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# Pressure-Redistributing Support Surface Use and Pressure Ulcer Incidence in Elderly Hip Fracture Patients

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## Abstract

**OBJECTIVES—**To evaluate the association between pressure-redistributing support surface (PRSS) use and incident pressure ulcers in older adults with hip fracture.

**DESIGN—**Secondary analysis of data from prospective cohort with assessments performed as soon as possible after hospital admission and on alternating days for 21 days.

**SETTING—**Nine hospitals in the Baltimore Hip Studies network and 105 postacute facilities to which participants were discharged.

**PARTICIPANTS—**Six hundred fifty-eight people aged 65 and older who underwent surgery for hip fracture.

**MEASUREMENTS—**Full-body examination for pressure ulcers; bedbound status; and PRSS use, recorded as none, powered (alternating pressure mattresses, low-air-loss mattresses, and alternating pressure overlays), or nonpowered (high-density foam, static air, or gel-filled mattresses or pressure-redistributing overlays except for alternating pressure overlays).

**RESULTS—**Incident pressure ulcers (IPUs), Stage 2 or higher, were observed at 4.2% (195/4,638) of visits after no PRSS use, 4.5% (28/623) of visits after powered PRSS use, and 3.6% (54/1,496) of visits after nonpowered PRSS use. The rate of IPU per person-day of follow-up did not differ significantly between participants using powered PRSSs and those not using PRSSs. The rate also did not differ significantly between participants using nonpowered PRSSs and those



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**Author Contributions:** Dr. Rich had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. Rich: study concept and design, data collection, data management and analysis, data interpretation, preparation of manuscript. Shardell and Hawkes: oversight of data collection, data management and analysis, data interpretation, preparation of manuscript. Margolis: study design, oversight of data collection, data interpretation, preparation of manuscript. Amr and Miller: study design, data interpretation, preparation of manuscript. Baumgarten: study leadership, study concept, acquisition of funding, study design, oversight of data collection, data management and analysis, data interpretation, preparation of manuscript.

not using PRSSs, except in the subset of bedbound participants (incidence rate ratio = 0.3, 95% confidence interval = 0.1–0.7).

**CONCLUSION—**PRSS use was not associated with a lower IPU rate. Clinical guidelines may need revision for the limited effect of PRSS use, and it may be appropriate to target PRSS use to bedbound patients at risk of pressure ulcers.

## Keywords

pressure ulcers; prevention; mattresses; overlays; guidelines

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The Centers for Medicare and Medicaid Services (CMS) defines pressure ulcers as "any lesion caused by unrelieved pressure that results in damage to the underlying tissues."[1] Pressure ulcers are a significant health problem in terms of numbers of patients,[2,3] cost,[4,5] and human suffering to patients and families.[6–8] Attention has focused on the prevention of pressure ulcers as a result of CMS's decision to use pressure ulcer incidence as a quality indicator in nursing homes[9] and the CMS policy not to reimburse hospitals for the treatment of hospital-acquired pressure ulcers.[10]

Pressure-redistributing support surfaces (mattresses and overlays; PRSSs) are designed to prevent pressure ulcers by deforming to distribute the pressure due to a person's weight over a larger area.[11] Whereas standard mattresses are filled with springs and low-density foam, PRSSs are filled with alternative materials such as gel, fiber, and air.[12] Several national clinical guidelines for pressure ulcer prevention recommend that all people at risk for or with pressure ulcers should use PRSSs,[13–17] but the evidence supporting the effectiveness of PRSSs in preventing pressure ulcers is limited. Meta-analyses of randomized controlled trials of PRSS effectiveness have emphasized the limitations of existing trials and the need for additional, adequately powered studies of PRSSs.[18–20] A major difficulty in evaluating results of most existing trials and observational studies is their failure to categorize PRSSs consistently. Thus, despite a large number of studies examining the association between PRSS use and incident pressure ulcers, there remains a substantial gap in knowledge.

To improve standardization of comparisons, the National Pressure Ulcer Advisory Panel has recently identified categories for PRSSs based on their need for external sources of energy.[21] According to this categorization, powered support surfaces include alternating pressure, low-air-loss, and air fluidized mattresses and alternating pressure overlays, whereas nonpowered support surfaces include static air, gel-filled, fiber-filled, water-filled, and high-density foam mattresses and pressure-redistributing overlays other than alternating pressure overlays. This categorization is particularly useful given the considerable variation in cost and burden associated with different PRSSs. Powered PRSSs generally cost hundreds or thousands of dollars to rent or purchase, whereas nonpowered PRSSs generally cost only a few dollars. The burden to patients, including discomfort, noise, and sleep disturbance, and the burden to healthcare providers due to mechanical unreliability is also generally greater for use of powered support surfaces than nonpowered support surfaces.[22–24] Given this differential in burden, it is of particular interest to determine whether powered PRSSs are more effective at preventing pressure ulcers than nonpowered PRSSs and to determine whether using any PRSS is more effective than not using a PRSS. This study used data from a large cohort of older adults with hip fracture, a population with a high incidence of pressure ulcers,[2,25–28] to compare the rates of incident pressure ulcers stage 2 or higher (IPUs) associated with use of powered PRSSs, nonpowered PRSSs, and no PRSS. In particular, this study examined the association between the category of support surface in use at each study visit and the occurrence of new pressure ulcers at the following study visit approximately 2 days later. A new pressure ulcer was defined as a stage 2 or higher pressure ulcer that was not present or was stage 1 at the previous visit.

# METHODS

## Participants

This study was a secondary analysis of data collected for a prospective cohort study of older adults with hip fracture who were admitted between 2004 and 2007 to one of nine hospitals that participate in the Baltimore Hip Studies network. The methods for this study have previously been described in detail.[29] Briefly, eligible participants were aged 65 and older, underwent surgery for hip fracture (*International Classification of Diseases, Ninth Revision*, code 820), and provided consent before discharge from the admission hospital. Of the 1,167 individuals screened, 1,055 (90%) were eligible for the study. Sixty-two percent of eligible individuals were enrolled (N = 658).

Data about pressure ulcer status and risk and use of pressure ulcer preventive devices including PRSSs were collected for each participant at study visits that occurred at baseline (as soon as possible after hospital admission) and subsequently on alternating days for 21 days. Specially trained research nurses performed these study assessments where the participant resided at the time of the visit; thus, data were collected in the nine hospitals of admission and in the 105 postacute facilities to which patients from these hospitals were discharged.

Data about repositioning frequency were collected for the first 5 days of each participant's initial hospitalization, so participants who did not have any study visits during the first 5 days of hospitalization (n = 103) were excluded from the analysis (described later) that adjusted for repositioning. Because national clinical guidelines recommend repositioning only for bedbound patients,[30] participants were also excluded if they were not bedbound according to the activity item of the Braden scale[31] during at least one study visit in the first 5 days of hospitalization (n = 286), leaving a sample of 269 participants with 354 visits for the analysis that adjusted for repositioning.

Permission to contact patients for screening and recruitment was obtained from attending physicians. The participant's written consent was obtained for those with a Mini-Mental State Examination (MMSE)[32] score of 20 or greater; otherwise the participant's verbal assent and a proxy's written consent were obtained. Proxy consent was also obtained for participants who were unconscious or noncommunicative. The institutional review boards of each of the participating hospitals and of the University of Maryland, Baltimore, approved the parent study; the latter also approved the current analyses.

## Measures

**Pressure Ulcer Status—**Research nurses collected data about pressure ulcer presence and stage at each study visit using a whole-body skin examination conducted according to standard wound assessment practice,[33] including definitions for staging that were standard at the time of the study.[34] Stage 1 pressure ulcers were characterized by alteration of intact skin with persistent redness; Stage 2 by partial-thickness dermal loss or serum-filled blister; Stage 3 by full-thickness dermal loss; and Stage 4 by full-thickness tissue loss with exposed bone, tendon, or muscle. The outcome was defined as an IPU. Pressure ulcers that were classified as Stage 1 at a given visit and later developed into Stage 2 or higher were designated as outcomes at the visit at which they first were classified at the higher stage, because the clinical significance of Stage 1 pressure ulcers is unclear.[25,33,35] Results of all analyses were similar when Stage 1 pressure ulcers were included in the definition of the outcome (data not shown). Participants continued to be followed for additional pressure ulcers even after onset of an IPU.

**Support Surface Group—**At each study visit, research nurses recorded the type of PRSS, if any, observed on the participant's bed. Each type of PRSS was then categorized as powered or nonpowered. An air-fluidized PRSS was observed at only one study visit, so this visit was dropped from the analysis. Visits with both an overlay and pressure-redistributing mattress (79 person-visits) were classified according to the type of overlay; visits with other combinations of multiple PRSSs (9 person-visits) were dropped from the analysis. Visits with both powered and nonpowered PRSSs (9 person-visits) were classified as having powered support surfaces in use. If the research nurse was unable to identify the type of support surface (358 person-visits), the PRSS was recorded as "other" or "type unknown", and information about the support surface's appearance was recorded in handwritten notes. The first author reviewed this information, and whenever possible, support surfaces were categorized as powered or nonpowered (11 person-visits with no PRSS, 26 with powered PRSS, and 239 with nonpowered PRSS). Results of all analyses were similar when these visits were excluded (data not shown). Support surfaces for which information was incomplete or unclear were classified as missing (82 person-visits). For visits at which only the type of bed was noted, the category of support surface was coded based on the mattresses intended for use with that type of bed.

**Covariates—**Braden Scale score, acute mental status, incontinence status, use of pressure ulcer preventive devices other than PRSSs, and care setting were documented at each study visit and were included as time-dependent covariates in the analysis. The research nurse recorded the participant's Braden Scale score[31] based on observation and discussion with clinical staff. The Braden Scale is used to classify an individual's risk of pressure ulcers by assessing sensory perception, moisture, activity, mobility, nutrition, and friction or shear. Scores on the Braden Scale range from 6 to 23, with lower scores indicating higher risk. Acute mental status was measured by counting the number of orientations to person, place, and time. Incontinence status was based primarily on the research nurse's observation of skin moisture or soiling with stool at the time of the study visit and secondarily on the research nurse's rating of participant incontinence status on the Norton Scale[36] (another tool for classifying an individual's pressure ulcer risk) based on observation and discussion with clinical staff. Cushions to prevent pressure ulcers were considered to be in use if they were observed on the participant's chair or wheelchair. Heel protectors, elbow protectors, and positioning pillows and wedges were considered to be in use only if they were observed to be on or under the participant at the time of assessment. Finally, care setting was based on the level and location of care as follows: acute hospital (acute care in an acute hospital), rehabilitation (acute or skilled rehabilitation in an acute hospital or rehabilitation facility), nursing home, home, and readmission to acute hospital (return to the acute hospital setting after discharge from the initial acute setting).

Research nurses used the Subjective Global Assessment of Nutritional Status[37] to classify risk of nutrition-associated complications at the baseline study visit. Arterial in-sufficiency at the baseline study visit was defined as absence of pedal pulses or an ankle–brachial index less than 1. Weight and height, obtained from the medical chart (or from participant or proxy interview when missing from the chart), were used to calculate the participant's body mass index (weight in kg/(height in m)$^2$), and standard categories for underweight body mass index (<18.5 kg/m$^2$), normal weight body mass index (18.5–24.9 kg/m$^2$), and overweight or obese body mass index (≥25.0 kg/m$^2$) were used in the analysis.[38] Finally, information in the medical chart was used to measure severity of illness according to the Rand Sickness at Admission Scale (hip fracture version)[39] and comorbidity according to the Charlson Comorbidity Index.[40]

### Analysis

For each PRSS group and for each type of support surface, pressure ulcer incidence was determined as the proportion of study visits, of visits following PRSS use, at which participants had an IPU; the *P*-value for this association was obtained using the chi-square test. Generalized estimating equation (GEE) models with a log link, a Poisson working model, and an exchangeable working correlation matrix were fit to determine the association between type of PRSS in use at a given study visit and development of an IPU at the following study visit, accounting for within-participant correlation. Incidence rate ratios (IRRs) and 95% confidence intervals (CIs) were estimated, both unadjusted and adjusted for covariates including the presence of a pressure ulcer before or at the study visit at which the support surface use was observed. Weighted estimating equation (WEE) analysis was used in the GEE models to account for the effects of missing data,[41,42] with marginal structural modeling (MSM) used to ensure appropriate treatment of time-dependent covariates.[43] MSM was implemented by weighting GEE models by the inverse propensity of observed PRSS status. A covariate-adjusted MSM was used to explore effect modification by the participant's activity status (bedbound vs nonbedbound) according to the activity item in the Braden Scale, and subsequently covariate-adjusted models were used to analyze data from bedbound and nonbedbound participants separately. Results were similar when analyses were repeated with the outcome de-fined two visits after the visit at which the use of the support surface was observed (data not shown).

To adjust for the use of frequent repositioning in the association between PRSS use and incident rate of pressure ulcers, an analysis was performed using data from the subset of 354 visits at which participants were bedbound during the first 5 days of initial hospitalization (the period for which information about repositioning was collected). Estimates of IRRs and 95% CIs were computed using methods similar to those described above, except that an additional weight was used to account for the effect of missing repositioning data. All analyses were performed using SAS version 9.1 (SAS Institute, Inc., Cary, NC), and statistical significance was defined as $P<.05$.

## RESULTS

### Study Sample

Baseline characteristics of study participants are shown in Tables 1 and 2. Of the 658 study participants, 202 developed at least one IPU during their participation in the study. Almost all of the participants in the study population were white, and most had resided in the community before their hospital admission for hip fracture. Fourteen percent of the participants had a pressure ulcer at their baseline study visit. Most of the participants in the study population were categorized as being at risk for pressure ulcers (69% with a Braden score ≤16). Participants who developed an IPU had poorer nutritional status ($P = .002$) and poorer cognitive status ($P<.001$) at baseline than participants who did not. They were also more likely to be bedbound or chairbound ($P = .007$), to be at risk for pressure ulcers according to the Braden Scale ($P = .02$), and to have a pressure ulcer at the baseline visit ($P<.001$). Participants with powered or nonpowered PRSSs in use at the baseline visit had better nutritional status ($P = .01$), were less likely to be bedbound ($P<.001$), and were less likely to be at risk for pressure ulcers ($P = .02$) than participants with no PRSS in use. The mean interval between hospital admission and the baseline study visit was 2.9 ± 2.0 days.

Nearly 85% of the IPUs were Stage 2, 1.1% were Stage 3, and 14.4% were unstageable because of eschar, necrotic tissue, or dressing. Fifty percent of these IPUs were located on the sacrum or posterior iliac crest, 18.4% were located on the heels, and 11.6% were located on the ischium.

### Use of PRSSs and Incidence of Pressure Ulcers

An IPU was observed at 4.2% (195/4,632) of study visits following a visit with no PRSS in use, 4.5% (28/623) of visits following use of powered PRSS, and 3.6% (54/1,496) of visits following use of nonpowered PRSS. The association between PRSS group and rate of IPU was not significant ($P = .52$). The association between type of support surface and rate of IPU was also not significant ($P = .47$; Figure 1). The adjusted rate of IPU per person-day was somewhat lower in those using a powered PRSS (IRR = 0.79, 95% CI = 0.37–1.70) and in those using a nonpowered PRSS (IRR = 0.84, 95% CI = 0.55–1.30) at a given visit than in those not using a PRSS (Table 3), although these results were not statistically significant.

The effect of using a nonpowered PRSS on the incidence rate of pressure ulcers varied according to the participant's activity status, although the interaction term was not significant ($P = .13$). At visits following the use of non-powered PRSS, the rate of IPU was significantly lower (IRR = 0.28, 95% CI = 0.12–0.67) for bedbound participants (859 person-visits) but not (IRR = 0.98, 95% CI = 0.61–1.58) for nonbedbound participants (5,975 person-visits). The effect of using powered PRSSs did not vary according to the participant's activity status (Table 3).

To examine the effect of frequent repositioning, the association between PRSS use and rate of IPU was estimated in bedbound participants with study visits during the first 5 days of initial hospitalization, the period for which repositioning data were collected. In this subset, results were similar for fully adjusted models and models adjusted for all covariates except frequent repositioning.

## DISCUSSION

This study found little evidence of an association between the use of PRSSs and a lower rate of IPUs in a large cohort of older adults with hip fracture, a population at particularly high risk of pressure ulcer development because of the common experience of long periods of immobility.[29,34,44–46] In the full cohort, no evidence was found of an association between use of powered or nonpowered PRSSs at a given study visit and rate of IPU at the following visit, compared to no PRSS use, although for bedbound participants in the acute setting, the use of nonpowered PRSSs was significantly associated with a lower rate of IPUs. Frequent manual repositioning or pressure ulcer risk factors did not appear to explain this association, because results of analyses adjusting for these covariates did not differ from the unadjusted results. If confirmed in future studies, these results suggest that the effect of PRSSs may be limited to patients who are at particularly high risk because of immobility and that powered PRSSs are not effective at pressure ulcer prevention.

Although prior studies have found that high-density foam mattresses are effective in preventing pressure ulcers,[18,20,47] this finding was not replicated in the current study. The reason for this disagreement is unclear, because there was not a good measure for use of high-density foam mattresses in the current study, which limits interpretation of this finding or there may have been a misclassification of mattress type, because the definition of foam mattresses provided to the research nurses was ambiguous.

Findings of this study in a high-risk population suggest that there is little or no preventive effect of PRSS use in nonbedbound patients at risk of pressure ulcers, indicating that the resources used to provide PRSSs to these individuals may be better allocated to other methods of pressure ulcer prevention. Although guidelines for pressure ulcer prevention recommend the use of PRSSs for all at-risk patients,[13–17] there is little evidence that all patients would benefit equally. The heterogeneity of effects seen in this study suggests that future studies should examine the effect of PRSSs in various subgroups of patients,

particularly those at risk of pressure ulcers because of immobility and those at risk because of other factors, to inform the guidelines about the appropriate use of these devices.

This study found no significant differences in pressure ulcer prevention according to whether powered or non-powered PRSSs were in use. This finding is particularly important given the considerable variation in burden associated with different PRSSs. As previously described, powered PRSSs generally cost much more and have higher burdens for patients and healthcare providers than non-powered PRSSs. Given these considerations, it is important to determine the clinical outcomes of using different PRSS types in order to choose PRSSs that will maximize the cost-effectiveness of pressure ulcer prevention. Current guidelines are unable to provide much guidance on this issue because of the heterogeneity of previous studies. Thus, the finding of no significant difference in pressure ulcer incidence rate between powered and nonpowered PRSSs suggests that the additional expense and burden of powered PRSSs may be unwarranted for pressure ulcer prevention.

These findings may have additional implications for use by Medicare beneficiaries, because the categorization of PRSS into powered and nonpowered is closely related to the policy for Medicare Part B reimbursement. Nonpowered PRSSs are categorized as Group 1 support surfaces, intended primarily for prevention of pressure ulcers, whereas powered PRSSs are categorized as Group 2 and 3 support surfaces, intended for both treatment and prevention of pressure ulcers. Thus, powered PRSSs may be better reserved for treatment of pressure ulcers in Medicare beneficiaries rather than for use in prevention.

The observational design of this study limits the ability to assess the effectiveness of PRSSs, in part because indications for the use of PRSSs (e.g., pressure ulcer risk factors) may be predictive of pressure ulcer incidence, resulting in confounding by indication. To address this, a number of clinically important pressure ulcer risk factors were adjusted for, and WEE was used to mitigate the problem of selection bias due to missing data. Nevertheless, as in any observational study, residual bias due to unmeasured confounders is a possibility. Also, potential misclassification of support surface use, which is likely to be nondifferential, may have been present and would tend to bias the association between PRSS use and incident rate of pressure ulcers toward the null. A possible source of misclassification is due to the inclusion of data from the 276 visits (4% of the study sample) at which nurses were unable to identify the PRSS in use, although results were similar in secondary analyses in which these visits were excluded (data not shown). Misclassification of support surface use may also have occurred if the participant was changed to a different type of support surface between the study visit at which it was observed and the development of an IPU within the following 2 days. Finally, although this study was larger than many previous studies of PRSS effectiveness, the sample size was limited. The number of participants observed on each type of PRSS was small, limiting the ability to estimate the association between specific types of PRSSs and the incidence rate of pressure ulcers. Also, only a small number of bedbound participants were observed, so this study was limited in its ability to estimate the association between PRSS use and the incidence rate of pressure ulcers in these participants.

In summary, the rate of incident pressure ulcers in older adults with hip fracture was not lower for participants using powered or nonpowered PRSSs than for those not using a PRSS, although in bedbound participants, the use of non-powered, but not powered, PRSSs was associated with a significantly lower rate of IPUs than for those not using PRSS. Thus, future studies should account for the bedbound status of study participants; clinical guidelines may need to be revised to account for the more-limited effect of PRSS use. The fact that powered PRSSs were not found to be effective at preventing pressure ulcers

suggests that the higher expense and patient and healthcare provider burden associated with their use may not be warranted for pressure ulcer prevention.

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Data from this study have been the subject of other analyses, the results of which have been previously published. The publications are as follows: (a) Baumgarten, M., Margolis, D.J., Orwig, D.L., Shardell, M.D., Hawkes, W.G., Langenberg, P., Palmer, M.H., Jones, P.S., McArdle, P.F., Sterling, R., Kinosian, B.P., Rich, S.E., Sowinski, J., and Magaziner, J. 2009. “Pressure Ulcers in Elderly Patients with Hip Fracture Across the Continuum of Care.” Journal of the American Geriatrics Society. 57(5):863–70. (b) Baumgarten, M., Margolis, D., Orwig, D., Hawkes, W., Rich, S., Langenberg, P., Shardell, M., Palmer, M.H., McArdle, P., Sterling, R., Jones, P.S., and Magaziner, J. 2010. “Use of Pressure-Redistributing Support Surfaces Among Elderly Hip Fracture Patients Across the Continuum of Care: Adherence to Pressure Ulcer Prevention Guidelines.” Gerontologist. 50(2):253–62. Neither of these previously published articles has examined the hypotheses addressed in this article.

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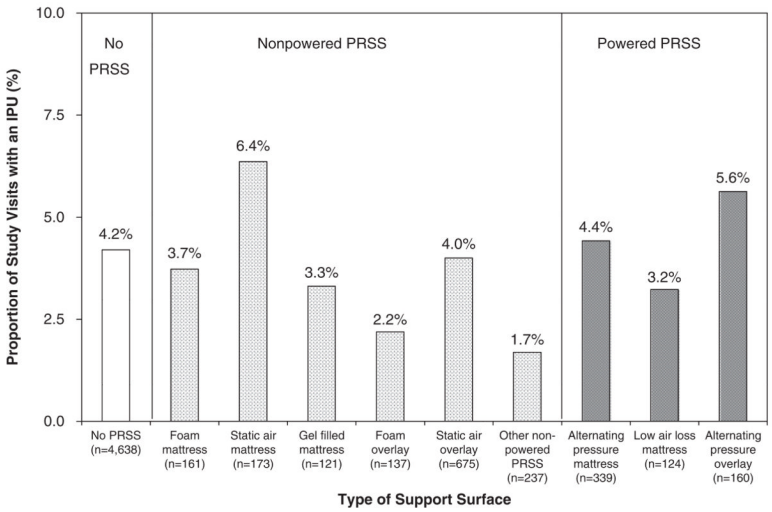


**Figure 1.**

Proportion of study visits with an incident pressure ulcer Stage 2 or higher (IPU) at the following visit, according to type of support surface in use at a given visit. $P = .47$ for the association between type of support surface in use at a given visit and IPU at the following visit as derived from chi-square, indicating 10 significant difference. PRSS = pressure-redistributing support surface; n = number of person-visits at which each type of support surface was used.

## Table 1

Baseline Characteristics of Study Participants According to Development of an Incident Pressure Ulcer Stage 2 or Higher (IPU) During Follow-Up

| Characteristic | Participants with No IPUs (n = 456) | Participants with ≥1 IPUs (n = 202) | All Participants (N = 658) | *P*-Value* |
|---|---|---|---|---|
| Age ≥85, n (%) | 211 (46.3) | 94 (46.5) | 305 (46.4) | .95 |
| Male, n (%) | 107 (23.5) | 45 (22.3) | 152 (23.1) | .74 |
| White, n (%) | 446 (97.8) | 199 (98.5) | 645 (98.0) | .55 |
| Community resident before admission, n (%) | 319 (70.0) | 131 (64.9) | 450 (68.4) | .19 |
| Medicaid beneficiary, n (%) | 22 (4.8) | 18 (8.9) | 40 (6.1) | .04 |
| Trochanteric fracture, n (%) | 204 (44.7) | 89 (44.1) | 293 (44.5) | .87 |
| Partial or total arthroplasty, n (%) | 157 (34.4) | 79 (39.1) | 236 (35.9) | .25 |
| Diabetes mellitus, n (%) | 82 (18.0) | 43 (21.3) | 125 (19.0) | .32 |
| Serum albumin<3.0 g/dL, n (%) | 139 (30.5) | 67 (33.2) | 206 (31.3) | .49 |
| Not fully oriented to person, place, and time, n (%) | 160 (35.6) | 81 (42.4) | 241 (37.7) | .11 |
| High risk of nutrition-related complications, n (%) | 30 (6.7) | 28 (14.1) | 58 (9.0) | .002 |
| Incontinence status, n (%) | | | | .26 |
| None | 326 (71.7) | 132 (66.0) | 458 (69.9) | |
| Urinary only | 81 (17.8) | 39 (19.5) | 120 (18.3) | |
| Fecal with or without urinary | 48 (10.6) | 29 (14.5) | 77 (11.8) | |
| Activity level, n (%) | | | | .007 |
| Walks occasionally | 74 (16.3) | 24 (11.9) | 98 (15.0) | |
| Chairbound | 196 (43.2) | 69 (34.3) | 265 (40.5) | |
| Bedbound | 184 (40.5) | 108 (53.7) | 292 (44.6) | |
| Arterial insufficiency, n (%) | 171 (37.5) | 83 (41.1) | 254 (38.6) | .38 |
| Braden Scale score ≤16, n (%) | 295 (65.9) | 149 (75.3) | 444 (68.7) | .02 |
| Pressure ulcers at baseline visit, n (%) | 40 (9.8) | 41 (22.0) | 81 (13.6) | <.001 |
| Age, mean ± SD | 83.1 ± 6.8 | 83.3 ± 6.3 | 83.2 ± 6.6 | .84 |
| Severity of illness, mean ± SD† | 12.0 ± 5.8 | 12.9 ± 6.4 | 12.3 ± 6.0 | .06 |
| Number of comorbidities, mean ± SD‡ | 1.3 ± 1.5 | 1.5 ± 1.4 | 1.3 ± 1.5 | .16 |
| Mini-Mental State Examination score, mean ± SD | 19.3 ± 10.6 | 16.3 ± 11.2 | 18.4 ± 10.9 | <.001 |
| Body mass index, kg/m$^2$, mean ± SD | 24.0 ± 5.0 | 23.5 ± 5.1 | 23.8 ± 5.1 | .34 |
| Braden Scale score, mean ± SD | 15.6 ± 2.2 | 15.0 ± 2.3 | 15.4 ± 2.2 | .001 |
| Length of hospital stay, days, mean ± SD | 5.7 ± 3.0 | 6.4 ± 3.6 | 5.9 ± 3.2 | .02 |
| Interval between admission and baseline study visit, days, mean ± SD | 3.0 ± 2.1 | 2.7 ± 1.8 | 2.9 ± 2.0 | .05 |

Missing values: body mass index, n = 20; incontinence status, n = 3; risk of nutrition-related complications, n = 13; activity level, n = 3. All other variables had no missing values.

* *P*-values derived from chi-square, Fisher exact, and *t*-tests, as appropriate, comparing participants with and without an IPU.

† Severity of illness measured according to the Rand Sickness at Admission score.

≠ Comorbidities measured according to the Charlson Comorbidity Index.

SD = standard deviation.

**Table 2**

Baseline Characteristics of Study Participants According to Use of a Pressure-Redistributing Support Surface (PRSS) at Baseline Visit

| Characteristic | Participants Not Using a PRSS (n = 309) | Participants Using a Nonpowered PRSS (n = 250) | Participants Using a Powered PRSS (n = 92) | All Participants (N = 651) | *P*-Value* |
|---|---|---|---|---|---|
| Age ≥85, n (%) | 141 (45.6) | 119 (47.6) | 40 (43.5) | 300 (46.1) | .78 |
| Male, n (%) | 74 (24.0) | 52 (20.8) | 25 (27.2) | 151 (23.2) | .42 |
| White, n (%) | 304 (98.4) | 246 (98.4) | 88 (95.7) | 638 (98.0) | .22 |
| Community resident before admission, n (%) | 202 (65.4) | 173 (69.2) | 69 (75.0) | 444 (68.2) | .20 |
| Medicaid beneficiary, n (%) | 20 (6.5) | 15 (6.0) | 5 (5.4) | 40 (6.1) | .93 |
| Trochanteric fracture, n (%) | 136 (44.0) | 112 (44.8) | 42 (45.7) | 290 (44.6) | .96 |
| Partial or total arthroplasty, n (%) | 116 (37.5) | 92 (36.8) | 26 (28.3) | 234 (35.9) | .25 |
| Diabetes mellitus, n (%) | 63 (20.4) | 43 (17.2) | 18 (19.6) | 124 (19.1) | .63 |
| Serum albumin<3.0 g/dL, n (%) | 110 (35.6) | 55 (22.0) | 39 (42.4) | 204 (31.3) | <.001 |
| Not fully oriented to person, place, and time, n (%) | 112 (36.7) | 98 (41.5) | 29 (31.5) | 239 (37.8) | .21 |
| High risk of nutrition-related complications, n (%) | 37 (12.2) | 14 (5.8) | 5 (5.4) | 56 (8.8) | .01 |
| Incontinence, n (%) | | | | | .23 |
| None | 203 (65.9) | 182 (72.8) | 68 (75.6) | 453 (69.9) | |
| Urinary only | 66 (21.4) | 38 (15.2) | 14 (15.6) | 118 (18.2) | |
| Fecal with or without urinary | 39 (12.7) | 30 (12.0) | 8 (8.9) | 77 (11.9) | |
| Activity level, n (%) | | | | | <.001 |
| Walks occasionally | 33 (10.8) | 49 (19.6) | 33 (35.9) | 98 (15.1) | |
| Chairbound | 105 (34.3) | 114 (45.6) | 43 (46.7) | 262 (40.4) | |
| Bedbound | 168 (54.9) | 87 (34.8) | 16 (17.4) | 288 (44.4) | |
| Arterial insufficiency, n (%) | 127 (41.1) | 93 (37.2) | 32 (34.8) | 252 (38.7) | .45 |
| Braden Scale score ≤16, n (%) | 220 (73.6) | 155 (62.3) | 64 (70.3) | 439 (68.7) | .02 |
| Pressure ulcer present at baseline visit, n (%) | 43 (15.4) | 26 (11.4) | 12 (14.3) | 81 (13.7) | .42 |
| Age, mean ± SD | 82.9 ± 6.9 | 83.4 ± 6.5 | 82.9 ± 6.0 | 83.2 ± 6.6 | .67 |
| Rand Sickness at Admission score, mean ± SD | 12.8 ± 6.5 | 11.6 ± 4.5 | 12.4 ± 7.8 | 12.3 ± 6.0 | .06 |
| Charlson Comorbidity Index, mean ± SD | 1.4 ± 1.5 | 1.2 ± 1.3 | 1.6 ± 1.6 | 1.3 ± 1.5 | .08 |
| Mini-Mental State Examination score, mean ± SD | 18.5 ± 10.5 | 17.7 ± 11.6 | 19.5 ± 10.3 | 18.4 ± 10.9 | .35 |

| Characteristic | Participants Not Using a PRSS (n = 309) | Participants Using a Nonpowered PRSS (n = 250) | Participants Using a Powered PRSS (n = 92) | All Participants (N = 651) | *P*-Value* |
|---|---|---|---|---|---|
| Body mass index, kg/m$^2$, mean ± SD | 24.1 ± 5.0 | 23.6 ± 5.1 | 23.5 ± 5.1 | 23.8 ± 5.1 | .37 |
| Braden Scale score, mean ± SD | 15.1 ± 2.1 | 15.8 ± 2.4 | 15.5 ± 2.1 | 15.4 ± 2.2 | .002 |
| Length of hospital stay, days, mean ± SD | 5.8 ± 3.2 | 5.8 ± 2.8 | 6.5 ± 3.9 | 5.9 ± 3.2 | .17 |
| Interval between admission and baseline visit, days, mean ± SD | 2.5 ± 2.1 | 3.2 ± 1.8 | 3.3 ± 2.2 | 2.9 ± 2.0 | <.001 |

Seven participants were missing data about use of powered or nonpowered PRSS at baseline. Missing values for other characteristics: orientation, n = 18; body mass index, n = 20; incontinence, n = 3; nutritional risk, n = 13; activity level, n = 3; Braden Scale, n = 12. All other variables had no missing values.

**P*-values are derived from chi-square or one-way analysis of variance, as appropriate, comparing participants not using PRSSs, those using nonpowered PRSSs, and those using powered PRSSs at the baseline visit.

SD = standard deviation.

## Table 3

Rate Ratios of Developing an Incident Pressure Ulcer Stage 2 or Higher (IPU) at the Following Study Visit, According to Use of a Pressure-Redistributing Support Surface (PRSS) at a Given Visit

| PRSS Use at Given Study Visit | Visits, n | Had Developed ≥ 1 IPUs at Following Visit, % | Incident Rate Ratio (95% Confidence Interval) | |
|---|---|---|---|---|
| | | | Unadjusted | Adjusted* |
| All participants | | | | |
| No PRSS | 4,632 | 4.2 | Reference | — |
| Powered PRSS | 623 | 4.5 | 0.92 (0.56–1.50) | 0.79 (0.37–1.70) |
| Nonpowered PRSS | 1,496 | 3.6 | 0.82 (0.61–1.09) | 0.84 (0.55–1.30) |
| Bedbound participants | | | | |
| No PRSS | 472 | 11.7 | Reference | — |
| Powered PRSS | 130 | 7.7 | 0.72 (0.37–1.41) | 0.83 (0.32–2.13) |
| Nonpowered PRSS | 248 | 4.4 | 0.42 (0.21–0.81) | 0.28 (0.12–0.67) |
| Nonbedbound participants | | | | |
| No PRSS | 4,160 | 3.4 | Reference | — |
| Powered PRSS | 493 | 3.7 | 1.00 (0.57–1.74) | 0.64 (0.23–1.76) |
| Nonpowered PRSS | 1,248 | 3.5 | 0.96 (0.69–1.35) | 0.98 (0.61–1.58) |

Powered support surfaces included alternating pressure overlays and alternating pressure and low air loss mattresses. Nonpowered support surfaces included static air, gel-filled, fiber-filled, water-filled, viscose elastic, foam, and sheepskin overlays and static air, gel-filled, fiber-filled, water-filled, and high-density foam mattresses. All models accounted for within-participant correlation using generalized estimating equations by way of an exchangeable structure for the working correlation matrix.

*Accounted for missing covariates by weighted estimating equations analysis and adjusted using marginal structural modeling for activity level, acute mental status, risk of nutrition-related complications, weight status, incontinence status, arterial insufficiency at the baseline visit, use of other pressure ulcer preventive devices, severity of illness, comorbidity, age, sex, days since hospital admission, care setting, incident pressure ulcer before or at index study visit, and admission hospital.