ORIGINAL RESEARCH

Construct validity of the Braden scale in acute- and long-term care settings in Austria: A structural equation modeling analysis

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ABSTRACT

Objective: The Braden scale is frequently used to assess pressure ulcer risk in health care settings. Selected psychometric properties have been tested using various methods of classical test theory in international studies. However, limited information on construct validity is available. Aim was to determine if the Braden subscale items correlate with the construct pressure ulcer risk and whether the construct validity concerning the factor structure of the Braden scale is adequate in acute and long-term settings.
Methods: A quantitative design with secondary analysis of data from one acute (n = 328) and eight long-term care facilities (n = 311) in Austria was used to test construct validity. Data analysis included principal axis factor analysis with Promax rotation and assessment of internal consistency, followed by structural equation modeling.
Results: For the acute care setting, a structure equation model with two latent factors and for the long-term care setting with one latent factor was tested according to principal axis factoring results. The Braden subscale items correlated with the construct pressure ulcer risk. Almost all examined model fit indices were within recommended reference values. Thus, the construct validity of the Braden scale was adequate in both settings.
Conclusions: The factor structure in the acute care setting did not match that in the investigated long-term care setting. Further research regarding the construct validity of the Braden scale is therefore necessary.

Key Words: Braden scale, Construct validity, Structural equation model, Factor analysis

1. INTRODUCTION

Pressure ulcers are a major health concern in both acute and long-term care facilities throughout the world. They are defined as “localized injury to the skin and/or underlying tissue, usually over a bony prominence, resulting from sustained pressure (including pressure associated with shear)”.[1] The global pooled prevalence in the acute care setting was 12.8% (n = 1,366,848).[2] In Germany between 2010 and 2015, the prevalence reported in a systematic review with 67 studies was between 2% to 4% in hospitals and between 2% and 5% in the long-term care setting.[3] As a result, the prevention and treatment of pressure ulcers is of outstanding

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importance.[1] Immobility is a major contributing factor for pressure ulcer development and elderly care-dependent persons are often affected. The consequences for the affected persons are manifold. Pressure ulcers may cause pain and discomfort, reduce the quality of life, and lead to prolonged hospital stays.[4,5] This leads to high costs in the health care system, since both the treatment and the prevention consume many materials as well as human resources.[1,6]

There are over 30 pressure ulcer risk assessment scales and adaptions described in the scientific literature[7] and some of these are structured, scientific validated, and used in clinical practice. One of the most frequently clinically used and validated risk assessment instrument is the Braden scale for Predicting Pressure Sore Risk [Braden scale],[7] which is based on a conceptual model.[8] Although the Braden scale's psychometric properties (i.e., inter-rater reliability and predictive validity) were tested frequently, there is limited information on the construct validity available because only two studies tested the construct validity of the Braden scale with exploratory factor analysis[5] and structural equation modeling[9] in the acute care setting and only two studies[10,11] evaluated the convergent validity in the long-term care setting. Therefore, it is unknown if the Braden subscales correlate with the construct Pressure Ulcer Risk; and if the construct validity concerning the factor structure of the Braden scale is adequate.

Aim

The aims of this study were (1) to determine if the subscales Sensory Perception, Activity, Mobility, Moisture, Nutrition, and Shear & Friction of the Braden scale correlate with the construct Pressure Ulcer Risk and (2) to demonstrate whether the construct validity concerning the factor structure of the Braden scale is adequate in acute and long-term care settings in Austria.

2. METHODS

2.1 Study design

The construct validity study had a quantitative multicenter design with secondary analysis of data based on cross-sectional data collection from one acute hospital and eight nursing homes in Austria.

2.2 Setting and sample size determination

Medical records of patients and residents with previously recorded Braden scale total and subscale scores were included from one hospital and from eight nursing homes. Since the Braden scale has six subscales and at least 250 participants were required for the maximum-likelihood [ML] method to achieve high communality (h^2 = 0.60 - 0.80),[12,13] the targeted sample size was 300 patients and residents. Only medical records of patients and residents over the age of 18 with no missing data were included in the analysis.

2.3 Data collection procedures and study materials

Data collection started in April 2019 and was completed by the nursing quality managers of both settings. Medical records of hospital patients and nursing home residents recorded between 2016 and 2018 were reviewed and recorded for socio-demographic data (patients' and residents' year of birth, gender, Braden scale total and subscale scores). The data collection process from both settings were double-checked for quality control by one of the authors. The socio-demographic data of the registered nurse [RN] administrating the Braden scale at the time of the assessment (gender, year of birth) was also collected by the nursing quality managers at both settings.

2.4 Data analysis

The socio-demographic data of the RN from both settings, hospital patients, and nursing home residents were analyzed descriptively with SPSS version 26 on an exploratory level. In addition, percentage and absolute frequencies were calculated separately for each dataset (hospital and nursing homes). For all data analysis, a significance level of 5% was chosen.

The prerequisites for the structure equation model [SEM] were examined in SPSS. As a first step, the assumed measurement model of the Braden scale was evaluated by exploratory factor analysis [EFA]. First, the prerequisites to perform EFA were checked by the calculation of Pearson correlation coefficients [r],[12] the measure of sampling adequacy [MSA], and communalities.[13] Both, the MSA values and communalities can take on values between 0 and 1. Items below 0.5 were excluded from the EFA.[13] Other EFA prerequisites that were checked were the Kaiser-Meyer-Olkin Criteria [KMO $\geq$ 0.6] and the Bartlett-Test. Since the null hypothesis was rejected, EFA was performed.[13] The KMO coefficient was used to check whether substantial correlations existed in the correlation matrix. Since none of the KMO values were below 0.5, a factor analysis was performed.

After checking the prerequisites, principal axis factoring [PAF] method was used for the EFA[13] with Promax rotation.[14] The Stevens ad hoc rule was determined for significance (α = 0.01, two-sided) depending on the sample size.[15] For a sample size of 300, the loading [λ] of an item had to be above 0.149. Since an oblique rotation was used, the structure matrix was considered for the Stevens ad hoc rule and the loadings doubled. Hence, for a sample size of 300 the loadings were set at λ = 0.298.[15] The Kaiser criterion with the support of the Scree test[16] were used to determine the number of factors to be extracted. Here, the number of factors was extracted whose eigenvalue was greater than 1.[17] In a final step the reliability of the items was tested with standardized Cronbach's alpha [α], item-to-item correlations, and item-to-total correlation.[13]

As prerequisite to perform Confirmatory factor analysis [CFA], data had to be interval-scaled;[12] hence, the ordinal data was z-standardized. For the SEM, the data analyses were completed with IBM SPSS Analysis of Moment Structures [Amos] version 26. First, a hypothesized reflective measurement model of the CFA structure was drawn with the six Braden subscale items and one latent factor (Pressure Ulcer Risk) (see Figure 1 for further information).

Then a reflective measurement model was built with two latent factors (Pressure Ulcer Risk 1 & 2) with six endogenous manifest variables (Braden subscale items) assigned only once to one of the two factors. The structural model was then built[12] (see Figure 2).

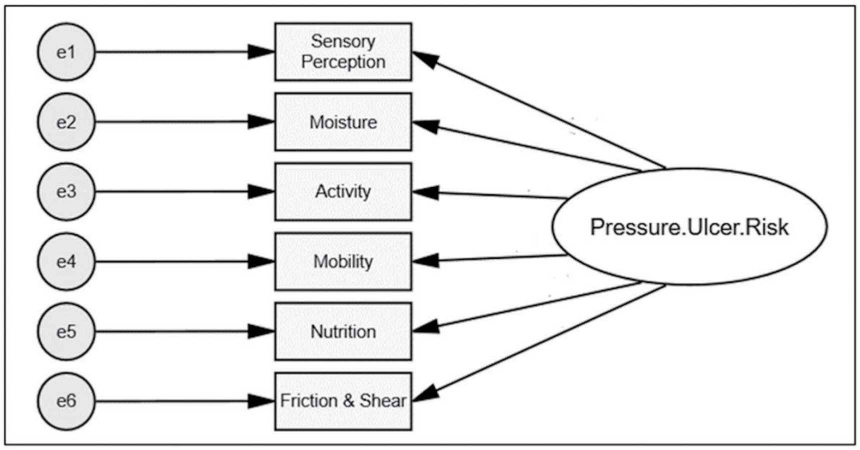

Figure 1. Hypothesized reflective measurement model of the Braden scale
In this reflective measurement model, the hypothetical construct (Pressure Ulcer Risk) represented the cause of the measurement indicators (Braden subscale items) to be collected at observation level. Therefore, the Braden subscale items were observable consequences of the effectiveness of a construct at the observation level.[13] Hence, the measurement model defined which manifest variable represented indicators of the latent variable.[12]

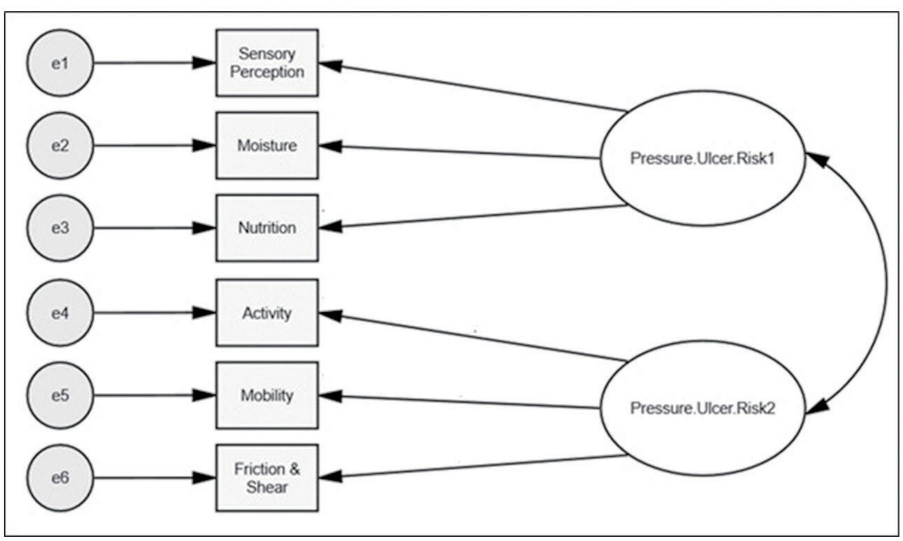

Figure 2. Hypothesized reflective measurement and structural model of the Braden scale
Since the arrows are pointing from the latent or exogenous factors to the manifest or endogenous variables, they represent loadings [λ] or partial standardized regression weights. The partial standardized regression weights correspond to correlations because each item loads only on one factor.[12] The manifest items present coefficients of determination [R^2]. These indicate how much variance of an item is explained by the latent factor. Thus, these values represent the communalities [h^2] of the items. The communalities are minimum estimates of item reliability. The difference between one and the communality is the standardized error variance [e1 – e6][12]

For the SEM, a maximum-likelihood [ML] estimation was used as an estimation procedure for the covariance structure analysis.[12] The following values and result presentations were chosen: standardized estimates, squared multiple correlations or coefficients of determination [R^2], all implied moments, residual moments as well as test for normality and outliers.[12] The model parameter estimates were reviewed for feasibility, appropriateness of standard error, and statistical significance.[18] In addition, the test statistic reported for the statistical significance of the parameter estimates was the critical ratio [c.r.]. Nonsignificant parameters were considered unimportant to the model[18] and were not considered.

At last, different goodness-of-fit indices were used to estimate the model fit: Chi-squared test value [χ^2] with probability [p] value and normed chi-square [χ^2 / df < 3], Goodness-of-Fit [GFI $\geq$ 0.9], Comparative-Fit-Index [CFI $\geq$ 0.95], Standardized-Root-Mean-Residual [SRMR < 0.11], Root-Mean-Square-Error of Approximation [RMSEA < 0.08], Normed-Fit-Index [NFI $\geq$ 0.9], Tucker-Lewis-Index [TLI $\geq$ 0.9], and Incremental-Fit-Index [IFI $\geq$ 0.9].[12, 13] Since the χ^2-test is very sensitive to changes in sample size and deviations from the normal distribution assumptions, the Hoelter test value was reported to indicate the critical sample size at which the model under consideration was accepted based on the χ^2-test with a probability error of α = 0.01 and = 0.05.[13, 19]

2.5 Ethical considerations

The study was approved by the ethics committee of the hospital (EK 08.01.2019) and the local Research Committee for Scientific and Ethical Questions (EK 2532/06.02.2019). Patients', residents', and registered nurses' informed consent was waived by the ethics committee due to the nature of secondary analysis of previously recorded data.

3. RESULTS

3.1 Acute care setting

In total, 328 medical records were extracted. The socio-demographic characteristics of the patients are summarized in Table 1. The age of three female patients was missing.

The average age of the 57 RN (44 female, 13 male) administrating the Braden scale was 36.09 (SD $\pm$ 10.57) years ranging from 23 to 59 years.

In the hospital setting, the prerequisites to perform an EFA were fulfilled (MSA > 0.5, Bartlett's Test: $\chi^2_{(15)}$ = 572.23 (p < .001), KMO = 0.72). Two factors were extracted for the PAF analysis based on the results of the Kaiser criterion > 1 and Scree test. Two factors explained 67.84% of the total variance of the items. After the extraction by the PAF method with Promax rotation, the percentage of variance explained was 52.14% (see Table 2).

Table 1. Socio-demographic Characteristics of Sample

Acute care setting (n = 325)								
	Gender	**n (%)**	**Min**	**Max**	**MD**	**IQR**	**Mean**	**SD**
Years in age	Female	194 (59.7)	18	100	87.00	81.00; 92.00	84.21	12.44
	Male	131 (40.3)	37	97	83.00	72.00; 90.00	79.62	13.11
Braden scale total score	Female	197 (60.1)	8	18	13.00	10.00; 16.00	13.04	3.12
	Male	131 (39.9)	8	18	13.00	10.00; 16.00	12.92	3.25
Long-term care setting (n = 311)								
	Gender	**n (%)**	**Min**	**Max**	**MD**	**IQR**	**Mean**	**SD**
Years in age	Female	235 (75.6)	50	100	89.00	81.00; 94.00	87.01	9.76
	Male	76 (24.4)	39	100	83.50	74.25; 90.00	82.24	11.65
Braden scale total score	Female	235 (75.6)	6	23	18.00	14.00; 21.00	17.03	4.31
	Male	76 (24.4)	7	23	17.00	13.00; 20.00	16.51	4.31

Note. Abbreviations: n = number, % = percent, Min = minimum, Max = maximum, MD = median, IQR = interquartile range, SD = standard deviation

Table 2. Exploratory factor analysis – Principal axis factoring method with promax rotation

Acute care setting		**Braden subscale**	**Long-term care setting**
Latent Factor 1 [λ]	**Latent Factor 2 [λ]**		**Latent Factor 1 [λ]**
0.714	0.225	Sensory Perception	0.728
0.505	0.079	Moisture	0.577
0.202	0.848	Activity	0.878
0.276	0.786	Mobility	0.876
0.623	0.263	Nutrition	0.388
0.260	0.788	Friction & Shear	0.719

Note. Abbreviations: λ = factor loading

Cronbach's α for factor 1 with the Braden subscale items Sensory Perception, Moisture, and Nutrition was 0.63. For factor 2 with the items Activity, Mobility, and Friction & Shear, Cronbach's α was 0.84. Some inter-to-inter correlations were below the recommended cut-off value of ≥ 0.3. However, since Cronbach's α was above the recommended cut-off value and the data was multivariate normal, the ML method was performed (see Figure 3).

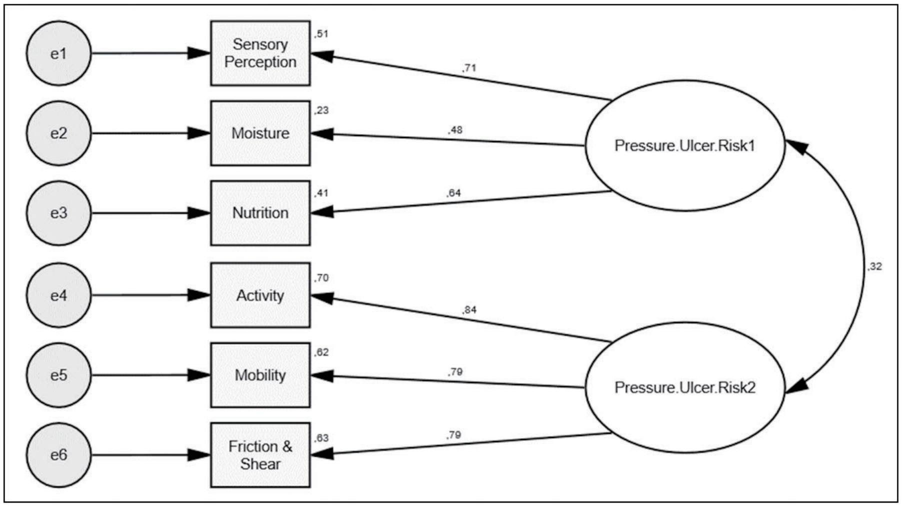

Figure 3. Standardized model estimations of the Braden scale in the acute care setting
The values above the arrows represent loadings [λ] or standardized regression weights. The values displayed next to each Braden subscale items are coefficients of determination [R^2]. The correlation [r] between the two latent factors is also depicted.

All unstandardized regression weights [λ] reported were statistically significant. The standard errors of the parameters estimated were small, and therefore accurate estimations. The standardized errors of variance reported with critical ratios of the Braden scale's manifest and latent variables were all significant. The significant regression weights and variances of the Braden subscale items indicated local model fit. The covariance between the two latent factors was significant and showed a positive moderate correlation. All evaluated model fit indices were within recommended cut-off values and therefore, the overall fit of the measurement model was perfect (see Table 3).

Table 3. Overall fit of the measurement model

Model Fit Indices	Acute care setting	Long-term care setting
Chi-Square Test [χ^2 / df < 3]	χ^2/df = 1.500	χ^2/df = 3.727
Goodness-of-Fit [GFI ≥ 0.9]	GFI = 0.988	GFI = 0.964
Comparative-Fit-Index [CFI ≥ 0.95]	CFI = 0.993	CFI = 0.972
Standardized-Root-Mean-Residual [SRMR < 0.11]	SRMR = 0.0353	SRMR = 0.0387
Root-Mean-Square-Error of Approximation [RMSEA < 0.08]	RMSEA = 0.039	RMSEA = 0.094*
Normed-Fit-Index [NFI ≥ 0.9]	NFI = 0.979	NFI = 0.962
Tucker-Lewis-Index [TLI ≥ 0.9]	TLI = 0.987	TLI = 0.953
Incremental-Fit-Index [IFI ≥ 0.9]	IFI = 0.993	IFI = 0.972

Note. Values in the square brackets are reference values; *PCLOSE = 0.016 (*p*-value for [RMSEA ≤ .05][12, 13]

3.2 Long-term care setting

In total, 311 medical records were extracted (see Table 1). The average age of the 35 RN (28 female, 7 male) administrating the Braden scale was 41.97 (SD ± 8.87) years ranging from 28 to 58 years.

The prerequisites to perform an EFA were also fulfilled (MSA > 0.5, Bartlett's Test: $\chi^2_{(15)} = 868.84$ ($p = .001$), KMO = 0.83). One factor was extracted for the PAF analysis based on the results of the Kaiser criterion > 1 and Scree test. One factor explained 57.88% of the total variance of the items. After the extraction by the PAF method with Promax rotation, the percentage of variance explained was 51.13%

(see Table 2).

The calculated Cronbach's α was 0.84. Some inter-to-inter correlations were below the recommended cut-off value of ≥ 0.3. The corrected item-to-total correlation for the Braden subscale item Nutrition was below the recommended cut-off value of ≥ 0.5. Since Cronbach's α was above the recommended cut-off value and the data was also multivariate normal, the ML method was performed (see Figure 4).

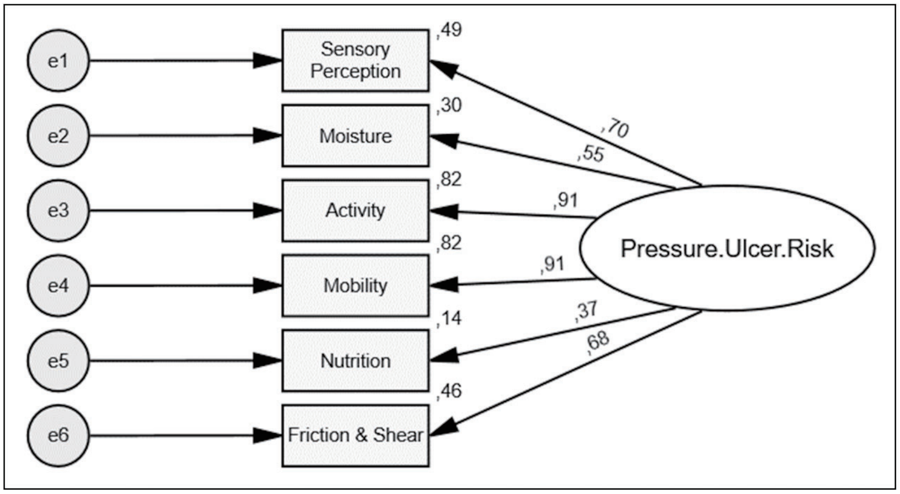

Figure 4. Standardized model estimations of the Braden scale in the long-term care setting
The values above the arrows represent loadings [λ] or standardized regression weights. The values reported next to each Braden subscale item are coefficients of determination [R^2]

All unstandardized regression weights [λ] reported were also statistically significant, with small standard errors, suggesting accurate estimations. All evaluated model fit indices were within recommended reference values except for the significant chi-square test and the normed chi-square fit. Therefore, the overall fit of the measurement model was good (see Table 3).

4. Discussion

The Braden scale's psychometric properties have been tested frequently since its development in 1984.[20] However, there was scarce evidence available for the construct validity by using SEM of the Braden scale in the acute and long-term care setting.

In the investigated acute care setting, two factors explained 67.84% of the total variance of the items. After the extraction by the PAF method with Promax rotation, the percentage of variance explained with two factors was 52.14%. The SEM results showed that all unstandardized regression weights and standardized errors of variance reported with critical ratios were statistically significant. The overall fit of the measurement model was perfect. Thus, for this investigated hospital setting, the construct validity of the Braden scale was adequate.

Only two other studies[5,9] tested the construct validity of the Braden scale with exploratory factor analysis[5] and with SEM[9] in the acute care setting. Palese et al. performed secondary data analysis of 1,464 hospital medical records to develop a meta-tool assessing patients' risks and problems from four established instruments (Brass, Barthel, Conley, and Braden scale).[5] EFA using Promax rotation with Kaiser normalization of each scale was completed. Cronbach's α of the Braden scale was 0.78 with one extracted factor.[5] This contrasts with the results of the investigated acute care setting in Austria, with two extracted factors (Cronbach's α factor 1 = 0.63; factor 2 = 0.84). In the study conducted by Palese et al., the EFA extracted one factor and explained 71.20% of the cumulative variance of the Braden scale,[5] while in the Austrian study, two factors explained 67.84% of the total variance of the items. After the extraction by the PAF method with Promax rotation, the percentage of variance explained with two factors was reduced to 52.14%. Recently, the construct validity of the Braden scale was tested by Chen et al. in a retrospective study of consecutive patients (n = 2,588) from an acute care facility with SEM. The reported factor loadings[9] of the original Braden subscales ($p < .001$) were 0.77 for Sensory Perception, 0.69 for Mobility, 0.56 for Moisture, 0.27 for Friction & Shear, 0.19 for Nutrition, and 0.14 for Activity. The original model indicated an insufficient model fit ($\chi^2_{(9)}$ = 22.85, CFI = 0.90, GFI = 0.97, RMSEA = 0.09).[9] The original model was modified[9] and the fit measurements improved with each modification (final model: $\chi^2_{(2)}$ = 2.05, CFI = 0.99, GFI = 0.99, RMSEA = 0.20). The factor loadings (p < .001) for three subscales were below 0.2 (Activity λ = 0.13, Nutrition λ = 0.14, Friction & Shear λ = 0.16) and correlated with other subscales. The other three subscales were above 0.5 (Moisture λ = 0.55, Mobility λ = 0.62, Sensory Perception λ = 0.82), thus indicating important risk factors for developing a pressure ulcer.[9] This contrasts with the examined acute care setting in Austria. The Braden subscale items Sensory Perception, Moisture, and Nutrition loaded high to moderate between λ = 0.71 and 0.48 on Pressure Ulcer Risk 1 and the Braden subscale items Activity, Mobility, and Friction & Shear loaded high between λ = 0.83 and 0.79 on Pressure Ulcer Risk 2. The overall fit of the original measurement model with two factors was perfect (see Table 3), and no model re-specification was needed. The Hoelter test for the critical sample size was 201 (α = 0.01) and 157 (α = 0.05), which was met with a sample size of 328. Thus, the global model fit indices indicated a perfect model fit of the investigated acute care setting in Austria.

In the investigated eight long-term care facilities, the prerequisites to perform an EFA were fulfilled. One factor explained 57.88% of the total variance of the items. After the extraction by the PAF method with Promax rotation, the percentage of variance explained was 51.13%. The internal consistency was acceptable in the evaluated facilities. Only the subscale Nutrition was below the recommended cut-off value for the corrected item-to-total correlation. The reflective measurement model consisted of one latent factor (Pressure Ulcer Risk) with six manifest variables (Braden subscale items). The SEM results showed that all unstandardized regression weights and standardized errors of variance reported with critical ratios were statistically significant. The overall fit of the measurement model was good. All evaluated model fit indices were within recommended reference values except for the significant chi-square test and the normed chi-square fit [χ^2/df < 3]. However, this might happen with larger sample sizes and a few variables since the χ^2-test is affected by the sample size.[19] Thus, for the investigated nursing home setting, the construct validity of the Braden scale was considered adequate.

No other identified study evaluated the construct validity of the Braden scale with SEM or factor analysis in the long-term care setting, only two studies were identified that tested the convergent validity.[10,11] Omolayo et al. reported that the Moisture subscale of the Braden scale was inversely related to the frequency of wet observations (ANOVA [F] = 8.78, p < .001; rho (ρ) = -0.23, p < .0001), soiled observations (ρ = -0.13, p < .013), and daily brief changes (F = 4.26, p < .0057; ρ = -0.105, p < .518).[10] Xakellis et al. tested if the Braden or Norton scale predicted the same at-risk patients (n = 504) while receiving preventive nursing interventions. 45% of patients received preventive interventions.[11] The Norton scale identified 38% and the Braden scale 27% at-risk patients. The Cohens Kappa value among all three methods was 0.53, between the Braden and Norton scales 0.73, and between the use of a preventive intervention and the Braden scale 0.41.[11]

For the evaluation of the construct validity a reflective measurement model was applied, and it is characterized by the fact that the manifestations of the measurement variables (Braden subscale items) are causally caused by the latent variable (Pressure Ulcer Risk). This is accompanied by the assumption that changes in the latent variable lead to an effect in all the observed variables simultaneously (neglecting measurement errors).[21] Only one other study[9] derived a reflective measurement model to map the relationships between the latent variable and measurement variables as well as the explained variance in the measurement variables. The secondary data analysis of consecutive hospital patients (n = 2,588) indicated an insufficient model fit and that the Braden subscales Nutrition, Activity, and Friction & Shear were not independent risk factors for pressure ulcer development.[9] Those findings could not be confirmed in the present study in Austria with a perfect model fit for two latent factors and six manifest variables for the hospital setting. However, these two latent factors (Pressure Ulcer Risk 1 & 2) contrast with the conceptual model for the study of the etiology of pressure ulcers,[8] which the Braden scale is based on. In Braden and Bergstrom[8] model, the Braden subscale items Mobility, Activity, and Sensory Perception contribute to the latent factor Pressure and the Braden subscale items Moisture, Friction & Shear, and Nutrition to the latent factor Tissue Tolerance.[8] Therefore, Braden and Bergstrom factor names were not used to label the factors in the evaluated reflective measurement model and the conceptual scheme could not be depicted in the factor structure of the evaluated model in the hospital setting.[8] This was also true for the investigated long-term care setting, with only one extracted factor.

Limitations

Evaluation of the Braden scale is limited to adults aged 18 and assessed with the original German version of the Braden scale in both settings. It was unknown if nurses received any training on pressure ulcer risk assessment with the Braden scale or what experience nurses had with the Braden scale. A selection bias is possible since the nursing quality managers at both settings collected data and chose, which records to include to reach the required number of at least 300 participants. The data collection process was then double-checked for quality control by one of the authors in both settings. The analysis results of this study were based on secondary data from one acute hospital and eight nursing homes in a single state in Austria and are thus, not representative for the acute and long-term care settings in Austria.

5. CONCLUSION

In the nursing home setting, all subscale items except Nutrition loaded high to moderate on the factor Pressure Ulcer Risk. The subscale item Nutrition seems to occupy a special position, which theoretically might have its cause in the distinction between extrinsic and intrinsic factors of the latent construct Tissue Tolerance as displayed in the conceptual model by Braden and Bergstrom for the study of the etiology of pressure ulcers.[8] The overall fit of the measurement model was good in the evaluated nursing home settings and thus, the construct validity was considered adequate. Even though, two factors were extracted in the hospital setting, the separation of the items of the Braden scale into two latent constructs was not supported since the results were based only on one setting and were not representative for the entire acute care setting. Conclusions cannot be drawn as to which Braden subscale items played a more distinctive role in identifying pressure ulcer risk. Overall, the model fit for the acute care setting was perfect and the construct validity was adequate.

Regarding the presented results in the acute care setting (2 factors), a separation into two total scores is at this point not reasonable since the empirical results need to be replicated in further research to support these findings. The factor structure in the investigated long-term care setting did not match those in the acute care setting with only one latent factor extracted. Thus, further research is required.

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AUTHORS CONTRIBUTIONS

Petra Schumacher (PS) and Gerhard Müller (GM) were responsible for study design and revising. PS was responsible for data collection. PS and Eduardo Santos(ES) were responsible for data analysis. PS, ES, and Bettina Wandl (BW) drafted the manuscript and GM revised it. All authors read and approved the final manuscript.

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CONFLICTS OF INTEREST DISCLOSURE

We have no conflict of interest to disclose.

INFORMED CONSENT

Obtained.

ETHICS APPROVAL

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PROVENANCE AND PEER REVIEW

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

DATA SHARING STATEMENT

No additional data are available.

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