Published in final edited form as:

J Wound Ostomy Continence Nurs. 2009 ; 36(3): 277–284. doi:10.1097/WON.0b013e3181a19e53.

Sub-epidermal moisture is associated with early pressure ulcer damage in nursing home residents with dark skin tones: Pilot findings

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Abstract

OBJECTIVE—To examine the relationship between a measure of skin and tissue water, sub-epidermal skin moisture (SEM), and visual assessment of early PU damage in nursing home (NH) residents with dark skin tones.

DESIGN, SETTING AND PARTICIPANTS—Descriptive, cohort study with 66 residents in four U.S. nursing homes (NH).

METHODS—Data were pooled from two previous NH studies to evaluate persons with dark skin tones. Data were analyzed for concurrent visual assessments and SEM which were obtained at the right and left buttocks and sacrum weekly for 20 weeks. SEM was measured with a surface electrical capacitance dermal phase meter, where higher readings indicate greater SEM (range: 0–999 dermal phase units [DPU]). Visual assessment was rated as normal, erythema/stage I PU, or stage II+ PU. SEM and specific SEM threshold values (50, 150, 300 DPU) were modeled as detectors of visual assessment of early PU one week later (controlling for clustering and incontinence); with concurrent SEM, and PU risk status, in separate analyses for persons with light and dark skin tones.

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Financial Disclosure(s):

Barbara M. Bates-Jensen: none

Heather E. McCreath: none

Voranan Pongquan: none

Author Contributions:

Barbara M. Bates-Jensen: conceived and designed the study, acquisition of subjects, performed statistical analysis, analyzed and interpreted data, and preparation of manuscript.

Heather E. McCreath: performed statistical analysis, analyzed and interpreted data, and preparation of manuscript.

Voranan Pongquan: data collection, data management

Sponsor's Role: The sponsor had no role in the design, methods, subject recruitment, data collection, analysis or preparation of the paper.

RESULTS—Participants had a mean age of 84 years, were 83% female, 77% non-Hispanic white. Higher SEM predicted greater likelihood of erythema/stage I PU and stage II+ PU in persons with dark skin tones the next week (OR=1.88 for every 100 DPU increase in SEM, $p=0.004$). When SEM was greater than 50, 150, and 300 DPU, persons with dark skin tones were 8.5, 13, and 10 times more likely to present with stage II+ PU the following week compared to persons with light skin who were 7.2, 3.5, and 4.3 times more likely to present with stage II PU (50, 150, 300 DPU, respectively). SEM threshold of 50 DPU was also significant for detecting erythema/stage I PU in persons with dark skin tones (OR 5.3, CI 1.87—15.11, $P<.001$).

CONCLUSIONS—SEM was associated with future (one week later) PU in persons with dark skin tones. SEM threshold values may assist in detecting early PU in persons with dark skin tones, allowing for earlier intervention to prevent PU. These findings should be further evaluated in persons with dark skin tones.

Keywords

erythema; stage I pressure ulcers; darkly pigmented skin; moisture

Introduction

Pressure ulcers (PU) are the result of injury to the skin and underlying tissues and are common among nursing home (NH) residents, with annual incidence rates reported between 2.2% and 24%¹⁻³. Most are stage I and II PU³⁻⁵. Lower stage PU have been suggested as outcome measures of PU prevention care processes in NHs rather than the more severe and rare stage III and IV lesions^{6,7}.

African American NH residents experience a higher incidence of PU when compared to Caucasians (0.56 per person year compared to 0.35 per person year)⁸. They also have a higher rate of Stage II-IV PU emergence, are more likely to have multiple PU⁸⁻¹¹, and show a higher PU-associated mortality (age-adjusted rate ratio, 4.22; 95% CI, 4.16-4.27)¹².

Historically, a stage I PU was defined as persistent redness or non-blanchable erythema of intact skin, detected using visual skin assessment¹³. However, detection and accurate identification of erythema and stage I PU with this standard visual method is unreliable, and often fails to detect skin color changes in persons with darkly pigmented skin^{8,9,11}. This failure to detect and diagnose erythema in people with highly pigmented skin is evidenced by the incongruity between prevalence of stage I PU in Caucasians (48%) versus African Americans (20%)¹⁰. Another study found that 32% of PU detected in Caucasian residents were Stage I, whereas no Stage I PU were detected in African American residents⁹. Thus, clinicians may miss early visible signs of pressure induced damage in persons with darker skin tones because the standard visual method depends on observation of skin color changes, a more difficult task in highly-pigmented skin.

Pressure, over time, occludes blood and lymphatic circulation. If pressure is relieved before a critical time period is reached, a normal compensatory mechanism, reactive hyperemia, restores tissue nutrition and compensates for compromised circulation. If pressure is not relieved, the blood vessels collapse. The resulting ischemia deprives local tissues of oxygen,

nutrients, and waste removal is impaired. In the absence of oxygen, cells use anaerobic pathways for metabolism and produce toxic byproducts^{13,14}. The toxic byproducts lead to tissue acidosis, increased cell membrane permeability, edema, and eventual cell death.

Cellular damage also may occur with reperfusion and reoxygenation of ischemic tissues^{15,16}. Postischemic injury occurs when oxygen is reintroduced into tissues during reperfusion following ischemia. Reintroduction triggers oxygen-free radicals such as superoxide anion, hydroxyl radicals, and hydrogen peroxide, which induce endothelial damage and impair microvascular integrity. All of these cellular changes result in inflammation and edema at the site of injury. Inflammation is the earliest sign of impending ulceration¹⁷⁻²⁰ and inflammatory changes exist in the tissues before damage is fully visible on the skin surface. Inflammatory changes and tissue edema occur from 3-10 days before visible skin breakdown^{21,22}. Thus, in the physiological cascade leading to frank ulceration, detecting damage to the tissue before it is visible could lead to more effective prevention practices and less severe skin damage. We have previously tested a method of detecting this non-visible spectrum of pressure induced tissue damage²³⁻²⁶; this approach may be particularly beneficial for persons with dark skin tones for whom the standard, visual skin assessment, is inadequate.

Quantification of skin and tissue water (sub-epidermal moisture, SEM) is a biophysical measure used to represent the epidermal barrier function of skin.²⁷⁻³² Surface electrical capacitance can be used to measure SEM and evaluate restoration of an intact stratum corneum after injury with formation of the epidermal barrier as a function of hydration^{27,29,31}. The impedance of the skin to electrical forces is used to calculate surface electrical capacitance, which directly reflects localized edema or water in the epidermal and sub-epidermal tissues. Surface electrical capacitance has been used to quantify wound healing in burn patients and to examine the relationship between SEM and chronic wound healing in several small case series³²⁻³⁷. For example, Harrow and colleagues³⁴ measured SEM at PU wound margins to assess periwound edema at four standardized sites in a series of six patients with spinal cord injury and chronic non-healing stage III or IV PU. They found higher SEM values at wound margins when compared to control sites and suggested using SEM to assess tissue edema levels as a marker for potential healing.

In our prior studies we showed that a hand-held device that assesses SEM identified minor skin damage (erythema or stage I PU) at the sacrum and buttocks locations^{23,24}. Further, SEM was higher (indicating increased edema and inflammation) when there was no visible skin damage at the time but erythema or stage I PU was visible on the skin one week later. SEM values detected 26%²³ to 30%²⁴ of the occurrences of damage to the skin the following week, representing 20% to 25% more than detected with visual skin assessment by a skin care expert. As an extension of our previous work, the purpose of this study was to gather preliminary descriptive information on the relationship between SEM and direct visual assessment of erythema/stage I PU and stage II or greater PU in a sub-sample of persons with dark skin tones. The following research questions are addressed in this paper: 1) Does a relationship exist between SEM and visual detection of the presence of early PU in persons with dark skin tones and 2) Can SEM be used to detect early PU in persons with dark skin tones?

METHODS

Subjects and Setting

We pooled data from two previous NH studies in order to compare SEM values in persons with dark versus lighter skin tones. The prior studies were conducted as part of a large randomized trial to improve nutrition in NH residents. Residents were recruited from one non-profit and three for profit NH in the Los Angeles area. Residents were eligible for the skin health study if they were participating in the larger nutrition trial. The University of California, Los Angeles, Human Subject Protection Committee approved the protocol. Research staff obtained written informed consent to participate in the current study from residents who were able to provide informed consent or from their designated representatives (in residents unable to provide consent) with assent obtained from the resident. Figure 1 shows the flow of participants for the data used in this study.

Medical Record Data

At baseline, and monthly thereafter, research staff extracted medical and demographic information from all consented participants' medical records and their most recent Resident Assessment Instrument Minimum Data Set (MDS). The MDS is a multi-domain assessment tool that is completed on admission and at quarterly intervals for residents in Medicare and Medicaid accredited NHs.

Race/Ethnicity as Proxy for Skin Tone

The study was not originally designed to detect differences by skin tone. Therefore, skin tone was not directly measured. Instead, we used race/ethnicity as completed within the MDS as a proxy for skin tone. While this measure is imprecise, it enabled us to evaluate these pilot data.

Braden Scale Risk Assessment Scores

Research staff assessed participants' risk for PU development each month using the Braden Scale for Predicting Pressure Sores^{38,39}. The Braden Scale is composed of six subscales that conceptually reflect degrees of sensory perception, moisture, activity, mobility, nutrition, and friction and shear. All subscales are rated from 1 to 4 (1=worst, 4=best for subscale), except for friction and shear, which is rated from 1 to 3. The subscales may be summed for a total score, with a range from 6 to 23, with lower scores indicating lower function and higher risk for developing a pressure ulcer³⁸. In older patients, cutoff scores of 17 or 18 have been shown to be predictors of risk status.³⁹ In the current study, inter-rater agreements tested by comparing two raters' total score on 31 observations resulted in a Pearson correlation of 0.90 ($P<.001$). Inter-rater agreements on at risk (total scores ≤ 18) versus not at risk (total scores 19-23) in these 31 cases yielded a Kappa statistic of 0.69 ($P<.001$)^{23,24}.

Visual Skin Assessment

Trained research staff assessed skin health through direct independent visual assessments of the sacrum, trochanters, buttocks, and ischium each week for 20 weeks. Training emphasized stage I PU because this condition may be transient and difficult to detect.^{40,41}

Discoloration was graded as minimal (pink/redness in lightly pigmented skin or slight deepening of normal color in darkly pigmented skin), moderate (bright redness in light skin, purple in dark skin), or severe (dark red to purple in light skin, black to blue-grey in dark skin). Erythema was defined as moderate or severe skin discoloration, with blanching (based on the finger method of palpation). Stage I PU were defined as moderate or severe skin discoloration, with non-blanching. As the blanch response is often not detectable in persons with dark skin tones, we combined erythema and stage I PU categories for analysis using moderate or severe skin discoloration as the defining criteria. PU more severe than Stage I were staged using the NPUAP's 1998 four-stage definition.⁴² The presence or absence of urinary or fecal incontinence was also recorded. Inter-rater agreement was assessed on 98 pairs of observations (21 of which were paired observations of persons with dark skin tones). For erythema presence Kappas ranged from 0.70 to 1.00 across anatomic sites. Inter-rater agreement on stage was 1.00 on 10 paired observations of PU.

Sub-Epidermal Moisture Measures

Concurrent with the visual assessments, SEM was measured weekly at each of the anatomic locations using the NOVA Petite (NOVA Technology Corporation, 75 Congress St., Portsmouth, NH) dermal phase meter. This is a standard technique for measuring skin hydration that is used commonly in the medical and cosmetic industry.^{43,44} A small wand was used to take readings at each of the 7 anatomic locations (Figure 2). Readings were taken by placing the wand on the skin surface for 5 seconds after which the impedance value of the skin measured in dermal phase units (DPU) was automatically stored on the hand-held computer connected to the wand. The DPU is an arbitrary unit relative value; readings range from 0-999, with higher readings indicating higher SEM. SEM was measured immediately after a subject's incontinence containment pad and clothing were removed, before visual assessments were completed, and after incontinence care was provided (e.g., skin cleansed and patted dry) if required. Observers conducted both SEM and visual assessments but were blinded to the purpose of using the dermal phase meter.

Statistical Analysis

Chi square and t-tests were used to evaluate demographic, medical and functional characteristics, and PU related differences between persons with dark and light skin tones. To assess the relationship between visual skin assessment and sub-epidermal moisture, techniques were used that allowed for repeated measures, as an observation was defined by week and anatomic location. Thirty-five residents had 18 or more weeks of data (n=6 persons with dark skin tones); 18 residents had 12-18 weeks of data (n=4 persons with dark skin tones), three had 8-12 weeks of data, and two had less than 8 weeks of data (n=1 person with dark skin tones). There was no difference in the mean number of weeks of data between persons with dark or light skin tones (9.05, SD 5.8 vs 9.26, SD 5.8; $p=.661$, respectively). Of the participants with long observation periods, five had no visible skin damage at any site for the study duration. Trochanter sites were not used in analyses due to low or no occurrences of erythema, stage I PU or stage II+ PU.

To determine if increasing SEM was an indicator of subsequent skin damage, observations were first selected in which no stage II+ PU damage was noted by visual assessment and for

which no incontinence was observed. Proportional odds models using generalized ordered logistic modeling (Stata 9) were then calculated to determine if SEM measures detected occurrence of skin damage one week later controlling for within subject clustering. Skin damage was categorized as none, erythema/stage I PU, or stage II+ PU. Covariates were Braden Pressure Sore Risk Assessment Scale score (at risk scores of 0-18 and no risk scores of 19+) and SEM readings concurrent with visual assessment. We looked at data from sacral and buttocks sites as the ischial sites had low occurrences of erythema/stage I PU and stage II+ PU. We controlled for anatomic site by including dummy variables for right and left buttock anatomic locations in the model as follows:

$$\begin{aligned} \text{Skin damage} = & \beta_0 + \beta_1 \text{SEM 1 wk earlier} \\ & + \beta_2 \text{concurrent SEM} \\ & + \beta_3 \text{Braden risk category} \\ & + \beta_4 \text{L buttocks site} \\ & + \beta_5 \text{R buttocks site} + \varepsilon_{\text{subject}} + \varepsilon_{\text{time}} + \varepsilon \end{aligned}$$

We calculated an odds ratio for a 100 unit change in DPU reading because 1 unit changes in DPU readings were too small to be of clinical use. The odds ratio (OR) for 100 unit change in DPU reading was calculated using the following formula:

$$\exp(100 * \beta_1 \text{SEM 1 wk earlier} + 0 * \beta_2 \text{concurrent SEM} + 0 * \beta_3 \text{Braden Score risk status} + 0 * \beta_4 \text{L buttocks} + 0 * \beta_5 \text{R buttocks} + 0 * \beta_6)$$

We also assessed the relationship of three SEM threshold values (e.g., 50dpu, 150dpu, 300dpu) to concurrent and future visual assessment with a separate model for each threshold value, and Braden Pressure Sore Risk Assessment Scale category as a covariate (at risk scores= 0-18, no risk scores= 19+). Traditional sensitivity and specificity measures for the three threshold values have been reported previously.²⁶ They showed that lower thresholds of SEM were better at detecting areas where damage would occur (sensitivity) while higher thresholds of SEM could help identify areas with no damage (specificity). We analyzed data from light and dark skin tones in separate models.

RESULTS

Skin health and SEM measures pooled from 66 participants are reported in this paper. The participants were predominantly non-Hispanic white (83%) females (84.5%), cognitively impaired (MDS recall score mean, 2.36, $\pm$ 1.27), functionally impaired as indicated by their MDS bed mobility score mean, 1.93, $\pm$ 1.47, and at risk for PU development as indicated by their Braden PU Risk Score mean 16.67, $\pm$ 3.59. As shown in Table 1, there were no differences in demographic, medical and functional information, or PU risk between participants with dark skin tones (n=9 African Americans; n=2 Hispanic) and those with light skin tones (n=53 Caucasian, n=2 Asian Americans). Of those participants with light skin tones, 13 participants developed 21 incident stage II+ PU over the 20 weeks, for an incidence rate of 24% in this sample of at risk subjects. Among persons with dark skin tones, three developed nine incident stage II+ PU for an incidence rate of 27% over 20

weeks. Sixteen of the total incident PU developed over the sacral site. No differences existed between those with dark and light skin tones in the development or severity of incident PU.

There were significant differences in SEM values according to level of skin damage detected by visual assessment. For example, SEM values were higher when more severe skin damage was observed. For all pelvic sites combined, mean SEM was 83.45 ± 100.62 (SD) for normal skin, 150.42 ± 128.21 for erythema/stage I, and 564.42 ± 368.53 for stage II+ PU. Pairwise post-hoc differences were significant between all skin condition categories (normal - erythema/stage I PU; normal - stage II+ PU; and erythema/stage I PU - stage II+ PU; all $p < .001$). This relationship persisted across all anatomic sites, and in both observations with and without incontinence present (data not shown). The SEM values for persons with dark skin tones were lower for sacral sites and for normal skin assessment conditions compared to persons with light skin tones (Table 2) however, the SEM pattern of scores was similar in both groups.

To determine if SEM detected skin damage one week later, proportional odds models were evaluated using sacral and buttocks SEM data collected at time points when there was no visual evidence of Stage II+ PU skin damage, controlling for clustering of data within subjects. Among persons with dark skin tones, SEM values detected the incidence of erythema/stage I PU damage identified one week later (Table 3; OR=1.88 per 100 DPU) adjusting for concurrent SEM. Further, SEM values also detected the incidence of Stage II+ PU one week later (Table 3; OR=1.02 per 1 DPU, 95% CI 1.007 - 1.024). This relationship appears stronger in persons with dark skin tones compared to those with light skin tones in whom odds ratios for SEM values for detecting the incidence of stage II+ PU damage the following week while significant were lower (Table 3; OR=1.01 per 1 DPU, 95% CI 1.001 - 1.01; OR=1.15 per 100 DPU).

To determine if the three SEM threshold values detected skin damage (both erythema/stage I PU and stage II+ PU), we evaluated each of the threshold values with at risk status as a covariate in separate models for light and dark skin tones. SEM threshold of 50dpu was significant for detecting erythema/stage I PU in persons with dark skin tones (OR 5.3, CI 1.87—15.11, $P < .001$). As shown in Table 4, SEM threshold values of 50DPU and 150DPU were significant for detecting stage II+ PU in persons with dark skin tones one week later (OR 8.51, CI 1.95—3.71; and 13.06 CI 2.60—65.56, respectively, both $P < .001$). SEM threshold values above 300DPU were significant for detecting stage II+ PU in persons with light skin tones (Table 4).

DISCUSSION

In this sample of NH residents, we found that higher SEM was associated with both concurrent and incident (one week later) skin damage in persons with dark skin tones. When more skin damage was observed, SEM values were higher at all anatomic locations. Persons with dark skin tones had lower SEM values than those with light skin tones, but the pattern of relationship between SEM and visual assessment was the same. SEM values were higher when there was no visible PU damage on the sacrum, right or left buttocks at the time but stage I PU or stage II+ PU were visible on the sites the next week. Further, three different

threshold values of SEM were examined for usefulness in detecting skin damage in persons with dark skin tones with values of 50DPU significant for detection of erythema/stage I PU and stage II+ PU one week later and values of 150DPU significant for detection of stage II+ PU one week later in persons with dark skin tones.

Our previous work has demonstrated a relationship between SEM and visual skin assessment in two NH samples^{23,24}. In both of these prior studies we found that SEM was associated with level of visual skin damage at five anatomic sites on the trunk with mean SEM values ranging from 97dpu to 104dpu for normal skin, 185dpu to 264dpu for erythema and/or stage I PU, and 569dpu to 727dpu for stage II+ PU^{23,24}. The past studies with NH residents of all skin tones showed that SEM identified 26% of the erythema and/or stage I PU visible one week later at the sacrum and buttocks locations²³ and 32% of the erythema and/or stage I PU visible at the sacrum the following week²⁴. In this study of persons with dark skin tones we show that SEM identified 88% of the erythema/stage I PU that were visible at the sacrum and buttocks the following week. Our evaluations of the three SEM threshold values in this study of persons with dark skin tones found that lower SEM threshold values may be valuable in detecting both erythema/stage I PU and stage II+ PU in persons with dark skin tones. Persons with dark skin tones with SEM values at or above 50dpu were 5 times as likely to present with visible erythema/stage I PU damage the following week and over 8 times as likely to present with stage II+ PU the following week as compared to persons with dark skin tones with SEM values below 50dpu. The development of clinically meaningful values is still in development, but these preliminary data indicate that SEM holds promise for persons with dark skin tones, a population for whom the standard, visual skin assessment is inadequate.

Our findings suggest that SEM identifies local tissue edema related to inflammatory changes that occur from three to ten days prior to visible skin breakdown^{12, 20,21,45}. One way to examine the underlying processes being captured by SEM would be to compare surface electrical capacitance measures obtained at different depths and to compare surface electrical capacitance measures with ultrasound images of the same site.

Our findings are appealing because of the issues surrounding reliable detection of erythema/stage I PU in persons with dark skin tones and the ongoing global debate about the descriptors, inclusion, and assessment of erythema and stage I PU⁴⁶⁻⁴⁹. However, systematic evaluation of SEM within a larger sample of persons with dark skin tones who are at risk for PU is still needed. Our sample of persons with dark skin tones is small and based on ethnicity and race, a reasonable but imprecise proxy. Evaluation of SEM across a wide range of skin tones would contribute substantially to decreasing disparities in PU prevention delivery. Research on prevention of PU, especially in those persons with dark skin tones, can greatly benefit from objective, non-visual measurement of skin damage. SEM assessment is one promising tool for such objective measurement. If such measurement tools can be found, systematic evaluation of prevention strategies can move forward and be compared, ultimately leading to the improved care of all at risk patients.

Conclusions

The current standard for detecting early PU damage is routine visual skin assessment. Unfortunately, visual assessment is fraught with difficulties for persons with dark skin tones. Difficulties with accurate visual assessment may be responsible for existing disparities in prevalence of higher stage PU among persons with dark skin tones when lack of early recognition results in failure to institute preventive interventions. Our initial findings suggest that a handheld dermal phase meter that measures SEM may provide a more accurate method of detecting early PU damage than visual assessment. If these findings are supported in larger studies, SEM may emerge as a useful clinical technique for detecting early damage in persons with darker skin tones.

Acknowledgments

This research was supported by grants from National Institute on Aging: UCLA Claude D. Pepper Older Americans Independence Center Pilot Grant and Sigma Theta Tau Nursing Honor Society, UCLA Chapter.

We thank NOVA Technology Corporation, Portsmouth, NH for providing dermal phase meters.

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Figure 1.

Flow of participants through the study. Of the 66 consented subjects there were no differences between decline rates between persons with dark and light skin tones (62% versus 64%, respectively). 56 subjects completed the 20 weeks of the study, 6 died, 2 were discharged, and 2 withdrew from the study.

- 1 = Sacral coccyxgeal
- 2 = Right buttock
- 3 = Left buttock
- 4 = Right Ischial tuberosity
- 5 = Left Ischial tuberosity
- 6 = Right trochanter
- 7 = Left trochanter

Figure 2.

Diagram showing the seven anatomic sites included in the visual and SEM assessments.

Table 1

Characteristics of study participants

Characteristic	Residents with Light Skin Tones (n=55)	Residents with Dark Skin Tones (n=11)
	Mean (±SD) or % (n)	Mean (±SD) or % (n)
Gender (% Female)	81.8 (45)	90.9 (10)
Age (yrs)	83.9 (10.9)	87.3 (5.2)
Length of stay (months)	32.2(35.0)	21.6(22.0)
MDS Bed Mobility Score (0-4) *	2.0 (1.5)	1.6 (1.4)
MDS Transfer self performance (0-4) *	2.4(1.4)	2.4(1.3)
MDS Recall Score (0-4) ‡	2.4(1.3)	2.0(1.5)
Braden PU Scale risk score (0-23) †	16.3 (3.6)	17.5 (3.5)
MDS PU Resident Assessment Protocol initiated -baseline (%)	71.2 (37)	90.9 (10)

SD=Standard deviation; MDS=Minimum Data Set; PU=Pressure Ulcer

* MDS Bed Mobility and MDS Transfer score from 0—4, with 0=independent and 4=total dependence

‡ MDS Recall score from 0—4, with 0=no recall to 4=answers 4 memory questions correctly

† Braden Pressure Sore risk scores from 0-23, with 19-23 = no risk, < 18 = at risk

Table 2

Mean sub-epidermal moisture for sacral and buttocks observations by visual skin assessment and skin tone.

Characteristic	Normal Skin Mean (SD) N observations			Erythema/Stage I PU Mean (SD) N observations			Stage II+ PU Mean (SD) N observations		
	Sacral	R Buttocks	L Buttocks	Sacral	R Buttocks	L Buttocks	Sacral	R Buttocks	L Buttocks
Residents with light skin tones	118.74 (118.53) 589	89.15 (101.36) 733	84.85 (99.36) 734	201.88 (161.23) 191	153.90 (129.86) 77	138.57 (121.38) 67	617.30 (327.57) 43	521.27 (376.35) 15	551.48 (310.17) 25
Residents with dark skin tones	74.35 (81.45) 147	70.77 (83.83) 171	70.45 (80.28) 170	143.48 (102.26) 21	127.83 (92.89) 6	163 (134.37) 8	311 (309.82) 12	684.75 (407.14) 4	-- *
P Value [†]	<.001	.028	.079	.106	.632	.596	.005	.457	

* insufficient number of observations for comparison,

[†] t-test between light and dark skin tone SEM values

Table 3

Odds ratio of skin damage in persons with light and dark skin tones one week later using SEM

Predictor	Light Skin Tones		Dark Skin Tones	
	Erythema – Stage I PU	Stage II+ PU	Erythema – Stage I PU	Stage II+ PU
SEM 1 week prior	1.00 (1.000—1.003)	1.01 (1.001—1.01)	1.01 (1.001—1.012)	1.02 (1.007—1.024)
Concurrent SEM	1.00 (1.002—1.006)	1.01 (1.004—1.011)	1.01 (1.004—1.012)	1.01 (.992—1.033)
Site (ref=Sacral)				
Left Buttock	.31 (.1556--.600)	.52 (.097—2.752)	.19 (.034—1.015)	.67 (.148—3.047)
Right Buttock	.29 (.141--.592)	.92 (.102—8.294)	.23 (.035—1.510)	.02 (.001—2.247)
Risk Status (Braden 18)	1.87 (.657—5.301)		4.23 (.607—29.529)	1.00 (.169—5.960)
OR: 100 unit change in SEM measure	1.14		1.88	

SEM=Sub-epidermal moisture, OR=Odds Ratio, CI=Confidence Intervals, Bold indicates P 0.005.

* Proportional odds models using generalized logistic regression. Unless otherwise noted, OR reflect a one unit change in the SEM measure. Excludes observations with incontinence present.

Table 4

Predicted odds ratio (95% CI) of pressure ulcer damage one week later using SEM threshold values

Predictor	Light Skin Tones		Dark Skin
	Erythema/Stage I	Stage II or Greater	Erythema/Stage I
SEM (50 DPU)	1.27 (.69—2.34)	7.17 (0.79—64.92)	5.31 (1.87—15.11)
Left Buttock (Ref=Sacral)	.25 (.13--.45)	0.29 (0.05—1.87)	.19 (.04--.90)
Right Buttock	.23 (.11--.45)	0.38 (0.05—2.60)	.25 (.04—1.68)
Risk Status (Braden 18)	2.14 (.73—6.30)	5.98 (0.48—79.82)	6.44 (.90—45.88)
SEM (150 DPU)	1.52 (.88—2.60)	3.47 (0.88—13.72)	2.72 (.62—11.91)
Left Buttock (Ref=Sacral)	.27 (.14--.50)	0.35 (0.06—2.15)	.19 (.04--.87)
Right Buttock	.24 (.12--.47)	0.42 (0.05—3.73)	.26 (.04—1.82)
Right Status (Braden 18)	2.12 (.74—6.08)	5.85 (0.42—81.34)	5.69 (.59—55.17)
SEM (300 DPU)	2.11 (1.06—4.20)	4.30 (1.42—13.0)	1.53 (.13—18.18)
Left Buttock (Ref=Sacral)	.26 (.13--.50)	0.28 (0.05—1.48)	.18 (.04--.72)
Right Buttock	.24 (.12--.48)	0.35 (0.05—2.22)	.24 (.04—1.46)
Risk Status (Braden 18)	2.10 (.72—6.09)	5.99 (0.37—97.67)	6.77 (.68—67.41)

SEM=Sub-epidermal moisture, OR=Odds Ratio, CI=Confidence Intervals, Bold indicates P < 0.005.

* Proportional odds models using generalized logistic regression. OR reflect a one unit change in the SEM measure. Excludes observations with incontinence present.