diseases was high, but the specificity at a cut-off point of ≤36 was low. The optimal cut-off point for these groups of patients seems to be ≤31. At this point, the best relationship between sensitivity and specificity was achieved. Bergstrom & Braden (1998) used the Braden scale among patients from tertiary-care, medical–surgical wards and long-term care. The predictive value for the Braden scale varied considerably for the different patient groups. This indicates that there may be some other risk factors to be considered when assessing the risk of pressure sore development among patients undergoing surgical treatment. Some of these factors may be hypotensive episodes during surgical treatment, serum albumin level, extra corporeal circulation, preoperative immobility time, as well as the length and type of surgery (Kemp *et al*. 1990, Ek *et al*. 1991, Allman *et al*. 1995, Nixon *et al*. 2000). These are some factors that have to be studied in future in the attempt to find an optimal risk assessment tool for surgical patients.

As there are many factors that are complicated to observe and measure and which may alter the risk of pressure sore development, we may have to accept some level of over-prediction, despite increased costs.

Study limitations

Focusing on a certain problem, such as pressure sores, can be one source of error in the data collection. In this study, preventive measures were not excluded because of ethical considerations, but there is a risk that intensified use of preventive measures could interfere with and influence the results. The sensitivity of the scale may be poorer because of the better care given to the patients. No evidence of preventive measures having been performed to a higher degree than usual were, however, been observed.

The inclusion of patients took place on 3 days per week. Precautions were taken to ensure that no groups of patients were systematically excluded. There was, however, a small risk of exclusion of some patient categories as the sampling was not random. Another limitation of this study may be the fact that the nurses who made the risk assessments also made, in some cases, the skin inspections. It is possible that the assessment of the skin may have influenced the scoring of the RAPS scale, which is a problem in clinical studies.

Conclusion

In conclusion, the RAPS scale is reliable concerning internal consistency and has achieved the necessary level of equivalence. The predictive validity was especially good for medical patients and those with infectious diseases at a cut-off point of ≤31. This indicates that the RAPS scale may be useful in clinical practice for these patients, and the scale may be possible to use in clinical practice for these groups of patients. For patients undergoing surgical treatment further analysis will be performed.

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