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Midrange Braden Subscale Scores Are Associated With Increased Risk for Pressure Injury Development Among Critical Care Patients

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ABSTRACT

PURPOSE: The purpose of the current study was to examine the relationship between pressure injury development and the Braden Scale for Pressure Sore Risk subscale scores in a surgical intensive care unit (ICU) population and to ascertain whether the risk represented by the subscale scores is different between older and younger patients.

DESIGN: Retrospective review of electronic medical records.

SUBJECTS AND SETTING: The sample comprised patients admitted to the ICU at an academic medical center in the Western United States (Utah) and Level 1 trauma center between January 1, 2008 and May 1, 2013. Analysis is based on data from 6377 patients.

METHODS: Retrospective chart review was used to determine Braden Scale total and subscale scores, age, and incidence of pressure injury development. We used survival analysis to determine the hazards of developing a pressure injury associated with each subscale of the Braden Scale, with the lowest-risk category as a reference. In addition, we used time-dependent Cox regression with natural cubic splines to model the interaction between age and Braden Scale scores and subscale scores in pressure injury risk.

RESULTS: Of the 6377 ICU patients, 214 (4%) developed a pressure injury (stages 2-4, deep tissue injury, or unstageable) and 516 (8%) developed a hospital-acquired pressure injury of any stage. With the exception of the friction and shear subscales, regardless of age, individuals with scores in the intermediate-risk levels had the highest likelihood of developing pressure injury.

CONCLUSION: The relationship between age, Braden Scale subscale scores, and pressure injury development varied among subscales. Maximal preventive efforts should be extended to include individuals with intermediate Braden Scale subscale scores, and age should be considered along with the subscale scores as a factor in care planning.

KEY WORDS: Braden Scale, Critical care, Pressure injury, Risk assessment.

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INTRODUCTION

Hospital-acquired pressure injuries occur in 3% to 24% of acutely ill patients in the United States; they are associated with longer hospital stays, increased morbidity, and human suffering.[1-3] Among hospitalized older adults, pressure injuries are twice as common among those admitted to the intensive care unit (ICU), which is particularly concerning because older age is a risk factor for both ICU admission and slower healing of pressure injuries.[4,5]

In the United States, pressure injury risk has historically been ascertained using the Braden Scale for Predicting Pressure Sore Risk (Braden Scale).[6] The Braden Scale is the sum of 6 subscales and was developed to be used for planning effective pressure injury prevention interventions; however, the use of a cumulative score to ascertain pressure injury risk is controversial. A recent systematic review found that formal pressure injury risk assessment tools with associated intervention protocols were no more effective in preventing pressure injuries than usual care.[7] Therefore, some authors propose that Braden Scale subscale scores, rather than the cumulative score, should be the focus of pressure injury prevention efforts.[8] Studies

detailing pressure injury risk associated with Braden Scale subscale scores among critical care patients are limited, however.[9] Moreover, although older age is a risk factor for pressure injury development in the critical care population, no studies have examined pressure injury risk associated with Braden Scale subscale scores in older people specifically.[3,10,11]

The purpose of the Braden Scale is to help clinicians plan effective pressure injury prevention interventions. The scale is comprised of 6 items (subscales): sensory perception, moisture, activity, mobility, nutrition, and friction/shear. Cumulative scores range from 6 (highest risk) to 23 (lowest risk). Evidence concerning pressure injury development based on cumulative Braden Scale score is mixed (Table 1). While the cumulative Braden Scale score identifies most critical care patients who go on to develop a pressure injury (high sensitivity), cumulative scores classify most critical care patients as "at risk" for pressure injuries, thus limiting its specificity.[9]

In contrast, few studies have examined Braden Scale subscale scores in critical care patients. Cox[9] conducted a systematic review of the literature and concluded that more information was needed. Among studies that examined Braden subscale scores, 4 subscales (friction/shear, moisture, mobility, and sensory perception) demonstrated some predictive value on multivariate analysis whereas 2 subscales (nutrition and activity) did not.[9,10,12,22,23] However, a major methodological limitation noted by Cox[10] was lack of a repeated-measures approach. Subscale scores were obtained from a single point in time (eg, admission) or were averaged in some way, failing to reflect the dynamic nature of critical care patients' physiologic status.

In an effort to analyze the risk represented by the various Braden subscales, Gadd[8] reviewed medical records of 20 patients with hospital-acquired pressure injuries and concluded that some injuries might have been avoided if preventive interventions based on Braden Scale subscale scores were implemented. Additional research is needed to confirm these findings and to identify the magnitude of risk represented by the various subscale scores. The purpose of this study was to identify pressure injury risk associated with the Braden Scale cumulative and subscale scores in critical care patients and to determine whether the risk represented by subscale scores is different between older and younger patients.

METHODS

Working with a biomedical informatics team, we queried an enterprise data warehouse for electronic health record (EHR) data matching our sampling criteria and variables of interest. We refined the query and the data using an iterative approach entailing data validation procedures and iterative review by domain experts, data stewards, and the biomedical informatics team. We validated the data extracted from the EHR by manually comparing the values and date/time stamps found in the extracted data to those displayed in the human-readable system views for 60 cases. On implementing the fully developed query for all manually validated cases, we found consistent values and date/time stamps.

The sample comprised patients admitted to the ICU at an academic medical center in the Western United States (Utah) and level 1 trauma center between January 1, 2008, and May 1, 2013. The main inclusion criterion was admission to our adult surgical ICU or cardiovascular ICU, either directly or following an acute care stay. We included individuals younger than 18 years who were admitted to the adult ICU in an effort to study the Braden Scale as it was actually used among all patients in the adult surgical ICUs. We excluded patients with pressure injuries present on admission to the ICU due to concern about misattribution of community-acquired pressure injuries as hospital-acquired pressure injuries. Study procedures were reviewed and approved by the University of Utah institutional review board (#00068783).

Outcome Measures

During the time period encompassed by the study, it was standard practice for nurses in the ICU to conduct a head-to-toe skin assessment and record Braden Scale scores at least once during each 12-hour shift (twice per day). The nurses received annual training on the Braden Scale and pressure injury identification. We averaged the Braden Scale score for each shift to derive a once-daily value. The primary outcome variable was a hospital-acquired stage 2-4 pressure injury, deep tissue injury (DTI), or unstageable injury. The secondary outcome variable was a hospital-acquired pressure injury of any stage (stages 1-4, DTI, or unstageable). We did not include stage 1 pressure injures in the primary analysis due to concern about the difficulty in differentiating between transient redness caused by friction or dermatitis versus true tissue injury[24]; however, we did include stage 1 injuries in a separate secondary analysis in an effort to capture the full spectrum of tissue injury.

Data Analysis

We used time-dependent survival analysis to determine the hazards of developing a pressure injury based on the cumulative Braden Scale and each subscale score. We chose time-varying Cox regression to take into account all Braden Scale measurements, assuming that the hazard of developing a pressure injury changes in synchrony with the Braden Scale changes. For each subscale and for the total Braden Scale score, the lowest-risk category represented the reference. In addition, we used time-dependent Cox regression with natural cubic splines to model the association of developing a pressure injury with age by the total Braden Scale score and also by each Braden subscale category. We performed the analysis using statistical software STATA 13 (STATA Data Analysis and Software, College Station, TX), and the statistical significance level was defined at $\alpha = .05$.

RESULTS

The query produced 7218 records. We omitted 841 records due to incomplete patient IDs (examples include a date instead of an ID or single-digit numbers). The final sample comprised 6377 patients admitted to the adult surgical ICU or adult cardiothoracic ICU; their mean age was 54 ± 19 years (mean ± SD). There were 2403 females (38%) and 3924 males (62%). The majority of the sample was white (n = 4838; 78%). Their mean length of hospital stay was 10 ± 12 days (range, 1-229 days).

Two hundred fourteen individuals (4%) developed stage 2 or greater pressure injuries and 516 (8%) developed a stage 1 or greater injury (Table 2). Demographic information for individuals with and without pressure injuries are summarized in Table 3.

Individuals with a cumulative Braden Scale scores between 10 and 12 (indicating high risk for pressure injury development) were 8.4 times (OR = 8.4, 95% confidence interval [CI], 5.7-12.6) more likely to develop a pressure injury compared with people whose Braden Scale score indicated no risk

TABLE 1.
Braden Scale Predictive Validity

Study	Sample	Design	Pressure Injury Incidence and Stages	Findings
Jiricka and colleagues (1995)[12]	85 ICU patients in the United States	Prospective	56% (stages 1-4)	Braden Scale at cutoff point 11: Sensitivity = 75% Specificity = 64% Positive predictive value = 73.5% Negative predictive value 66.7%
Lee and colleagues (2003)[13]	112 ICU patients in Korea	Prospective	31.3% (stages 1-4)	Braden Scale: Sensitivity = 97% Specificity = 26% Positive predictive value = 37% Negative predictive value = 95%
Pender and Frazier (2005)[14]	40 mechanically ventilated ICU patients in the United States	Prospective record review	20% (stages 1-4)	No relationship identified between Braden Scale score and PI development
Feuchtinger and colleagues (2007)[15]	53 surgical ICU patients in Germany	Prospective	49% (stages 1-4; all but one injury were stage 1)	Braden Scale at cutoff point 11: Sensitivity = 31% Specificity = 100% Positive predictive value = 100% Negative predictive value = 41%
Fernandes and Caliri (2008)[16]	48 ICU patients in Brazil	Prospective	48% (stages 1-4)	Bivariate results showed individuals who developed PIs had lower Braden Scale scores ($P = .0$-$.01$) No multivariate results reported
Kim and colleagues (2009)[17]	219 surgical ICU patients in Korea	Prospective	18.3% (stages 1-4)	Braden Scale at cutoff point 14: Sensitivity = 92.5% Specificity = 69.8% Positive predictive value = 40.6% Negative predictive value = 97.6%
Kaitani and colleagues (2010)[18]	98 ICU/high-care unit patients in Japan	Prospective	11.2% (stages 1-4)	Individuals in the "moderate-risk" Braden Scale score group (13-14) had greater PI incidence than those in the "high-risk" group (<12)
Cho and Noh (2010)[19]	715 ICU patients in Korea	Retrospective	5.9% (stages 1-4)	*Note*: The Braden Scale was administered to only 11% of ICU patients for reasons that are unclear. Braden Scale at cutoff point 13: Sensitivity = 75.9% Specificity = 47.3% Positive predictive value = 18.1% Negative predictive value = 92.8%
Slowikowski and Funk (2010)[3]	369 ICU patients in the United States	Prospective	23.9% (stages not reported)	The Braden Scale was significant on multivariate logistic regression; odds ratio = 1.3
Iranmanesh and colleagues (2012)[20]	82 trauma ICU patients in Iran	Prospective	13.4% (stages not reported)	Bivariate results showed that individuals who developed PI had lower Braden Scale scores ($P < .05$) No multivariate results reported
Cox (2011)[10]	347 medical-surgical ICU patients in the United States	Retrospective	18.7% (stages 1-4, DTI, and unstageable)	Braden Scale at cutoff point 18: Sensitivity = 100% Specificity = 7% Positive predictive value = 20% Negative predictive value = 100%
Tschannen and colleagues (2012)[21]	3225 surgical ICU and intermediate care patients in the United States	Retrospective	12% (stages 1-4, DTI, and unstageable)	The admission Braden Scale was significant upon multivariate logistic regression analysis; odds ratio = 0.89

Abbreviations: DTI, deep tissue injury; ICU, intensive care unit; PI, pressure injury.

(≥19). Among those in the severe-risk category (total score ≤9), the chances of developing a pressure injury were similar to patients in the moderate cumulative Braden score category (13-14); their hazard rate ratios (HRRs) were 5.3 (95% CI, 1.6-17.1) and 5.7 (95% CI, 3.9-8.3), respectively (Table 4).

Additional analysis revealed that individuals with a cumulative "high-risk" score were more likely to develop a pressure injury than individuals at the "severe-risk" level was reflected in findings from the Braden subscale scores, with the exception of the friction/shear subscale (Table 4). The effect was particularly

TABLE 2.
Pressure Injury Stages

Stage	Stage 1 or Greater	Stage 2 or Greater
Stage 1	259 (50%)	N/A
Stage 2	214 (41.5%)	214 (83%)
Stage 3	13 (2.5%)	13 (5%)
Stage 4	4 (0.8%)	4 (1.5%)
Deep tissue injury	8 (1.5%)	8 (3.1%)
Unstageable	18 (3.5%)	18 (7%)

pronounced in the moisture and mobility subscales. People in the "often moist" category were 12 times (OR = 12.5, 95% CI, 7.8-20.2) as likely as those who were in the "rarely moist" category to develop a pressure injury, while the risk of developing a pressure injury was relatively lower in the more severe "constantly moist" category (hazard rate ratio [HRR] = 6.8; 95% CI, 2.2-21.5). Similarly, individuals with "very limited" mobility were 7.7 times as likely (95% CI, 4.9-12.1) to develop a pressure injury compared to patients without mobility limitations. Those deemed "completely immobile" were only 4.9 times as likely (95% CI, 2.7-8.8) to develop a pressure injury compared to individuals without mobility limitations.

Risk of Pressure Injury: All Stages

Analysis based on inclusion of all pressure injuries (including stage 1) was similar to the results for stages 2-4, DTI, and unstageable injuries described earlier (Table 5). Individuals with a cumulative Braden Scale score between 10 and 12 (high risk) were 6.7 times (95% CI, 4.8-9.4) more likely to develop a pressure injury compared with people whose Braden Scale score indicated no risk (≥19). Among those in the severe-risk category (total score ≤9), the chances of developing a pressure injury were similar to patients in the moderate cumulative Braden score category (13-14), with hazard rate ratios of 4.6 (95% CI, 1.7-12.7) and 4.8 (95% CI, 3.6-6.6), respectively (Table 4).

The finding that individuals with a cumulative high-risk score were more likely to experience pressure injury development than individuals at the severe-risk level was also reflected in the results for the various subscale scores, with the exception of the friction/shear subscale (Table 5). The effect was particularly pronounced in the moisture, activity, and mobility subscales. People in the "often moist" category were 8.8 times (95% CI, 5.7-13.6) as likely as those who were in the "rarely moist" category to develop a pressure injury, while the risk of developing a pressure injury was relatively lower in the more severe "constantly moist" category (HRR = 4.2; 95% CI, 1.4-13.2). People whose activity fell in the mid-range severity level of "chairfast" were 7.2 times (95% CI, 4.0-13.0) more likely to develop a pressure injury, whereas those who were bedfast were at relatively lower risk, (HRR = 4.5, 95% CI, 2.5-8.0). Similarly, individuals with "very limited" mobility were 5.7 times as likely (95% CI, 4.0-8.0) to develop a pressure injury compared to patients without mobility limitations, and those deemed "completely immobile" were more likely to develop a pressure injury than individuals without mobility limitations (HRR = 4.2, 95% CI 2.6-6.7).

Age and Braden Scale Score

Tables 4 and 5 identify the hazards of developing a pressure injury of stage 2 and greater and stage 1 and greater, respectively, associated with the Braden Scale categories for the total population and also for individuals who are older or younger than 65 years. However, the relationship between the Braden Scale subscale score and age was not linear in some subscales. Therefore, in an effort to fully represent the age dimension, we used time-dependent Cox regression with natural cubic splines to model the association of developing a stage 2 or greater pressure injury with age. Analysis indicated that individuals in the high- and severe-risk cumulative Braden Scale categories experienced increases in risk for pressure injury development with advancing age, whereas the effect of age within the moderate- and mild-risk categories was relatively static (Figure 1). The relationship between the Sensory Perception subscale, age, and pressure injury risk was linear, with increased risk at younger

TABLE 3.
Demographics

		Stage 1 or Greater		Stage 2 or Greater	
Variable	Total Population	Intact Skin	PI	Intact Skin	PI
Age, mean (SD), minimum-maximum, y	54 (19), 12-100	53 (19), 12-100	59 (17), 14-96	53 (19), 12-100	59 (16), 19-96
No. available (No. missing)	6317 (60)	5842 (19)	475 (41)	6061 (59)	256 (1)
Gender					
Male, n (%)	3924 (62%)	3626 (62%)	293 (62%)	3723 (62%)	201 (63%)
Female, n (%)	2403 (38%)	2216 (38%)	182 (38%)	2286 (38%)	117 (37%)
No. available (No. missing)	6317 (60)	5842 (19)	475 (41)	6061 (59)	256 (1)
Race					
White, n (%)	4838 (78%)	4455 (77%)	375 (80%)	4601 (78%)	237 (76%)
Nonwhite, n (%)	1395 (22%)	1300 (23%)	94 (20%)	1320 (22%)	75 (24%)
No. available (No. missing)	6224 (153)	5755 (106)	469 (47)	5972 (148)	256 (1)
Length of stay,[a] mean (SD), d	10 (12), 1-229	9 (9), 1-224	27 (24), 1-229	9 (9), 1-224	30 (27), 1-229
No. available (No. missing)	6317 (60)	5842 (19)	469 (47)	6061 (59)	256 (1)

Abbreviations: No, number of cases, PI, pressure injury/-ies; SD, standard deviation.
[a]Partial days are included as a day if more than 12 hours.

TABLE 4.
Hazards of Developing a Stage 2-4, Deep Tissue Injury, or Unstageable Pressure Injury

	Hazard Rate Ratio (95% CI), *P*		
Braden Scale/Subscale Category	**Total ICU Population**	**Age > 65 Years**	**Age ≤ 65 Years**
Total Braden Scale (ref = no risk, total score ≥19)			
Mild risk (total score = 15-18)	2.2 (1.6-3.2), $P < .001$	1.7 (1.0-2.8), $P = .053$	2.4 (1.5-3.7), $P < .001$
Moderate risk (total score = 13-14)	5.7 (3.9-8.3), $P < .001$	4.1 (2.4-7.2), $P < .001$	6.1 (3.9-9.8), $P < .001$
High risk (total score = 10-12)	8.4 (5.7-12.6), $P < .001$	4.1 (2.1-8.3), $P < .001$	10.4 (6.5-16.6), $P < .001$
Severe risk (total score ≤9)	5.3 (1.6-17.1), $P = .005$	(Too few cases)	2.1 (0.3-15.1), $P = .480$
Sensory Perception (ref = no impairment, score = 4)			
Slightly limited (score = 3)	2.1 (1.6-2.7), $P < .001$	2.9 (1.4-3.0), $P < .001$	2.1 (1.5-2.8), $P < .001$
Very limited (score = 2)	2.0 (1.4-2.8), $P < .001$	1.3 (0.7-2.6), $P = .400$	2.3 (1.6-3.5), $P < .001$
Completely limited (score = 1)	1.1 (0.6-2.1), $P = .738$	0.8 (0.2-3.1), $P = .713$	1.3 (0.6-2.7), $P = .487$
Moisture (ref = rarely moist, score = 4)			
Occasionally moist (score = 3)	5.7 (4.5-7.1), $P < .001$	5.8 (3.9-8.5), $P < .001$	5.7 (4.3-7.6), $P < .001$
Often moist (score = 2)	12.5 (7.8-20.2), $P < .001$	45.5 (20.7-100.3), $P < .001$	8.7 (4.6-16.2), $P < .001$
Constantly moist (score = 1)	6.8 (2.2-21.5), $P = .001$	13.7 (1.9-98.8), $P = .010$	5.8 (1.4-23.5), $P = .014$
Activity (ref = walks frequently, score = 4)			
Walks occasionally (score = 3)	3.1 (1.7-5.9), $P < .001$	7.5 (1.8-31.2), $P = .005$	2.0 (1.0-4.2), $P = .060$
Chairfast (score = 2)	4.3 (2.3-8.1), $P < .001$	5.7 (1.3-24.3), $P = .019$	4.1 (2.0-8.2), $P < .001$
Bedfast (score = 1)	3.3 (1.8-6.0), $P < .001$	5.6 (1.4-22.9), $P = .017$	2.7 (1.4-5.4), $P = .004$
Mobility (ref = no limitations, score = 4)			
Slightly limited (score = 3)	3.8 (2.4-6.0), $P < .001$	4.0 (1.8-8.8), $P = .001$	3.6 (2.1-6.3), $P < .001$
Very limited (score = 2)	7.7 (4.9-12.1), $P < .001$	7.2 (3.2-15.9), $P < .001$	7.9 (4.5-13.6), $P < .001$
Completely immobile (score = 1)	4.9 (2.7-8.8), $P < .001$	1.7 (0.4-8.1), $P = .511$	6.1 (3.1-12.1), $P < .001$
Nutrition (ref = excellent, score = 4)			
Adequate (score = 3)	4.0 (1.7-9.8), $P = .002$	3.8 (0.9-15.7), $P = .060$	4.2 (1.3-13.1), $P = 0.015$
Probably inadequate (score = 2)	4.4 (1.8-10.8), $P = .001$	3.8 (0.9-15.9), $P = .065$	4.8 (1.5-15.2), $P = .008$
Very poor (score = 1)	4.0 (1.1-15.0), $P = .038$	3.0 (0.3-33.5), $P = .365$	4.7 (0.9-23.1), $P = .060$
Friction/Shear (ref = no apparent problem, score = 3)			
Potential problem (score = 2)	5.2 (4.0-6.7), $P < .001$	3.5 (2.3-5.4), $P < .001$	6.2 (4.5-8.6), $P < .001$
Problem (score = 1)	454.6 (30.8-67.4), $P < .001$	31.7 (16.4-61.4), $P < .001$	55.0 (33.7-89.6), $P < .001$

Abbreviations: CI, confidence interval; ICU, intensive care unit; ref, reference.

ages, and the increased risk among younger people was particularly pronounced in the "very limited" sensory perception group (Figure 2). Moisture was associated with increased risk for pressure injury among older individuals who were often moist, as opposed to older individuals in the occasionally or constantly moist categories, while younger people who were often moist did not experience increased risk relative to those who were either occasionally or constantly moist (Figure 3).

Pressure injury risk associated with activity was also more pronounced among older people, particularly among those who were in the "walks occasionally" category (Figure 4), whereas altered mobility (very limited mobility or completely immobile) conferred the most risk among younger people (Figure 5). The nutrition subscale showed increased rates of pressure injury development among older people, but not younger people, who had "very poor" nutrition status (Figure 6). Finally, a friction/shear subscale score of "problem" was associated with dramatically increased risk for pressure injury compared to a score of "potential problem" or "no apparent problem" at all ages (Figure 7).

DISCUSSION

We evaluated the effects of cumulative Braden Scale scores and subscale scores in pressure injury development in an adult ICU and found that individuals with cumulative and subscale scores in the intermediate-risk levels had the highest likelihood of developing a pressure injury among all subscale categories

TABLE 5.
Hazards of Developing a Stage 1-4, Deep Tissue Injury, or Unstageable Pressure Injury

	Hazard Rate Ratio (95% CI), *P*		
Braden Scale/Subscale Category	**Total ICU Population**	**Age > 65 y**	**Age ≤ 65 y**
Total Braden Scale (ref = no risk, total score ≥19)			
Mild risk (total score = 15-18)	2.6 (2.0-3.4), $P < 001$	2.2 (1.4-3.4), $P < .001$	2.8 (2.0-4.1), $P < .001$
Moderate risk (total score = 13-14)	4.8 (3.6-6.6), $P < .001$	4.1 (2.5-6.6), $P < .001$	5.3 (3.6-7.9), $P < .001$
High risk (total score = 10-12)	6.7 (4.8-9.4), $P < .001$	4.1 (2.2-7.4), $P < .001$	8.4 (5.6-12.7), $P < .001$
Severe risk (total score ≤19)	4.6 (1.7-12.7), $P = .003$	(Too few cases)	2.8 (0.7-11.7), $P = .151$
Sensory Perception (ref = no impairment, score = 4)			
Slightly limited (score = 3)	1.7 (1.4-2.1), $P < .001$	1.5 (1.1-2.1), $P = .014$	1.9 (1.5-2.4), $P < .001$
Very limited (score = –2)	1.7 (1.3-2.3), $P < .001$	1.0 (0.5-1.7), $P = .866$	2.2 (1.6-3.1), $P < .001$
Completely limited (score = 1)	1.1 (0.7-1.8), $P = .736$	1.1 (0.4-2.6), $P = .883$	1.1 (0.6-2.1), $P = .656$
Moisture (ref = rarely moist, score = 4)			
Occasionally moist (score = 3)	5.0 (4.1-6.0), $P < .001$	4.5 (3.3-6.2), $P < .001$	5.3 (4.2-6.6), $P < .001$
Often moist (score = 2)	8.8 (5.7-13.6), $P < .001$	26.3 (12.8-54.2), $P < .001$	6.5 (3.7-11.5), $P < .001$
Constantly moist (score = 1)	4.2 (1.4-13.2), $P = .013$	7.6 (1.1-54.7), $P = .043$	3.8 (0.9-15.2), $P = .063$
Activity (ref = walks frequently, score = 4)			
Walks occasionally (score = 3)	4.6 (2.5-8.3), $P < .001$	7.9 (2.5-25.3), $P < .001$	3.3 (1.6-6.7), $P = .001$
Chairfast (score = 2)	7.2 (4.0-13.0), $P < .001$	8.0 (2.5-25.9), $P = .001$	6.9 (3.5-13.8), $P < .001$
Bedfast (score = 1)	4.5 (2.5-8.0), $P < .001$	5.6 (1.8-17.6), $P = .004$	4.1 (2.1-7.9), $P < .001$
Mobility (ref = no limitations, score = 4)			
Slightly limited (score = 3)	3.5 (2.5-5.0), $P < .001$	3.3 (1.9-5.8), $P < .001$	3.6 (2.3-5.5), $P < .001$
Very limited (score = 2)	5.7 (4.0-8.0), $P < .001$	4.7 (2.6-8.4), $P < .001$	6.1 (4.0-9.5), $P < .001$
Completely immobile (score = 1)	4.2 (2.6-6.7), $P < .001$	3.3 (1.4-7.9), $P = .007$	4.7 (2.7-8.2), $P < .001$
Nutrition (ref = excellent, score = 4)			
Adequate (score = 3)	3.1 (1.6-5.8), $P < .001$	1.9 (0.8-4.3), $P = .124$	4.8 (1.8-13.0), $P = .002$
Probably inadequate (score = 2)	3.4 (1.8-6.5), $P < .001$	2.1 (0.9-5.0), $P = .074$	5.3 (2.0-14.5), $P < .001$
Very poor (score = 1)	3.0 (1.1-8.4), $P = .031$	1.9 (0.4-9.6), $P = .419$	4.8 (1.2-19.2), $P = .027$
Friction/Shear (ref = no apparent problem, score = 3)			
Potential problem (score = 2)	4.7 (3.8-5.7), $P < .001$	4.1 (2.9-5.7), $P < .001$	4.9 (3.8-6.3), $P < .001$
Problem (score = 1)	27.6 (19.1-39.7), $P < .001$	22.5 (12.2-41.5), $P < .001$	30.3 (19.2-47.6), $P < .001$

Abbreviations: CI, confidence interval; ICU, intensive care unit; ref, reference.

except the friction/shear subscale, according to which patients with the most severe score were at markedly increased risk for pressure injury development. We also found that the risk associated with the subscales varied with age.

A major strength of this study was the use of a large data set incorporating repeated measures of Braden Scale scores that therefore reflects the variability in an individual's risk status throughout his or her ICU stay. Although other studies have examined Braden subscale scores, those studies that relied on a single assessment (eg, admission Braden Scale score), a mean measure, or cross-sectional approaches did not take into consideration the dynamic nature of a patient's physiologic status in the ICU.[9]

The finding that, with the exception of the friction/shear subscale, individuals with scores in the intermediate-risk levels had the highest likelihood of developing a pressure injury was unexpected. We speculate that nurses identified patients at most severe risk and applied maximal preventive measures, which effectively prevented some pressure injuries from occurring among individuals in the highest-risk categories, whereas patients with moderate-risk scores may not have received the same level of preventive interventions. The lack of information about preventive measures, however, is an important limitation. Although we speculate that high-risk Braden subscale scores cued the nurses and the healthcare team to apply maximal preventive interventions for high-risk patients, it is also possible that another, unrecorded, factor contributes to higher risk of pressure injury development among midrange patients.

The interaction between age and Braden Scale scores and subscale scores, particularly the activity, moisture, sensory

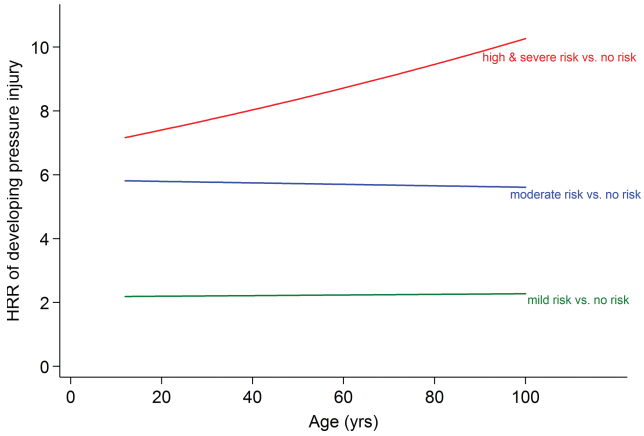

Figure 1. Total Braden Scale. HRR indicates hazard rate ratio.

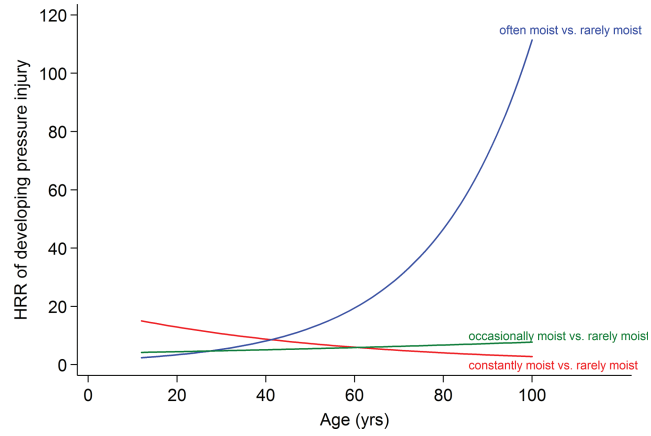

Figure 3. Moisture Braden subscale. HRR indicates hazard rate ratio.

perception, and nutrition subscales, added an important dimension that should be considered as a factor in care planning. Older people with midrange severity activity scores ("walks occasionally") were at markedly increased risk for pressure injury development compared with younger people with the same score (Figure 4). The results suggest that nurses should implement maximal preventive measures for older people with even mildly limited activity ("walks occasionally" vs "walks frequently").

Moisture was associated with an increased risk for pressure injury among older people who were often moist, as opposed to older people in the occasionally or constantly moist categories, while younger people who were often moist did not experience an increased risk relative to those who were either occasionally or constantly moist (Figure 3). It is likely that even moderate or episodic occasions of moisture are particularly harmful to older people's skin due to age-related changes in tissue resilience[25]; therefore, clinicians caring for older people in the ICU should be especially diligent in moisture management.

The sensory perception subscale showed increased risk for pressure injury development in younger critically ill patients (Figure 2). Sensory perception is operationalized in the Braden Scale, based on an individual's responsiveness and ability to feel pain or discomfort, and has been implicated as an important factor for pressure injury development among trauma and orthopedic patients.[26] Although exact numbers are not available, trauma patients make up a larger proportion of younger patients as opposed to older patients at our study site, a level 1 trauma center. Trauma patients are more likely than others to present with conditions that alter sensory perception such as head or spinal cord injuries. It is possible therefore that the increased risk associated with altered sensory perception among younger people is associated with the effects of traumatic injury in that age group.

Older people with poor nutrition had higher rates of pressure injury development, whereas younger people with equal nutrition were not at increased risk for pressure injury development (Figure 6). Although prior studies conducted among critical care patients did not reveal an association between pressure injury development and nutrition status, it is possible that age moderates the relationship due to decreased physiologic reserves among older people.[3,10,18]

Unlike the cumulative score and the other subscales, results for the friction/shear subscale showed markedly increased risk among individuals of all ages. Experts note that friction-induced skin injuries are not true pressure injuries. In contrast, shearing forces cause a decrease in regional blood flow and therefore are important in pressure injury etiology.[27,28] Prior studies documented the harmful effects of shear among critical care patients. Cox[10] noted that critical care patients with a friction/shear subscale score of "problem" were more than 5 times (OR 5.0, 95% CI, 1.423-22.95) as likely to develop pressure injuries compared to the

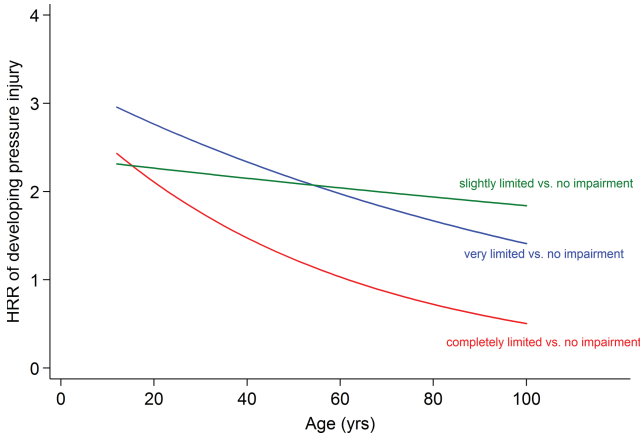

Figure 2. Sensory Perception Braden subscale. HRR indicates hazard rate ratio.

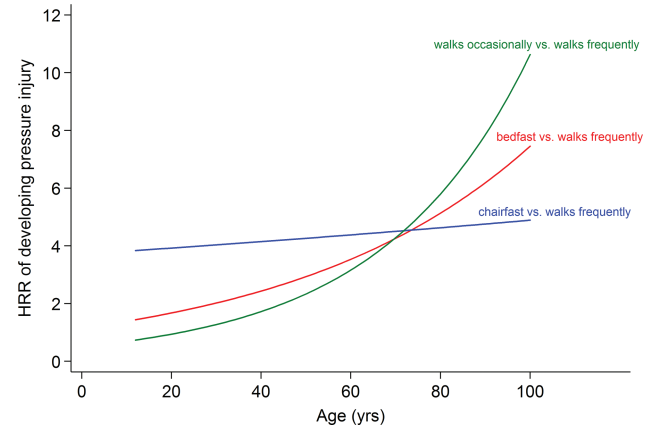

Figure 4. Activity Braden subscale. HRR indicates hazard rate ratio.

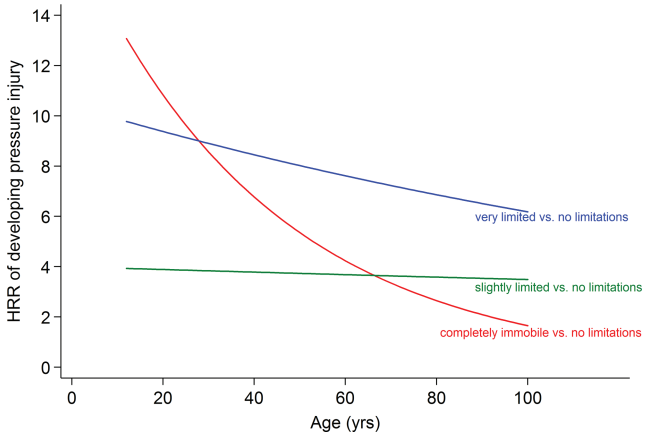

Figure 5. Mobility Braden subscale. HRR indicates hazard rate ratio.

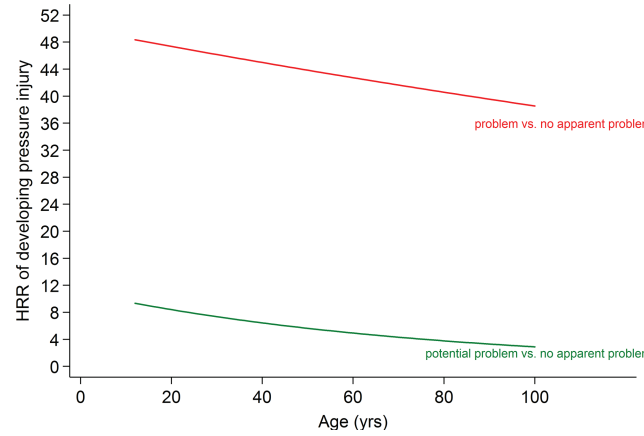

Figure 7. Friction/Shear Braden subscale. HRR indicates hazard rate ratio.

rest of her sample. Thus, measures to prevent or ameliorate shearing forces, including lifts, should be prioritized for all critical care patients at risk for shear.[29]

LIMITATIONS

Study limitations include the retrospective design. In addition, we did not collect data about treatment factors and therefore we are unable to specifically identify which preventative measures were applied. Finally, we excluded individuals with community acquired pressure injuries from our sample. It is possible that people with community acquired pressure injuries are at increased risk for developing subsequent, hospital acquired, pressure injuries and therefore our results may not be generalizable to individuals who come to the hospital with an existing pressure injury.

CONCLUSION

We found that patients with cumulative Braden Scale scores and subscale scores in the intermediate-risk levels had the highest likelihood of developing a pressure injury among all subscale categories except the friction/shear subscale. We postulate that high-risk Braden subscale scores cued the nurses and healthcare team to apply maximal preventive interventions for the patients at highest risk and propose that, in light of our results, maximal preventive interventions should be extended to patients with midrange risk scores. We also found that the risk associated with the subscales varied with age, indicating that age should be considered along with the subscale scores as a factor in care planning. We advocate additional research that evaluates the effects of treatment measures related to Braden Scale scores and subscale scores.

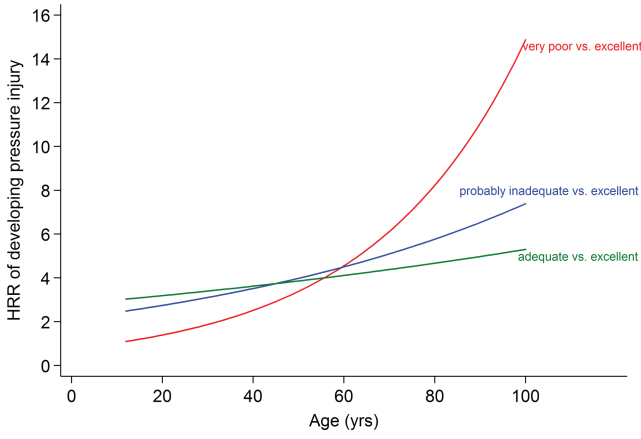

Figure 6. Nutrition Braden subscale. HRR indicates hazard rate ratio.

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