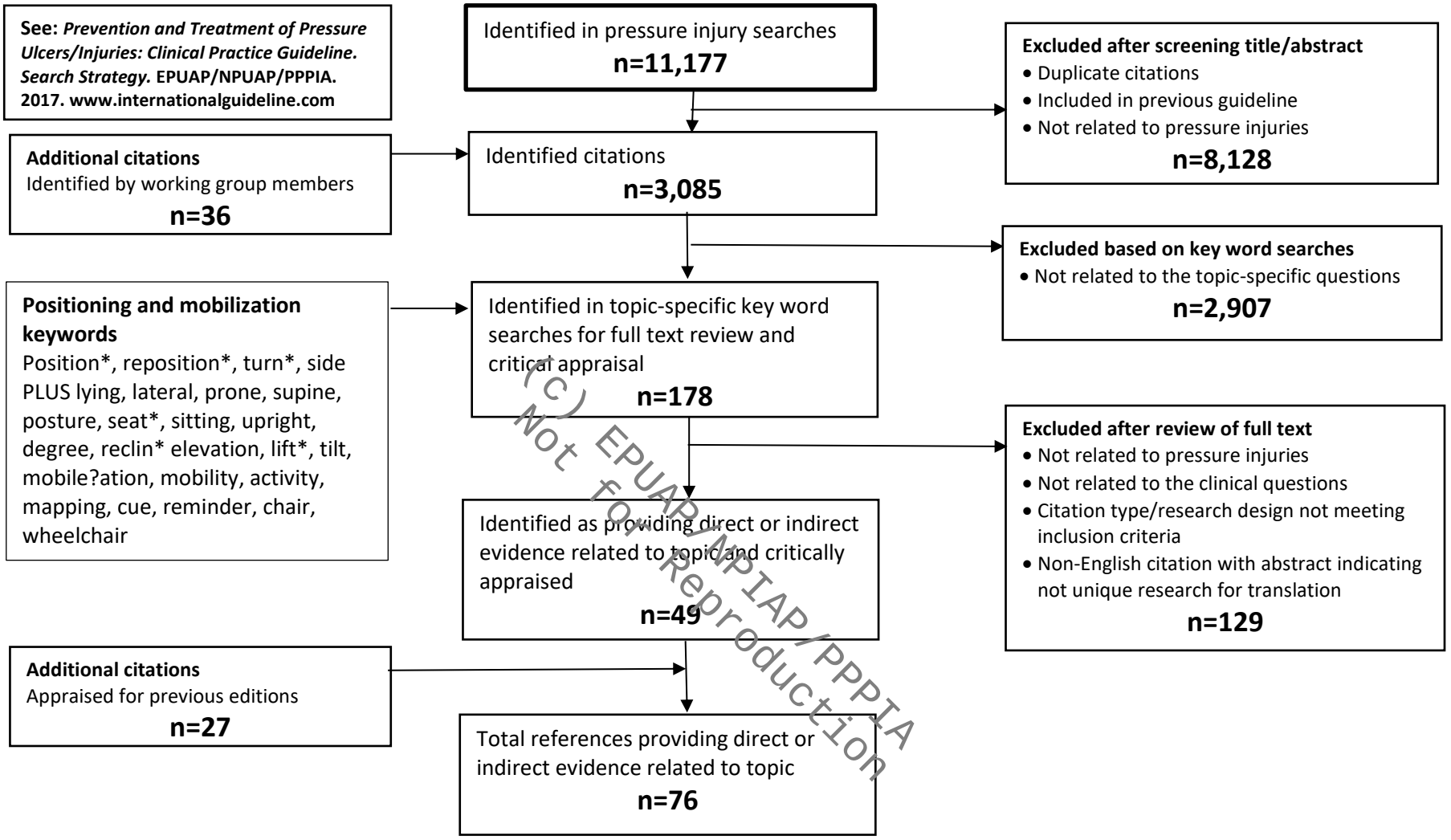
Search results for 2019 International Pressure Injury Guideline: Repositioning and Mobilization



European Pressure Ulcer Advisory Panel, National Pressure Injury Advisory Panel and Pan Pacific Pressure Injury Alliance. Prevention and Treatment of Pressure Ulcers/Injuries: Clinical Practice Guideline. The International Guideline. Emily Haesler (Ed.). EPUAP/NPIAP/PPPIA; 2019

Repositioning and Early Mobilization: data extraction and appraisals

Articles Reviewed for International Pressure Injury Guideline

The research has been reviewed across three editions of the guideline. The terms pressure ulcer and pressure injury are used interchangeably in this document and abbreviated to PU/PI. Tables have not been professionally edited. Tables include papers with relevant direct and indirect evidence that were considered for inclusion in the guideline. The tables are provided as a background resources and are not for reproduction.

European Pressure Ulcer Advisory Panel, National Pressure Injury Advisory Panel and Pan Pacific Pressure Injury Alliance. Prevention and Treatment of Pressure Ulcers/Injuries: Clinical Practice Guideline. The International Guideline. Emily Haesler (Ed.). EPUAP/NPIAP/PPPIA; 2019

Ref	Type of Study	Sample	Intervention(s)	Outcome Measures & Length of Follow-up	Results	Limitations and comments	
Clinical question one: How often should repositioning be performed to reduce the risk of pressure injuries?							
Manzano et al., 2014	RCT to compare the effectiveness of repositioning every 2 or 4 h for preventing pressure injury prevention in critical care	Participants were recruited in in an ICU in Spain (n=330) Inclusion: • Admitted in study time • Mechanical ventilation • Alternating air pressure mattress Exclusion criteria: • Pregnant • Aged < 18 years • Not treated on alternating pressure air mattress • Weight >140kgs or <45 kgs Participant characteristics: • Mean age 60 to 61 years • Mean APACHE II score 23.5	• Participants were randomized to receive: ○ 2 hourly turning with three positions – left and right sides with 30 tilt plus supine with 30 elevation (n=165) ○ 4 hourly turning with three positions – left and right sides with 30 tilt plus supine with 30 elevation (n=164) • Repositioning interrupted for hemodynamic or respiratory instability	• New Category/Stage II or greater pressure injury • Researchers evaluated pressure injuries (interrater reliability k=0.95) but does not state how frequently • Compliance with intervention	**Pressure injury incidence** No significant difference in pressure injury incidence between 2 hour turning group (10.3%) and the 4 hour turning group (13.4%) (unadjusted HR 0.89, 95 % CI 0.46 to 1.71, p=0.73) **Compliance with positioning regimen** Mean implementation rate for the 2 hour turning schedule was 60.46±23.55% and 61.03±22.36% for the 4-h group	• One withdrawal from 4 hour turn group Unclear how compliance was measured	**Level: 1** **Quality: high**
Bergstrom et al., 2013	RCT **to determine optimal repositioning frequency of nursing home (NH) residents at risk for pressure**	Participants were recruited in 27 nursing homes in USA and Canada (n=942) Inclusion criteria: • Moderate or high pressure injury risk on Braden Scale • Aged > 65 years	• All participants had a high density foam mattresses • Participants were randomly allocated based on risk stratification (moderate vs high) to either:	• Pressure injury incidence (coccyx or sacrum, trochanter, heels) • Blinded assessors assessed skin weekly.	**Pressure injury incidence** • No significant difference in pressure injury incidence based on frequency of repositioning group (2hr: 2.5%; 3hr:0.6%; 4hr: 3.1%, p=0.68). • No significant difference in pressure injury incidence between moderate	• Limited to only two risk levels • Being part of study and completion of associated documentation may have cued	**Level of evidence: 1** **Quality: High**

Ref	Type of Study	Sample	Intervention(s)	Outcome Measures & Length of Follow-up	Results	Limitations and comments	
	injuries when cared for on high-density foam mattresses	No pre-existing pressure injury Participant characteristics: • Primarily female (77.6%) • Primarily Caucasian (80.5%) • Mean age 85.1years • Most common diagnosis was cardiovascular (76.9%) • Primarily with dementia (72.5%)	○ Repositioning every 2 hours (n=321) ○ Repositioning every 3 hours (n=326) ○ Repositioning every 4 hours (n=295) • Intervention continued for 3 weeks.		and high-risk groups (moderate 2.1% versus high 1.8%, p=0.79) • All pressure injuries reported were Category/Stage I (n=2) or Category/Stage II (n=19) **Implementation of intervention** • 82% of turning occurred as prescribed • Mean time in one position was 2.07 hours for 2 hour group, 2.9 hours for 3 hour group and 3.7 hours for 4 hour group **Author conclusions: There was no difference in pressure injury incidence over 3 weeks between those turned at 2-, 3-, or 4-hour intervals when high density foam mattress and frequent skin assessment was used**	staff to be more vigilant • Relied on nursing documentation of interventions • See also Paulden et al 2014 for economic analyses based on this study	
Ceylan, Gunes, & Uyar, 2017	Observational study **exploring effect of immobility on sacral tissue oxygen saturation in patients lying on a supporting surface in supine position**	Participants from ICU in university hospital in Turkey (n=46) Inclusion criteria: • > 18 years old • Body Mass Index range of 18.50 to 29.99 • immobile (≤2 points on mobility subscale of Braden Scale) • peripheral oxygen saturation (SpO_2) ≥ 90% • blood pressure > 90/60 mmHg Exclusion criteria: • sacral inflammation, hyperemia or erythema	• The patients were their own control • Patient in lateral position for all measurements • Patients in supine position with head of the bed at 30° for 1 hour between measurements • Procedure repeated over 4 hours Other interventions: • At one ICU participants had alternating pressure air mattresses and at the other ICU vicsoelastic foam mattresses were used	• Sacral tissue oxygen (StO_2) was measured with an InSpectra Tissue Oxygenation Monitor providing a noninvasive method using near infra-red light • Mean $StO_2$was at baseline (30 mins), after 1h, 2h, 3h and 4h. • The sacral site was evaluated in terms of hyperemia during the measuring but no patient developed hyperemia before the fourth hour. •	**Mean StO_2** • Over time, there was no significant change in StO_2 (p=0.094) • 73.36%±10.04 at baseline • 74.91%±11.52 at first hour • 72.32%±11.49 at second hour • 71.89%±12.97 at third hour • 71.89%±14.09 at fourth hour **Authors conclusions: Changing the position of a patient lying on a supporting surface every four hours is justified based on data for supine position**	• The use of different mattresses was not discussed and may have influenced findings • To be able to measure the sacral StO2 they needed to reposition the patient into a lateral position, this only took 20 sec but it may have affected the results.	**Indirect evidence (PU not an outcome)** **Quality: Moderate**

Ref	Type of Study	Sample	Intervention(s)	Outcome Measures & Length of Follow-up	Results	Limitations and comments	
		• Lacking full tissue integrity • Difficulty positioning (spinal-cervical fractures, lung diseases) • Sacral capillary damage • Steroids, vasopressors or cytotoxic drugs • sacral edema • $SpO_2 \leq 90\%$ and whose blood pressure remained below 90/60 mmHg Participant characteristics: • Mean age 55.1±21.7 years • Mean BMI 25.2±4.1 • Mean SpO_2 95.2±2.6 • Mean systolic BP 131.6±21.6 • Mean Braden 13.4±1.7				• The cumulative effect of pressure on tissue oxygen saturation could not be evaluated.	
M. J. Peterson, Gravenstein, Schwab, van Oostrom, & Caruso, 2013	Observational study to investigate influence of repositioning on interface pressure	Participants were recruited in a tertiary hospital in US (n=23) Inclusion criteria: • Bedridden and unable to self-reposition • ICU or intermediate care • At risk for pressure injuries considered to be Braden score ≤ 18 • Lateral positioning as a part of usual care Participant characteristics: • Mean age 63.3±12.7 • Mean height 1.70±0.11m • Mean BMI 29.3±5.6	• Participants were continued to be repositioned every 2 hours, including into lateral position	• Peak interface pressure using a pressure senor map recorded every 30second • Measurements at perisacral area, buttocks, greater trochanters	**Interface pressure** • 100% of patients had always-at-risk regions i.e. those in which >95% of observations showed areas at a high pressure threshold • Mean area of always-at-risk areas was 206±182cm^2 • 13 participants were positioned supine, left and right and had areas that remained at high interface pressure in all three positions **Author conclusions: Regular repositioning of bedridden individuals may not sufficiently relieve pressure at some pressure points**	• Small sample sizes • Did not conduct skin inspections	**Indirect evidence (pressure injury incidence not reported)**

Ref	Type of Study	Sample	Intervention(s)	Outcome Measures & Length of Follow-up	Results	Limitations and comments	
		• Mean Braden score 13.3±2.8					
Zena Moore, Cowman, & Conroy, 2011	RCT **investigating 3 hourly turning and 30° tilt positioning for prevention of PUs**	Participants were older adults in 12 aged care facilities that were identified for the study (n=213) (99 in the experimental group and 114 in the control) Inclusion: • Aged ≥ 65 years • At risk of pressure injuries (assessed on Braden Scale) • No existing PU • No medical condition precluding repositioning Characteristics: • 79% female • 66% aged ≥ 81 years • 70% had low malnutrition risk assessed using MUST • 87% were chair-bound and 77% had limited activity • 86% control and 96% experimental had pressure relieving device on bed • No statistically significant difference for age, gender or Braden score • Significantly more in experimental group were bed-fast (20 versus 8, p<0.005)	• Facilities were randomized as control or experimental facilities to reduce the chance of contamination. • Facilities were either; ○ Experimental: participants were repositioned every 3 hours at night using the 30° tilt (left side, back, right side back) between 8pm and 8am (n=10 facilities, 99 participants) ○ Control: participants received routine repositioning every 6 hours using a 90° lateral rotation between 8pm and 8am (2 facilities, 114 participants) • Both groups received education on PU grading system, the study purpose and data collection. The experimental facilities received education on 30° tilt. • Day time care remained "routine" for all facilities. • 99% used a pressure relieving device in a chair	Primary outcome: • Incidence of stage I to IV PU as assessed using EPUAP classification system and assessed on every turning of participant. Identified PUs were confirmed by second assessor. • Follow up was 4 weeks	• Significantly less participants in the experimental group developed any PU (3% versus 11%, (p=0.03, intracluster correlation [ICC] =0.001) • Incidence rate ratio 0.27 (95% CI 0.08 to 0.93, p=0.038, ICC 0.001) • OR of PU in experimental group was 0.2343 (95% CI 0.067 to 0.879, p=0.034) • All pressure injuries were grade I (44%) or grade II (56%) • Mobility and activity were the highest predictors of PU development (multiple regression analysis, β=0.246, 95% CI –0.319 to –0.066; p=0.003 and β=0.227, 95% CI 0.041 to 0.246; p=0.006)	• Final sample size did not reach *a priori* target of 389 participants in each arm • Variance in the cluster sizes • No reporting of positioning in the day time and duration of time spent in bed • Control care was 6 hourly repositioning, which may not be considered standard care • Increased frequency of turning and use of the tilt position were assessed as a single intervention. • Control facilities had more participants which may have made maintaining adequate repositioning regimens more difficult	**Level: 1** **Quality: moderate**

Ref	Type of Study	Sample	Intervention(s)	Outcome Measures & Length of Follow-up	Results	Limitations and comments	
Rich et al., 2011	Analysis of a larger cohort study **investigating association between repositioning and PU incidence**	Participants were recruited between 2004 and 2007 from nine hospitals in the USA (n=269) Inclusion: • Aged ≥65 years • Hip fracture surgery • Bed-bound at index study visits during first 5 days of hospitalization Exclusion: • No study visit on first 5 days of hospitalization • Not bed-bound for at least one visit day according to Braden scale activity item Characteristics: • 51.7% aged ≥ 85 yrs • 98.5% White race • 43.9% had Braden scale ≤ 16 • 14.2% had PU at baseline	• Information about repositioning frequency for the first 5 days of hospitalization was collected from patient charts, including number of times manual repositioning performed • Study nurses performed skin assessments and Braden scale score at baseline and on alternating days for 21 days	• Primary outcome: development of stage 2 or greater PUs as defined on a scale on which stage II was partial thickness dermal loss or serum filled blister. • The association between frequent manual repositioning and PU incidence was estimated adjusting for PU risk factors using generalized estimating equations and weighted estimating equations • Frequent repositioning was defined as ≥12 manual repositions per hospital day	• Patients were repositioned frequently on 53% (187/354) of index visit days • The incidence of PUs per person-day did not differ between the two groups (incidence rate ratio 1.12, 95% CI 0.52 to 2.42) • Patients repositioned frequently were more likely to have a PU at baseline (p=0.006), more likely to have high risk of nutrition-related complications (p=0.006) and more likely to have a lower mean Braden score (p=0.07) • For participants with a high PU risk based on Braden score. There was a lower incidence of PUs among those who were frequently turned (IRR 0.39, 95% CI 0.08 to 1.84) • Although no association was found between frequent repositioning of bed-bound patients and lower PU incidence, there was an effect in patients at high risk of PU	• Limited adherence to repositioning recommendations • Observational design • Relied on medical records data, turning frequency was not verified	**Level of Evidence: 3** **Quality: moderate**
Vanderwee, Grypdonck, De, and Defloor (2007)	RCT to determine whether 2 hourly lateral positioning plus 4 hours supine position reduces pressure injuries compared to 4	Participants recruited in 16 nursing homes in Belgium (n=235) Inclusion: No pressure injury Able to be repositioned Length of stay to be > 3 days Median age: 84 years Median time in facility 42 months	• Facilities were randomly assigned to: ○ Experiment group receiving 2 hourly lateral positioning plus 4 hours supine positioning with 30° elevation(n=122) ○ Control group receiving 4 hourly repositioning using the same regimen (n=113) • Identical sitting regimen between groups	• Pressure injuries categorized using EPUAP system • Daily skin assessment	**Incidence of pressure injuries** • Overall prevalence of Category/Stage II or greater pressure injuries was 9.9% • No significant between group differences (experiment 16.4% versus control 21.2, p=0.40) in incidence of Category/Stage II or greater pressure injuries • Severity (p=0.565), location (p=0.19) and time to develop a pressure injury (p=0.29) • Relative risk was 0.66 (95% CI 0.37 to 1.20)	• Participants commonly changed position between scheduled repositionings • No blinding	**Level of evidence: 1** **Quality: High**

Ref	Type of Study	Sample	Intervention(s)	Outcome Measures & Length of Follow-up	Results	Limitations and comments	
	hourly repositioning		• All participants had a 7cm viscoelastic foam overlay mattress (Tempur®, Tempur-World, US)		**Author conclusions: Turning more frequently is not as a more effective preventive measure in and of itself**		
Defloor, De Bacquer, and Grypdonck (2005)	RCT to investigate effect of four different preventative regimes involving either frequent turning (2, 3 hourly) or the use of a pressure-reducing mattress in combination with less frequent turning (4, 6 hourly).	Participants recruited in 32 nursing home wards (n=838) Inclusion criteria: Braden score <17 or Norton score <12 Participant characteristics: Mean age 84.4 years Mean Norton score was higher in standard care group (p=0.035) but no significant difference in Braden score Mean time sitting out of bed was not different between groups (6.8 hours/day, p=0.27)	• Facilities were randomized to receive: • turning every 2 h on a standard mattress (n=65) • turning every 3 h on a standard mattress (n=65) • turning every 4 h on a viscoelastic polyurethane foam mattress (n=67) • turning every 6 h on a viscoelastic polyurethane foam mattress (n=65) • standard care group that received a range of different active and reactive support surfaces (n=576)	• Observation for 4 weeks • Two nurses conducted skin assessments (frequency unknown) • New pressure injuries occurring I the study	**Pressure injuries** • Total pressure injury rate was 43.8% for Category/Stage I pressure injuries and 18% for Category/Stage II or greater • No significant difference in Category/Stage I pressure injuries between intervention groups (p=0.95) • 3 hour turning regimen with a standard mattress had significantly higher rate of Category/Stage II to IV pressure injuries: 2hr group 14.3%, 3 hour group 24.1%, 4 hour turning group 3%, 6 hour turning group 15.9% (p=0.002) • Turning every 4 h on a pressure-reducing mattress was associated with significantly fewer pressure injuries Category/Stage II to IV than the standard-care group and the other intervention groups (odds ratio 0.12 (95% CI 0.03 to 20.48)	• No ITT analysis • No blinding • Volunteering facilities and observation of staff may increase compliance with repositioning	**Level of evidence: 1** **Quality: High**
Interventions to assist in compliance with positioning regimens							
Yap et al., 2013	Paired facility randomized trial to assess the effect of musical cues and 2 hourly repositioning to reduce the rate of pressure injuries in aged care	Study conducted in 10 aged care facilities in US (n=1,928) Facility inclusion criteria: • Not participating in other pressure injury prevention initiative • Had resources to support intervention In facilities, all residents aged ≥ 18 years were included	• 8 facilities were randomized to intervention or comparison group: ○ Intervention group (12-month intervention): Staff-selected music was played every 2 hours over the facilities PA system during 12 daytime hours to prompt multi-disciplinary staff	• Frequency of facility-acquired pressure injury divided by the total number of facility minimum data set (MDS) resident assessment conducted during the study period • Sub-analysis based on MDS2.0 versus MDS3.0 data collection tool • Clinical staff conducted skin assessment daily	**Facility-acquired pressure injuries** • Residents at the intervention facilities had 45% lower chance of developing a pressure injury compared to the comparison facility • Reduction in pressure injuries was significantly lower in intervention facilities (p=0.047) on MDS 3.0 tool bot not on MDS 2.0 tool	• Staff could not be blinded • Increased staff vigilance with pressure injury management at commencement of study • Generalizability limited as facilities	**Level of evidence: 1** **Quality: Moderate**

Ref	Type of Study	Sample	Intervention(s)	Outcome Measures & Length of Follow-up	Results	Limitations and comments	
		Participant characteristics: • Comparison and additional control facility had significantly more fewer people receiving nutrition program (p<0.001) • Significant different in BMI between groups (p=0.02)	(and family) to encourage mobilization in ambulant residents and nursing staff performed repositioning (4 facilities, n=948) ○ Comparison group months 1-6 received preexisting standard care, months 7-12 received intervention (4 facilities, n=722) • Additional control: pre-existing care for 12 months (2 facilities, n=294 without suitable PA systems) • The intervention included education, videos and pamphlets, telephone support and designation of a mobility champion.	• Research staff conducted case reviews	**Authors comment: Facility acquired pressure injury development was decreased when patients were moved 2 hourly following a musical cue reminder to staff to move patients**	volunteered to be in study • Some people not included in analysis due to opting out of intervention • Intervention group received more nutrition interventions that may have influenced finding	
Pickham, Berte, et al., 2018	RCT exploring whether a wearable sensor on the patient promotes turning compliance and prevents facility-acquired pressure injuries in an ICU	Participants were recruited in two ICUs in a facility in the US (n=1312 randomized) Exclusion criteria: • Aged <18 years • Issue preventing sensor adhesion • Extreme acuity or frailty Inclusion criteria: • All admissions Participant characteristics: • Mean age 60 (SD 17) • 54% Caucasian, 5% dark, 15% Asian, 16% Hispanic	• Nurse received education o the monitoring system before commencing trial • Participants were randomized to: • Sensor group: sensor applied to sternum, collecting data and relaying it to clinicians at a point-of-care dashboard on patient positioning, time to text turn. Visible warnings given when patient not turned in 2 hour frequency with 20° turning threshold (n=659) • Control group: sensor applied to sternum	• Hospital acquired pressure injury • Routine, shift-based top-to-tail skin assessment	**Hospital acquired pressure injuries** There was significant reduction in pressure injury rate in the sensor group compared with control group (0.76% versus 2.3%, odds ratio 0.33, 95% CI 0.12 to 0.90, p=0.031) Effect was significant when adjusting for admitting unit and in the per protocol analysis **Compliance** Compliance with turning residents at high risk was higher in the sensor group (67% compliance versus 47%, p<0.001) **Author conclusions: use of a patient sensor for people I the ICU increases nurse**	• Clinicians were not blinded however patients were • Per-protocol pls ITT analysis conducted	**Level of evidence: 1** **Quality: high**

Ref	Type of Study	Sample	Intervention(s)	Outcome Measures & Length of Follow-up	Results	Limitations and comments	
		• Acuity and Braden score risk were similar between groups	collecting data but not relaying it (n=653)		**compliance with repositioning leading to reduction in pressure injury incidence**		
Pickham, M., et al., 2018	Observational study investigating compliance with repositioning regimens	Participants were recruited in two ICUs in a facility in the US (n=555) Exclusion criteria: • Aged <18 years • Issue preventing sensor adhesion • Extreme acuity or frailty Inclusion criteria: • Admitted to participating facility • Participant characteristics: • Mean age 60 (SD 19) • 54% Caucasian, 6% dark skin, 16% Asian, 3% native American, 20% not noted	• Sensor group: patient sensor applied and collecting data on patient positioning, time to text turn • Participants maintained their designated turning regimens	Data collected every 10 seconds and a turn registered if the person's position changed for at least 1 minute with 20° turning threshold Compliance was measured as a percent of repositioning completed	**Compliance with repositioning regimen** • Overall compliance was 54% • Compliance on night shift (46%) was significantly lower than day shift (56%) or afternoon shift (56%) (p<0.005) • compliance was lower for residents with a high risk Braden score (55%) compared to those at low risk (66%) (p<0.005) • Compliance was significantly higher for female patients compared to male (57% versus 49%, p<0.005) • Compliance was significantly related to BMI, decreasing as BMI increased (p<0.005) • Compliance increased with patient aged (p=0.01) **Quality of turning** • Average turn magnitude was 24° ± 29° • Quality of turning was higher for people with a high risk Braden score compared to those at low risk (21° versus 12°, p<0.005) • Quality of turning was higher for medical versus surgical patients (p<0.005) **Author conclusions: wearable sensors can detect patterns of clinical care**	• System detected both spontaneous and nurse-initiated repositioning	**Indirect evidence (pressure injury not an outcome measure)**

Ref	Type of Study	Sample	Intervention(s)	Outcome Measures & Length of Follow-up	Results	Limitations and comments	
Clinical question two: What criteria should be used to determine and monitor frequency of turning?							
Assessing ability to self-reposition							
Gammon et al., 2016	Prospective case series **exploring if patients reposition themselves sufficiently**	Participants were recruited in US hospital over 3 months (n=153 recruited, n=101 met inclusion and completed) Inclusion criteria: • Able to move in bed without assistance • Able to understand teaching provided by nurses • On same bed for total hospital stay Exclusion criteria: • Underwent a procedure requiring ≥ 2 hours laying still • Requiring assistance to turn at any stage during hospitalization Participant characteristics: • 30% aged over 65 years 61% aged from 25 to 64 years • 35% had a stay ≥ 6 days • 75% had Braden scale score > 18, 18% had Braden score < 18 and 7% no documented score	Patients lay on a pressure mapping device	• Twice daily evaluation by nurses to determine if patient was appropriately designated as able to self-reposition • Twice daily head-to-toe skin assessment by nurses • Once weekly skin assessment by wound specialist • Pressure maps were analyzed to determine if patients repositioned based on image color changes within 4 hour intervals	• 84% of participants had recordings of 24 hours or less, of whom only 2 participants had periods of ≥4 hours with no movement (for both participants, this was at night) • No PU experienced in the trial **Author conclusions: Participants with good bed mobility and assessed as being able to self-reposition generally do so to a degree to sufficiently off load pressure within every 4 hour interval**	• No control group • Participants were from a younger cohort and had low PU risk • Participants frequently left the ward or had bed changes leading to exclusion and high dropout • Diagnosis, stage of disease unknown	**Level of evidence: 4** **Quality: moderate**
McInnes, Chaboyer, Allen, Murray, &	To describe the positioning patterns of patients at risk	Participants recruited in neurology and orthopedic wards in hospital in Australia (n=26)	No intervention	• Positions adopted by the patients were recorded during a two-hour observational period over	**Position changing** • Day shift position changes occurred a median of 3.0 times (IQR, 2.50; range 1–9)	• Very small sample • Orthopedic patients may not represent all	**Indirect evidence: PU not an outcome measure**

Ref	Type of Study	Sample	Intervention(s)	Outcome Measures & Length of Follow-up	Results	Limitations and comments	
Webber, 2013	of developing PIs	Inclusion criteria: • Aged 18 or older • English-speaking • hospitalized for ≥ 24 hours Exclusion criteria • Severe illness • Immobilized Participant characteristics: • Female: 15, male 11 • Median age of 66 years • Median length of stay at data collection was 5 days • Most had a history of cardiovascular disease, half had a BMI categorized as overweight or obese		three consecutive nursing shifts (day, evening, night) • Observation included frequency and type of change in the position • PI risk status as measured by the Waterlow risk assessment tool	• Afternoon shift position changes occurred a median of 4.0 times (IQR, 3.0; range 0–7) • Night shift, a median of 4.0 times (IQR, 3.0; range 1–8). **Preferred positions** Participants mostly assumed the supine 46°–90° position or sitting out of bed in the early part of the day and were more often observed in the supine 1°–45° in the later part of the day. **Author conclusions: Patients tend to adopt positions associated with developing PIs.**	patients as they could have mobility lmiitations	
Källman, Bergstrand, Ek, Engström, & Lindgren, 2015	Cross sectional study investigating nursing staff induced repositioning and the patients' spontaneous movements	• Participants recruited in • 8 nursing homes and 7 hospitals in the UK (n=62, n=52 in analysis) Inclusion criteria: • Considered at risk of pressure injuries according to RAPS scale • 1-2 RAPS regarding physical activity, confined to wheel chair or bed, cannot change position for self. • Aged ≥ 65 years • Exclusion: • skin sensitivity to adhesive Participant characteristics: • Mean age 85 (SD 7.3)	MovinSense® (Kinematix, Portugal) a microelectronic device was used to track movements Data collected for 3-day and nights (time, position angle, daily activity). Positions divided into categories: supine, lateral, and sitting in chair	• Tracking device measures position, self-repositioning or staff repositioning (congruence with a visual assessment was 92%) • periods between REP were a median of 3 hours and 12 minutes, with a max of 14 hours and 24 mins. •	***Repositioning by staff*** • patients were repositioned by the nursing staff a median of five times (Q1 4, Q3 6) during the day and two times (Q1 2, Q3 3) during the night (*P*<0·001) • Median duration between staff repositioning was 3hrs 12 mins (Q102:41, Q3 03:56) **Spontaneous repositioning** Large variations in the patients' spontaneous repositioning in the day (median 16, Q1 5 to Q3 52) and night (median 10 (Q1 4, Q3 33), **Author conclusions: Spontaneous movements was not correlated with risk scores. A monitoring system can aid**	• Small sample size • Large data which required simplistic calculations to avoid unequal measurements • Only measures movements of 25° or greater • No evidence on relationship to pressure injury development	**Indirect evidence: PU not an outcome measure**

Ref	Type of Study	Sample	Intervention(s)	Outcome Measures & Length of Follow-up	Results	Limitations and comments	
		• RAPS mean score 24 (SD 3.1) • BMI mean 26 (SD5.3) • Category/Stage I pressure injuries: 12%, Category/Stage II: 4%, Category/Stage III: 1% Category/Stage IV, 7%			**nursing decisions about frequency of repositioning.**		
Level of activity							
Chaboyer, Mills, Roberts, & Latimer, 2015	Observational study **to describe physical activity patterns of patients at risk of PU**	Consecutive sample of adults admitted to a tertiary hospital in Australia (n=84) Inclusion criteria: • Length of stay (LOS) ≥ 3 days • Reduced mobility defined as requiring a walking aid or physical assistance to walk Exclusion criteria: • Cognitive impairment • Screened positive for *Staphylococcus aureus* Characteristics: • Mean age 73.6±14.8yrs (range 24 to 97) • Mean LOS 5.9±3.9 days • 10.8% had a history of PU in previous 12 months	• Participants wore a physical activity monitor attached to sternum for a continuous 24 hour period	**% time spent in:** • sedentary (<100 counts/min) • light movement (100 to 760 counts/min) • moderate or greater movement (>760 counts/min) **Number of postural changes** Rotation of torso of >10° that is sustained for at least 5 mins	**% time spent in activity Median(interquartile ranking[IQR])** <u>Sedentary</u> • Total sample (n=84) 94.5% (4.7%) • Age ≤ 65 years (n=22) 93% (2.7%) • 66 to74 years (n=18) 95.6% (2.7%) • ≥ 75 years (n=44) 94.3% (5.3%) <u>Light activity</u> • Total sample (n=84) 5.0% (4.3%) • Age ≤ 65 years (n=22) 6.3% (4.2%) • 66 to74 years (n=18) 4.1% (4.2%) • ≥ 75 years (n=44) 5.1% (5.0%) <u>Moderate or greater activity</u> • Total sample (n=84) 0.4% (0.3%) • Age ≤ 65 years (n=22) 0.5% (0.4%) • 66 to74 years (n=18) 0.4% (0.2%) • ≥ 75 years (n=44) 0.4% (0.3%) **Number position changes/24 hrs Median (IQR)** • Total sample (n=84) 94 (48) • Age ≤ 65 years (n=22) 99 (51) • 66 to74 years (n=18) 93 (52) • ≥ 75 years (n=44) 93 (62) **Conclusions: participants had high levels of time spent sedentary but had large**	• No comparison with non-reduced mobility participants • No indication of how frequently the repositioning occurred (e.g. is the repositioning well-spaced or are long durations spent in one position) • Pressure ulcer incidence not measured • No consideration to confounding factors e.g. type of medical condition	**Indirect evidence: PU not an outcome measure** **Quality: moderate**

Ref	Type of Study	Sample	Intervention(s)	Outcome Measures & Length of Follow-up	Results	Limitations and comments	
					number of repositioning in a 24 hour period. Assess patients' level of repositioning before implementing regular repositioning assistance.		
Sonenblum, Sprigle, & Martin, 2016	To describe the in-seat movement and weight-shifting behavior of full-time wheelchair users	Individuals with chronic spinal cord injury (SCI), 2 years post-injury, use a wheelchair as their primary mobility device and be capable of independently performing weight shift maneuvers Data collected on 37 patients, drop-out of 9 patients and collecting of 192 days of data	Observational study: • Measuring everyday sitting behavior of the participants by using eight thin force sensors placed under participants' wheelchair cushions.	• Transfers in and out of the wheelchair • Amounts of pressure reliefs (90% off-loading of the entire buttocks for at least 15 s) • - Amounts of weight shifts	• Participants transferred out of the wheelchair 8.4 +/–4.3 times. • Participants performed pressure reliefs 0.4 +/–0.5 times per hour when they were seated in the chair. • Participants performed weight shifts with a frequency of 2.4 +/–2.2 times per hour **The pressure reliefs and weight shifts were not performed in a routine manner**	• Only tested with patients after spinal cord injury of ≥2 years postoperatively • Measurements by the pressure mapping were under the seating cushion. Influence of the different seating cushions that were used?	**Indirect evidence (pressure injury not an outcome measure)**
Skin changes							
Grap et al., 2017	Longitudinal study describing tissue interface pressure, **time spent above critical pressure levels and the effect on skin**	Patients admitted to ICU (Medical respiratory, neuroscience and surgical) in a mid Atlantic urban university hospital (n=132) Inclusion criteria: • Intubated patients, expecting to be intubated for the next 24 hours	• Patients were repositioned from supine to left or right side lying and tissue interface pressure measured • 97% of patients had skin barrier applied to their sacrum	• Tissue interface pressure was measured continuously using the XSENSOR pressure mapping system. Measurements collected twice per second. • Three maximum pressure levels were identified greater than or equal to 32, 45 and 60 mmHg. The percentage of	**Skin integrity** • Seven subjects (5.3%) showed fourteen changes in skin integrity in at least one anatomical location **Pressure mapping** • Percentage of time above 32mmHg before skin changes observed ≥99.4% in various locations	• Factors contributing to pressure injury formation other than interface pressure such as age, sheer, blood pressure, hydration and metabolism not	**Level of evidence: 4** **Quality: Low**

Ref	Type of Study	Sample	Intervention(s)	Outcome Measures & Length of Follow-up	Results	Limitations and comments	
	integrity on seven anatomical locations in mechanically ventilated adults	Exclusion criteria: • Nil mentioned Participant characteristics: • 57% male • Mean age 55.94 • Mean BMI 28.08 • Mean APACHE score 77.36 • Mean Braden score 12.71 Mean ICU length of stay 13.34 days		time spent above these levels was also measured • Areas of the body measured were the left and right scapula, left and right trochanter, sacrum and left and right heel. • Skin integrity was measured using the NPUAP staging system by trained evaluators • Also described skin integrity as improved or worsened but the way this was evaluated is not reported	• Percentage of time above 45mmHg before skin changes noticed ≥ 25.6% in various locations • Percentage of time above 60mmHg before skin changes noticed in various anatomical locations ≥ 3.2% • Skin changes noticed in sacrum (6), left scapula (2), right scapula (3), right trochanter (2) and right heel (1) • Table available for further information	measured in the study • Unclear how often skin integrity was measured • High pressures above critical levels were not ongoing (spikes in pressures measured as opposed to mean pressure) • Length of observation and therefore potential to improve skin integrity varied	
Pressure mapping							
Siddiqui, Behrendt, Lafluer, & Craft, 2013	Pretest/post test study to evaluate the change in hospital-acquired pressure injury prevalence with the use of bundle including a pressure mapping system	Participants were recruited in a Medical ICU in USA (n=627) Inclusion criteria: • Patients admitted to MICU Exclusion criteria: • Patients on fluidized support surfaces Participant characteristics: • Mean age 60 years • Male 50-53% • Days in ICU 6.2- to 7.5 • The groups were comparable for age, race, gender, recent surgery, associated comorbidities, history of pressure	• Intervention group (n=307): Continuous bedside pressure mapping (CBPM) was placed in the bed. Real time feedback images on monitor show the patients pressure points. Educators on the unit instructed and assisted with implementation of CBPM technology to augment the pressure ulcer bundle, based on the NPUAP guidelines. • Historical control group (n=320):occupying the same beds 1 year prior to	• Pressure injuries as per electronic data records • Follow-up period unclear	**Pressure injury incidence** Pressure injuries occurred more often in control group (0.3% versus 5%, p=0.001) **Author conclusions: Real-time, ongoing pressure mapping may be a useful tool to help care providers effectively reposition patients within the context of existing standardized protocols for the prevention an d minimization of pressure injuries**	• Pre-post study with historical controls. • Record review of pressure injuries (not observation by research staff) • Limited methodology reporting • Education over time may have influenced staff behaviors	**Level of evidence: 3** **Quality: Low**

Ref	Type of Study	Sample	Intervention(s)	Outcome Measures & Length of Follow-up	Results	Limitations and comments	
		injuries, immunosuppression, spinal cord injury, vasopressor use, ventilator use, mean Braden score on admission. • There were higher acuity in the intervention group (PEEP; APACHE, serum lactate)	the CBPM group, care not specifically defined				
Gunningberg, Sedin, Andersson, & Pingel, 2017	RCT to evaluate the effect of a pressure mapping system on pressure injury prevalence and incidence	Participants were recruited in one medical ward in a Swedish university hospital (n=190) Inclusion criteria: • Aged over 50 years • Admitted between Sunday 4 pm and Friday 4 pm • Expected stay ≥3 days Exclusion criteria: • discharged before data collection on day 3 • end-of-life care Participant characteristics: • Mean age 81 years • Intervention group with fewer patients with malignancy and cardiovascular disease • Mean hemoglobin and albumin values below the reference In both groups • 6.8% had history of pressure injuries • 45 (49.5%) intervention group and 43 (43.4%)	Participants were randomized to receive: • Intervention: continuous bedside pressure mapping (CBPM, MAP™ System, Wellsense USA Inc) displaying pressure points in real-time color imagery showing how pressure is distributed at the body–mat interface. Immediate feedback to staff about pressure points, facilitating preventive interventions. Intervention group also received standard care and pressure injury prevention • Control group: standard care and pressure injury prevention only • Staff received education on the CBPM system prior to use	• Interface pressure from the CBPM-monitor after individual had been in the same position for 5 min. • Self-rated comfort in bed on day 3 (numeric rating scale with endpoints 1: very uncomfortable and 10: very comfortable) • Pressure injury classification as: Category 1: nonblanchable erythema, category 2: partial thickness skin loss, category 3: full thickness skin loss, and category 4: full thickness tissue loss • Use of preventive interventions observed by researchers • Data collection at baseline conducted within 16 h admission. Repeated on days 3, 7, and 14.	**Prevalence of pressure injuries** No significant difference **Incidence of pressure injuries** Of people with no pressure injury on admission, no difference in incidence (intervention group 10.1% vs control group 8.6%, incidence rate ratio 1.13, 95% CI: 0.34–3.79) **Severity of the pressure injuries** No significant difference between groups on any day (p = 0.30 to p = 0.75). **Patient comfort** Both groups assessed level of comfort in bed as 8 on a 10-point scale on day 3. P**eak pressure** No significant difference between groups on any days **Use of preventive interventions** • No significant difference between groups in pressure redistribution mattresses, turning schedules, slide sheet use or dressing use	The intervention was not blinded either to the healthcare professionals, the patients, or the outcome assessors The CBPM system was still partly under development at the time Possible intervention bleeding – intervention group and control group cared for in the same ward and staff may have treated control group whenever intervention group treated	**Level of evidence: 1** **Quality: High**

Ref	Type of Study	Sample	Intervention(s)	Outcome Measures & Length of Follow-up	Results	Limitations and comments	
		control group at risk of pressure injuries • Median activity and mobility scores for both groups a base line were 3.			• Significantly higher use of heel cushions in control group on day 12 only (26.3% versus 44.4%, p=0.033) **Conclusion: The use of the CBPM-system did not result in any significant differences in pressure injury prevalence, incidence or staff practices**		
Behrendt, Ghaznavi, Mahan, Craft, & Siddiqui, 2014	Quasi experiment to determine if pressure mapping could reduce hospital acquired pressure injuries	Participants were recruited over a 2-month period in a US medical ICU (n=422) Inclusion criteria: • All admissions Exclusion: •None reported Characteristics: •Mean length of stay 5 days •Mean age 57-58 years •Mean time on ventilator approx. 6 days •Mean Braden scale approx. 15 to 17 •No significant differences between groups	Participants were assigned on admission to either: • Continuous bed pressure mapping (CBPM) with repositioned to off-load high-pressure points during 2 hourly turning, according to the CBPM graphic display (n=213), or • standard of care consisting of 2 hourly repositioning (n=209)	• Skin assessed daily and weekly • Number of newly formed pressure injuries (Category/Stage II or greater) that were in areas of skin that had no previous pressure injury • Only one pressure injury per person included, and this was the highest Category/Stage pressure injury • Categorization using 2013 Wounds International consensus system •	**Hospital-acquired pressure injuries** • Intervention group had significantly fewer pressure injuries compared to control group (0.9% versus 4.8%; p=0.02) • All pressure injuries in both groups were Category/Stage II **Author conclusions: CBPM provides real-time visual feedback in repositioning of patients to help staff correctly offload the skin and tissues, thereby preventing the formation of new pressure injuries**	• Excluded Category/Stage I pressure injuries • Minimal reporting on other factors that might influence pressure injury formation (e.g. nutritional status, continence etc) •	**Level of evidence: 2** **Quality: High**
Wininger & Crane, 2015	Observational study **investigating the incidence of sensor saturation in pressure sensor mapping**	Convenience sample drawn from six long term care facilities and local community (n=22) Inclusion criteria: • Any type of wheelchair/cushion • Ability to sit comfortably in a wheelchair for 15 to 20 minutes	• Participants sat in their own wheelchair on pressure map with no objects (e.g. linen or cushions) between buttock and pressure map • Participants all used on positioning supports to maintain pelvic symmetry with 90° hip and knee flexion	Force Sensitive Applications (FSA) pressure mapping system – a flexible mat with 43cm square sensor area with 16x16 resistive force sensors calibrated to standard 200mmHg maximum Interface pressure data was recorded for approximately 2 mins giving 120 frames of data per participant (total 2,643 frames of data)	13.7% of frames contained one or more saturated sensor Sensor saturation more common in patients with low BMI **Study conclusions: In designing trials that use sensor mapping researchers should allow for saturated data when determining study power**	• Informs research design • Small sample with high mean age that may not be representative of SCI populations	**Indirect evidence**

Ref	Type of Study	Sample	Intervention(s)	Outcome Measures & Length of Follow-up	Results	Limitations and comments	
		• Ability to follow basic instructions Exclusion criteria: • Current PU Participant characteristics: • Mean age 80 ± 10 years • Mean weight 74.84±20 kgs • BMI average 28 ± 5.8kg/m^2	• standard manual wheelchair (n=15) and custom manual tilt or power wheelchair (n=7) • Cushions: foam (n=8), air (n=6), foam/gel (n=4), other (n=4)				
Hultin, Olsson, Carli, & Gunningberg, 2017	Pre/post test to evaluate the **use of a pressure mapping system in improving staff knowledge, attitudes and practice**	Participants recruited as a convenience sample in an aged care facility in Sweden (n=40 nurses, n=12 patient participants) Inclusion criteria: (patients): • aged ≥ 65 years • Norton scale score ≤ 20 • requiring assistance with repositioning Exclusion criteria: • End of life care • Category/Stage 4 pressure injury Participant characteristics: • Nurses (CNAs): 90% female, mean age 41.3yrs • Patients: Mean age 86yrs, mean Norton 17.3	• Intervention: 20 minutes education followed by instructions on use of Continuous bedside pressure mapping system (CBPM) for 15 minutes and then a week of practice. • CBPM were incorporated into beds for 2 day (pretest) and then 5 days. • Staff members were instructed to reposition the resident if the monitor showed warm colors (red and orange). • 3 different CBPM systems were used for data collection over 6 weeks.	• Pressure Ulcer Knowledge and Assessment Tool (PUKAT) • Attitudes towards Pressure Ulcer (APuP) • Continuous bedside pressure mapping system (CBPM) peak pressures	**Staff knowledge** significant improvement in pressure injury knowledge from baseline to 3 months (mean score 49% increased to 59%, z =3.1, N-Ties = 38, p= .002) **Staff attitude** No change **Interface pressure** Mean peak pressure was significantly lower (z = 2.4, N-Ties= 11, P = .016) when CBPM system was used vs not used. **Author conclusions: A limited educational intervention combined with pressure mapping system improved staff knowledge about pressure injury prevention, reduced interface pressure, and increased PI prevention activities.**	• Pre-post design limits casual inference • 40% attrition from the APuP • Short data collection period • 3 month period between pre and post test does not demonstrate sustainability of improvement	**Indirect evidence (PU not an outcome measure)**
Gunningberg & Carli, 2014	Descriptive study to describe nurses' repositioning skills, attitudes and	Participants were staff members recruited in a university hospital's Clinical Training Centre in Sweden	• two patient volunteers, (one male and one female) over the age of 70 and with normal body mass • Data collected by two data collectors over 8 days in November 2013 and	Primary outcome: peak interface pressure measured in mm Hg. Secondary outcomes: • Number of pressure-reducing changes relative to	• Peak pressures for the same patient ranged from 44 to 95mm Hg, depending on the nursing pair. • AN pairs placed both male 1 and female 1 in the supine position after feedback from pressure mapping, peak pressures were lower (p=0·014, p=0·031), levels of	• Pressure injuries not measured • Possible that the interface pressure between the pillows or wedges that were	**Indirect evidence (PU not an outcome measure)**

Ref	Type of Study	Sample	Intervention(s)	Outcome Measures & Length of Follow-up	Results	Limitations and comments	
	knowledge of pressure injury prevention, to evaluate if the continuous bedside pressure mapping (CBPM) system provides staff with a pedagogic tool to optimize repositioning	Participant characteristics (demographic data for 71·2% [n=37] participants: • Registered nurses (RN, n=19) and, Assistant nurses (AN, n= 33) • Primarily females • 3 month follow-up with 8 RNs and 8 ANs	follow-up sessions over 3 days in February 2014. • RNs and ANs worked in pairs to place patient in the best pressure-reducing position using clinical judgement of pressure-reducing interventions. • Nurses had at their disposal two large pillows, four small pillows, a heel cushion, two wedges and one quilt.	bed's horizontal starting position • Patient comfort assessed with a Visual Analogy Scale (1=very low level of comfort and 10=very high level of comfort) • Nurses' pressure injury knowledge and attitude scores using Pressure Ulcer Knowledge and Assessment Tool (PUKAT) 3 month follow-up with 8 RNs and 8 ANs	comfort were higher (p=0·035, p=0·006) and more preventive interventions were used (p=0·002, p=0·031) compared with RN pairs • No significant differences in PUKAT score between RNs and ANs with regard to the results of the questionnaire (P=0·760, t=−0·308, df 35). **Author conclusions: In the majority of cases, the mean peak pressures were significantly reduced with visual feedback from the CBPM monitor. Repositioning improved after feedback from the CBPM monitor.**	supporting the laterally turned position remained high, but this was unable to be measured by the continuous pressure mapping	
Gunningberg, Baath, & Sving, 2017	Qualitative study describing **staff perceptions of using continuous pressure mapping as a way to prevent pressure injuries**	Participants were staff members in a 126 bed university hospital setting (n=21) Participant characteristics: • Registered nurses (n=6) • Assistant nurses (n=6) • Physical therapists (n=3) • Assistant nurse managers (n=3) • Senior Physician (n=2) • Range of years' experience	• Continuously pressure mapping was implemented on the unit to help facilitate better patient positioning. • This study was to identify staff's perceptions about using this type of equipment and the impact on client care.	• Semi structured focus groups occurred • Staff schedules were changed to foster participation in the focus groups	**5 key themes were identified:** Need of information, training and coaching over a long period of time Pressure mapping – a useful tool in the prevention of PI in high-risk patients Easy to understand and use, but some practical issues were annoying New way of working and thinking New possibilities with the continuous pressure mapping system **Author conclusions: Continuous pressure mapping helps identify the importance of pressure injury prevention for staff and alerted them to the need for repositioning.**	• Convenience sample with self-selection to participate • One unit of one hospital • Study does not evaluate the effectiveness of the pressure mapping	**Indirect evidence (High quality qualitative study)**
Scott & Thurman, 2014	Observational study on use of continuous bedside pressure mapping	Participants were recruited in long term acute care facility (n=10) Inclusion:	• All participants had a specialty air or air-foam mattress • All mattresses fitted with continuous bedside pressure mapping	• Peak interface pressure	**Peak interface pressure** average peak pressure without the CBPM image was 78mmHg (range 48 to107) versus average peak pressure with CBPM as 47mmHg (range 33 to 60mmHg)	• Limited information about recruitment and characteristics of participants	**Indirect evidence: PU not an outcome**

Ref	Type of Study	Sample	Intervention(s)	Outcome Measures & Length of Follow-up	Results	Limitations and comments	
		High risk for pressure injuries (Braden ≤12)	(M.A.P™, Wellsense USA) attached to pressure map • Caregivers repositioned individuals with pillows and positioning aids • Caregivers shown images and then given opportunity to change the individual's position		100% health professionals agreed there system was easy to use Health professionals reported that pressure mapping increased family and patient agreement to be repositioned	• Uncertain how long individuals remained in one position • No PU outcomes	**(low quality)**
Pompeo, 2013	Observational study investigating the **influence of a pressure map in increasing frequency of repositioning**	Study conducted in a 55-bed long term acute care facility in US (n = 43 in each phase) Characteristics: High risk of PU (Braden score ≤ 12)	• Intervention was a pressure mapping device that sent visual display of anatomical locations reaching high interface pressures. An alarm system was pre-set to sound 2 hours after patient repositioning. • Phase 1: all patients placed on pressure map device and no monitor or alarm used • Phase 2: monitor and alarm were turned on, staff received in-service training on system use • Phase 3: monitor and alarm were turned on, staff attended mandatory meetings with senior staff to discuss system use	• Mean time to patient repositioning by nurses measured by automated pressure map system	• In Phase 1 mean time to reposition was after the 2 hour alarm was 120 minutes (i.e. at 4 hours) • In Phase 2 mean time to reposition after the 2 hour alarm was 105 minutes • In Phase 3 mean time to reposition after the 2 hour alarm was 44 minutes • **Conclusions: pressure mapping system with visual interface pressure map and pre-set alarm reduced average time to patient repositioning. Mandatory staff meetings further decreased time to patient repositioning.**	• Did report measure PU rates • Pressure system was reported to reduced airflow around the skin which may influence PU risk	**Indirect evidence (PU not an outcome)** **Quality: low**
Clinical question three: What positioning techniques are most effective in redistributing pressure and preventing shear?							
Supine positioning							
Llaurado-Serra et al., 2016	To compare semi-recumbent position	Participants were recruited in 6 intensive care units at teaching hospitals in Spain (n=276)	• Head of bed elevation measured x 3 per day	Head of bed elevation was measured three times per day for three days, maximum 28 days	**Positioning** Mean head of bed elevation was 30.1° (SD 6.7)	• Does not indicate how pressure injuries were assessed	**Level of evidence: 4**

Ref	Type of Study	Sample	Intervention(s)	Outcome Measures & Length of Follow-up	Results	Limitations and comments	
	compliance and the degree of head of bed elevation relationship with pressure injuries	Inclusion criteria • ≥18 years of age • Expected to remain on mechanical ventilation for ≥48 hours Exclusion criteria: • Contraindications to semi recumbent position • Mechanical ventilation during the previous seven days • Pre hospital intubation • Individuals with pressure injury occurring on first day of admission were excluded from pressure injury outcome analysis Participant characteristics: • Male 70.7% • Mean age 63.5 years • Mean APACHE11 score 18.5 • Mean ICU stay 20 days	• If head of bed was more than 30 degrees, the nurse was questioned on reasons	Pressure injuries staged in accordance with European Pressure Advisory Panel/ National Pressure Ulcer Advisory Panel 2009 system Mean observations of 18 per person Mean study days 10	Mean patient compliance with raised head of bed was 53.6% (SD 26.1%) Main Reasons for noncompliance with 30° bed head elevation were patient care (66.3%), clinical causes (33.2%), obstacles related to resources (0.5%) **Pressure injury incidence** • Hospital acquired pressure injury incidence was 9.1% (n=25 people with n=34 pressure injuries) • 35.3% of pressure injuries were Category/Stage I, 44.1% Category/Stage II, 20.6% Category/Stage III • Primarily heel pressure injuries (41.2%) • Having a pressure injury did not influence amount of head of bed elevation (p=0.677 before and after pressure injury diagnosis) • Head of bed elevation was not significant in multivariate analysis for pressure injury risk factors (p=0.164) **Author conclusions: Head of bed elevation is suggested to not have an influence on pressure injury development**	• Development of new pressure injury was not primary outcome • Unclear if risk factors preceded the pressure injury • Of over 800 people screened, only 276 included	**Quality: High**
Schallom, Dykeman, Metheny, Kirby, & Pierce, 2015	Feasibility pilot RCT to **determine gastric adverse events and pressure injuries occurrence with head of bed (HOB)**	Participants recruited from a surgical ICU in US (n=screened n=143, included and randomized n=15) Inclusion criteria: • Gastric feeding tube • Endotracheal tube ventilation • ≥ 18 years of age	• Cross over trial: ○ 30° elevation on day one, 45° elevation on day 2 (n=7, n=6 completed both days) ○ 45° elevation on day one, 30° elevation on day 2 (n=8, n=5 completed both days) • Electronic HOB gauge recorded the HOB every 30 seconds	• Hourly oral secretions using suction device • Endotracheal secretions obtained 2-3 hourly and measured for pepsin concentration • Skin assessment with each repositioning and at 8m and 8pm conducted by the same assessors	**Completion of trial** 4 patients withdrew due to early extubation **Pressure injury outcomes** All patients were considered at risk of pressure injuries but no patients experienced a pressure injury within the trial or up to 48 hours after the trial. **Adverse events**	• Short study with > 10% dropout from small initial population • Study may be insufficient length to determine risks • Non-blinded • Cross-over study design is not appropriate for assessing long-term	**Level of evidence: 1** **Quality: Low**

Ref	Type of Study	Sample	Intervention(s)	Outcome Measures & Length of Follow-up	Results	Limitations and comments	
	elevations of 30° and 45°	• Expected to have gastric tube and mechanical ventilation for ≥48 hours • Approved for 45° elevation Exclusion: • Non-consent • Ventilation via other methods • Pre-existing PU Characteristics: • Mean age 59.6 years • 67% surgical patients, 33% medical • Mean BMI 33.8±10.4 • Mean Braden score 11.9±1.8 • 87% bolus feeding and 13% had continuous feeding	• Washout period of 12 hours overnight • All patients received a low-air-loss pressure relieving mattress and 2 hourly repositioning		• 1 patient experienced sliding down the bed in 45° elevation position • 3 patients at 45° elevation requested decrease of HOB due to discomfort, but tolerated 30° elevation	adverse events from positioning	
Kallman et al., 2015	Descriptive comparative design investigating **the effect of positioning on tissue blood flow and skin temperature in lying positions**	Participants were recruited in a nursing home (n=25) Characteristics: • No participants had a current PU, 1 participant had a history of PU • Mean age 85±7.3 • BMI mean 25±4 • Mean body temperature 36.2°±0.4 • Mean Risk Assessment Pressure Sore (RAPS) 30±3.5 • Participants were taking range of cardiac medications and other systemic medications	• Participants were place in four positions on a pressure reducing mattress for measurement of blood flow and skin temperature. • Four positions were used: Supine tilt 30° Supine 0° Lateral 30° Lateral 90° • Mean room temperature 23.7°±0.9	• Risk Assessment Pressure Sore (RAPS) scale to assess PU risk • Body temperature (ear probe) • Superficial and deep tissue blood flow measured at depth of 1mm using a laser Doppler flowmetry and photoplethysmography (PPG) instrument (measured at sacrum or trochanter) • Interface pressure using an inhouse developed pressure probe (measured at sacrum or trochanter) • measurements were taken continuously for a period of	**Interface pressure (mean)** • Supine 0°: 44.7±11.7mmHg • Lateral 90°: 48.4±16.3mmHg • Lateral 30°:29.5±10.4mmHg • Supine tilt 30°: 32.9±9.1mmHg • Mean IPs in Supine 0° and Lateral 90° were significantly higher (p<0.001) **Skin temperature** • Supine 0°: 33.0°C±1.1 (over sacrum) • Lateral 90°: 31.8°C±1.3(over trochanter) • Lateral 30°:31.9°C±1.5 (over trochanter) • Supine tilt 30°: 33.1°C±0.8 (over sacrum) • Mean temperatures were significantly lower over trochanter in lateral 90° and lateral 30° positions (p<0.001) and the difference persisted after 60mins of loading (p<0.001)	• Selection of participants not reported •	**Level of evidence: 4** **Quality: Low**

Ref	Type of Study	Sample	Intervention(s)	Outcome Measures & Length of Follow-up	Results	Limitations and comments	
				1 hour plus 10 minutes after unloading pressure	**Skin blood flow** • Mean blood flow response was significantly higher in supine tilt 30° position compared to other positions at 60 mins loading • Blood flow was positively associated with systolic blood pressure and negatively associated with diastolic blood pressure (p<0.001 for both) • Blood flow was associated with body and skin temperatures and loading times		
Grap et al., 2016	Longitudinal study comparing backrest elevation and anatomical position on interface pressure in patients on mechanical ventilation	Patients admitted to ICU (medical respiratory, neuroscience and surgical) in a mid Atlantic urban university hospital (n=133) Inclusion criteria: • Intubated patients, expecting to be intubated for the next 24 hours Exclusion criteria: • Patients with constantly moist skin Participant characteristics: • 57% male • Mean age 55.86 • Mean BMI 37.96 • Mean APACHE score 77.5 • Mean Braden score 12.71	Bed backrest elevation (head of bed elevation) and knee angle measured using microelectromechanical accelerometer	• Tissue interface pressure measured continuously for 72 hours using full bed size XSENSOR pressure mapping system. Measurements collected twice per second • Areas of the body measured were the left and Right scapula, left and right trochanter, sacrum and left and right heel.	**Interface pressure** • Tissue interface pressure was affected by backrest elevation although this relationship was also affected by knee angle, BMI and movement • Tissue interface pressure decreased as backrest elevation increased in the scapula but not in the trochanter, sacrum and heels • Tissue interface pressure increased with movement, especially in the heels • Higher interface pressures were measured in the trochanter and sacrum of those with higher BMIs • A minimal increase was measured in the sacrum with an increase in knee angle from straight	• Interface pressure measurement error associated with movement • Shear force not measured • Influence on pressure injury incidence is unknown	**Indirect evidence (pressure injury incidence not reported)**
Pepperl et al., 2014	To describe the effect of alertness levels and backrest elevation on	Healthy volunteers (n=50) Inclusion criteria: • ≥18 years of age Exclusion criteria:	Volunteers where placed on a bed at backrest elevation of 30°, 45° and 60°. Skin interface pressures were measured at the above angles with the volunteer	• Pressure sensing matt measured interface pressure in mmHg. • Bed elevation was measured with a custom designed inclinometer	• There was an increase in peak pressure and average pressure with an increase in backrest elevation • When volunteers were in an alert state there was an increase in interface pressure	• Simulated sedation is different to a sedated patient	**Indirect evidence (pressure injury incidence**

Ref	Type of Study	Sample	Intervention(s)	Outcome Measures & Length of Follow-up	Results	Limitations and comments	
	interface pressures of the skin	• Sacral skin disorders • Neuromuscular disorders • Inability to move • Inability to speak English Participant characteristics: • Female: 41 Male: 9 • Mean age: 30 (SD 10.98) • Mean height: 66.8" (SD 3.19) • Mean weight: 155.78 (SD: 38.51) lbs • Mean BMI: 24.39 (SD: 4.93)	being either alert or in a simulated sedated state		• A higher BMI was associated with higher average pressure but lower peak pressure **Author conclusions: Interface pressure alone is a poor indicator of patient discomfort, frequency of repositioning may be more important in offloading tissues.**		**not reported)**
Lippoldt, Pernicka, & Staudinger, 2014	Open prospective randomized crossover trial to measure interface pressure between the sacrum and different support surfaces at different upright angles	Healthy volunteers (n=20) Participant characteristics: • 50% female • Median age 31 years • Median height 176 cm • Median weight 77.5kg • Median BMI 24kg/m^2	Participants were placed on 4 types of mattresses (all from Kinetic Concepts): • Therarest® VE Mattress System (visoelastic foam mattress) • AtmosAir 4000® Replacement System (foam mattress consisting of 4 dynamic air cylinders and automatic internal air pressure adjustment) • Proficare® Mattress Replacement System (alternating and static pressure air mattress with 17 chambers) • Therapulse® ATP (integrated mattress/bed system combining pulsating air suspension and low-air-loss)	• Pressure mapping system was used to measure interface pressure in mmHg with 10 repeated measures in 10 seconds • Sacral interface pressure was measured at 6 positions 0, 10, 30, 45 degrees, reverse Trendelenburg and upright position of 10 degrees and 30 degrees	**Interface pressure** • When the angle of the upright position was 45° a significant increase in peak pressures was found (p<0.001) • Low-air-loss technology system mattresses reduced peak interface pressure at all angles (p<0.001) • The reverse Trendelenburg position measured lower peak pressures in all positions (p=0.01) **Author conclusions: Low-air-loss technology in combination with reverse Trendelburg position and elevated head of bed can reduce interface pressure, but consideration should be given to risk of shear forces**	• Conducted on healthy volunteers • Measured using peak pressure vs peak pressure index • 32mmHg used as pressure threshold for capillary closing pressure although no evidence available to suggest causes tissue damage	**Indirect evidence (pressure injury incidence not reported)**
B. A. Crane, Wininger,	Observational study	Convenience sample of healthy volunteers (n=40	• All measurements were taken on a Hill-Rom	• Interface mapping using FSA pressure mapping system	• Average deviation of the positioning of sacral region on the interface pressure	• Healthy young volunteers	**Indirect evidence**

Ref	Type of Study	Sample	Intervention(s)	Outcome Measures & Length of Follow-up	Results	Limitations and comments	
& Kunsman, 2015	comparing **interface pressures in supine and side lying positioning**	included, data complete for 37) Inclusion criteria: • Aged >18 years • No orthopedic or medical condition that limited ability to lie for various periods Participant characteristics: • 70% female • Mean age 46 ± 16 years • Mean BMI 27.45 ± 5.9 kg/m^2 Mean body fat 36% ±7.8%	VersaCare® bed with P500 surface, powered weight base distribution system and a built in indicator for angle of head of bed (HOB) elevation. • Participants lay in 40° and 35° HOB elevation in both supine and side lying positions.	with readings every second for 2 minutes per condition.	map was 101.6±48.26mm from the mat center in supine and 365.8±114.3mm from mat center in side lying • Neither contact area nor pressure ratio indicated a significant effect due to HOB angle (p>0.05) • Supine positioning showed significant decrease in peak to average pressure (4.45±1.29 peak-to-average ratio in supine vs 4.99±1.16 in side lying; effect on position: –0.07±0.33, p<0.001 • All measures associated with higher risk of sacral region PU were higher in 30° HOB incline than in the 45°HOB incline. **Author conclusions: Raising HOB to 45° elevation may reduce risk of sacral PU.**	• Did not examine shear forces from HOB inclination • Indirect outcome	**(PU not an outcome measure)**
M. Peterson et al. (2008)	Observational study to evaluate interface pressure associated with head-of-bed elevation	Healthy volunteers (n=15)	Raised bed	• Interface pressure	There was a significant increase in interface pressures associated with raising the head-of-bed to 30° when the individual was positioned in the 30° lateral position using pillows or wedges (p < 0.05)	• Healthy volunteers	**Indirect evidence (PU not an outcome)**
Chung et al., 2012	Descriptive comparative design investigating **the effect of head of bed elevation angle on sacral and tuberosity peak pressures**	Participants recruited in long term care in Hong Kong (n =42) Inclusion criteria: • Impaired bed mobility • Bed bound Exclusion: • Independent bed mobility • Agitated or uncooperative • Unstable medical condition • Sacral or tuberosity pressure injury	Participants were positioned on standard mattresses wearing hospital gowns Participant was in each position for 6 minutes before pressure readings commenced Participants were positioned flat and in 15°, 30°, 45° and 60° head elevation	• Interface pressure measured using a sensor pressure map • In each position, 5 pressure recordings were taken and the mean value recorded •	**Sacral peak interface pressure** • Mean peak interface pressure was significantly greater (all p< 0.001) than in a flat position (38.6±2.5 mmHg) at 30° (50.4±3.6 mmHg); 45° (74.3±5.3 mmHg) and 60° (98.5±7.4) elevations **Tuberosities peak interface pressure** • Mean peak interface pressure was significantly greater (all p< 0.001) than in a flat position(29.8±1.0 mmHg) at 30° (41.8±1.6 mmHg); 45° (60.1±4.1 mmHg) and 60° (87.1±6.6) elevations	• The pressure-time curve values extrapolated from the study and presented in the discussion are not based on clinical evidence (i.e. there was no examination of how long the patient could withstand each	**Indirect evidence (PU not an outcome)** **Quality: moderate**

Ref	Type of Study	Sample	Intervention(s)	Outcome Measures & Length of Follow-up	Results	Limitations and comments	
		• Contraindications to recumbent position Characteristics: • Mean age 58.8 yrs (range 24 to 95) • Mean weight 51.3±11.4 kg • Mean BMI 22.3±4.0 • 57% stroke patients,$14% cerebral palsy, 7% multiple sclerosis				position before developing a PU)	
Best, Desharnais, Boily, Miller, & Camp, 2012	RCT evaluating **the effect of a trunk release manoeuvre (TRM) on interface pressure for sitting in bed**	Participants were a convenience sample of healthy, community-dwelling adults (n=117) Inclusion: • aged over 60 yrs • MMSE ≥ 22 Exclusion: • moderate to high risk of PU ≤14 on Braden scale Characteristics: • mean age 67.4 yrs (SD 6.7 yrs) mean BMI 24.8 (SD 4.5)	• All participants on same bed with visco-elastic foam mattress and fitted sheet. • Participants were randomly assigned to either: o low-tech TRM consisting of manual handling technique that involved pulling the trunk forward and away from support surface of the bed without lifting the buttock (n=59) control group in standard high Fowler's position (n=58)	Primary outcome: • Interface pressure measured as peak pressure index (PPI) Secondary outcomes: • trunk displacement (proxy measure for shear) defined as change in distance between top edge of mattress to top of participant's shoulder • perceived discomfort using either a horizontal numerical scale (0 to 10) or Wong-Baker Faces • location of discomfort using a body map	• The TRM group had a significantly lower mean PPI value post-intervention compared to the control group 59.6 (SD 30.7) mmHg versus 79.9 (36.5) mmHg, p=0.002 • There was a significant trunk displacement between the TRM group and the control group +3.2mm versus –5.8 mm, p=0.005 There were no significant differences in perceived discomfort between the groups	• Generalizability of the results • Crude indicator of trunk entrapment to capture displacement of the trunk • Intervention group had significantly more co-morbidities • IP at points other than the sacrum was not measured	**Indirect evidence: (PU not an outcome)** **Quality: moderate**
Källman et al., 2013	Descriptive comparative design investigating **the effect of positioning on tissue blood flow and skin temperature**	Convenience sample recruited from hospital wards in Sweden. Participants acted as their own controls. (n=20) Inclusion: • aged 65 years and older • able to lie in study positions Exclusion:	Participants were place in six positions for measurement of blood flow and skin temperature. • In all positions a 14cm thick pressure reducing cold foam mattress with a 65+50kg/m^3 density and covered with a soft elastic, vapor permeable overlay was used. The	• Superficial and deep tissue blood flow measured over bony prominences and in gluteus muscle using a photoplethysmography (PPG)instrument and probe • skin temperature measured over bony prominences and in gluteus muscle using a single sensor optical probe	**Tissue blood flow** • The median relative change in superficial blood flow over bony prominences increased in all supine positions and decreased in the lateral positions. • The blood flow over the bony prominence areas was most changed in superficial skin and was decreased most in the 30° lateral position ($p<0.05$ compared with supine positions)	• Participant movements may influence readings • Skin temperature increased during the procedure due to heat accumulation between the patient and the bed • Study was contradictory to	**Indirect evidence: 4** **Quality: moderate**

Ref	Type of Study	Sample	Intervention(s)	Outcome Measures & Length of Follow-up	Results	Limitations and comments	
	in lying positions	• history of PU, or an existing PU, or skin damage to the sacrum, trochanter or gluteus maximus • with fever (>37.5°C) Characteristics: • Mean age 84±7.5 years • Mean BMI 23±3.5 • Mean body temperature 36.5±0.5°C • Mean arterial pressure 76±3mmHg • Participants were taking a range of cardiac medications, analgesia and other systemic medications	mattress was covered with a cotton sheet. • All patients were dressed in a hospital gown and covered with a blanket during measurements • Six positions were used: in the same order for each participant: • Supine tilt 30° • Supine 0° • Semi-fowler with elevated head 30° • Semi-fowler with head and legs elevated 30° • Lateral 30° • Lateral 90°	• measurements were taken after 25 minutes in position	• Mean arterial pressure was significantly correlated with superficial blood flow over bony prominences (p=0.039) • There were significant individual differences in blood flow responses but no common trend **Skin temperature** • Skin temperature was significantly correlated with overall relative change in superficial blood flow (r=0.23, p= 0.007) • No relationship was found between skin temperature and relative changes in deep blood flow **Study conclusions: lying positions influences superficial skin blood flow in different ways.**	previous findings that skin oxygenation is lowest in lateral 90° position •	
Side-lying positioning/lateral tilt							
Oomens, Broek, Hemmes, & Bader, 2016	Observational and modelling study **exploring effect of lateral tilt on sacral region strain**	Three healthy subjects	• Participants underwent magnetic resonance imaging (MRI)	• MRI of sacral region • Comparison of skin, fat and muscle in MRI measurement on a flat surface • Modeling simulations for tilting angles between 0° and 45°	• Supine or tilted position is associated with higher strains in muscle and fat. Tilting reduces highest peak strains, with an optimal tilt angle between 20° to 30° • Optimal tilt angle may vary according to individual factors including BMI	• Only investigated strain at sacral region • Generalizability of findings is uncertain as results were per specific individual modelling and sample was only three individuals	**Indirect evidence (PU not an outcome measure)**
Defloor (2000)	Observational study to investigate interface pressure measurementi n 10 different positions	Healthy volunteers (n=83)	Participants were placed in position for one hour of immobilization Two different mattresses used	• Interface pressure	**Interface pressure** • prone position resulted in the lowest average interface pressure measurements. • 30° side laterally inclined position gave lower average readings than the 90° side-lying position.	• Healthy volunteers	**Indirect evidence: PU not an outcome measure, healthy volunteer s**

Ref	Type of Study	Sample	Intervention(s)	Outcome Measures & Length of Follow-up	Results	Limitations and comments	
					Author conclusion: 90° side-lying position gives the highest interface pressure measurements		
Continuous lateral rotation							
Woodhouse, Worsley, Voegeli, Schoonhoven, & Bader, 2015	Observational study to **compare an automated lateral rotation bed to manual tilt**	Participants were recruited from a university (n=10) Exclusion: • History of skin conditions • Unable to lie supine for 2 hours Characteristics: • Mean age 41 years (range 23 to 61) • Mean height 1.75±0.18 m • Average weight 78.5±11.8kgs	• Room temperature was at 24°C and patients wore loose fit clothes • Baseline measures taken • Participants were positioned in four positions (right tilt, supine, left tilt, supine) for 15 minutes each and measures were taken 5 mins after repositioning • All participants were repositioned by both methods (on 2 separate days): ○ A lateral pressure redistribution (LPR) bed with a continuous low pressure mattress that provides a 14° tilt automatically and optimized to partipant's BMI ○ Manual tilt provided by a nurse on the same mattress and using a pillow positioned lengthways at the back for support	**Peak interface pressure (IP)** Pressure mapping at shoulder, body and sacrum **Transcutaneous oxygen (T_cPO_2)and transcutaneous carbon dioxide (T_cPCO_2)** measured using skin probes on sacrum and right shoulder Classified as: • Category 1: minimal change • Category 2: > 25% decrease in T_cO_2 and minimal change in T_cPO_2 • Category 3: > 25% decrease in T_cO_2 and > 25% increase in T_cPO_2 **Comfort and safety** Likert scale assessment by participants	**Peak IP** No significant differences were found in peak IP at the shoulder, sacrum or body) in supine, left tilt or right tilt (all p>0.05) **T_cPO_2 and T_cPCO_2** • In both tilt methods there was Category 1 change in initial supine position • In left tile, one participant had a change in sacral values (observed in both tilt methods) • During second supine phase one participant on LPR and two participants in manual tilt had a Category 3 change as shoulder **Comfort and safety** Participants reported greater comfort and safety in supine than tilt positions Feeling unsafe was more frequently reported in the tilt position for the LPR compared with manual positioning (p<0.005) **Conclusions: Response was generally similar for LPR and manual tilt. Confirmed that physiological changes occur in gas tensions during repositioning**	• Healthy subjects, the results may not be relevant to individuals in critical care • Small sample size • Only one cycle of tilting performed, effect of repositioning over time is not evaluated • Participants were in the center of mattress, which may not fully replicate clinical conditions	**Indirect evidence: PU not an outcome measure, healthy volunteers** **Quality: moderate**
Anderson, Kleiber, Greiner, Comried, & Zimmerman, 2016	Repeated measures observational study **to explore**	Convenience sample of healthy volunteers (n=10) Inclusion criteria: Healthy and consenting	• All measurements were taken on a Hill-Rom TotalCare SpOrt® bed with standard linen and an under pad.	Pain assessment using a verbal numeric scale (0 to 10 with 10 being worst pain) Pressure sensitive map (XSENSOR®) taking pressure	**Interface pressure at ischial tuberosity** • Average pressure showed significant time/scenario effect (p=0.012) • Scenario 1 mean pressure was 4.78±0.49 lower compared to scenario 2 (p <	• Healthy volunteers • Small sample that did not include older adults	**Indirect evidence (PU not an**

Ref	Type of Study	Sample	Intervention(s)	Outcome Measures & Length of Follow-up	Results	Limitations and comments	
	interface pressure in three lateral rotation positions	Exclusion criteria: • Diabetes mellitus • Peripheral vascular disease • Aged > 65 years or < 18 years • Current continuous use of non-steroidal anti-inflammatories • Chronic skin breakdown • Current PUs Participant characteristics: • 60% female • Age range 18 to 63 years • BMI range 20.3 to 48.9 kg/m^2 • 20% had dark skin	• Participants lay in semi-fowler's position and were aligned according to bed manufacturer recommendations (marks on side rails). • Three positioning scenarios were measured, each for a period of 30 mins: ○ Continuous lateral rotation therapy (CLRT) at 40°, 30-second pause L-C-R, no training ○ CLRT at 40°, 30-s pause L-C-R, no training; static manual wedge (40°) positioning to the left. ○ Static manual wedge (40°) positioning to the left. No CLRT.	every second for 30 mins per scenario Posterior skin check	0.0001), and 3.85±0.70 lower compared to scenario 3 (p = 0.0006), with no significant difference between scenarios 2 and 3 (p = 0.425) **Interface pressure at hip** • Average pressure showed significant time/scenario effect (p=0.0009) • Scenario 1 mean maximum pressure was 27.23±5.83 lower compared to scenario 2 (p = 0.001), and 27.22±7.58 lower compared to scenario 3 (p= 0.009), with no significant difference between scenario 2 and 3 (p > 0.99) **Interface pressure at heel** • Average pressure showed significant time/scenario effect (p<0.0001) • Scenario 1 mean pressure was 7.82 ±1.43 higher compared to scenario 2 (p =0.0003), and 7.95±1.83 higher compared to scenario 3 (p = 0.002), with no significant difference between scenarios 2 and 3 (p = 0.997) **Other outcomes** • No significant difference in pressure at elbow or scapula • Pain was lower in CLRT positions compared with static wedge. • No visible erythema before or after intervention for any participant **Author conclusions: CLRT showed significantly lower interface pressures at ischial tuberosity and hip compared to static wedge without CLRT; however heel interface pressure was higher.**	• Indirect outcome measure	**outcome measure)**

Ref	Type of Study	Sample	Intervention(s)	Outcome Measures & Length of Follow-up	Results	Limitations and comments	
Do et al., 2016	An observational study **exploring effects of continuous lateral rotation on interface pressure**	Convenience sample of healthy volunteers (n=24) Inclusion criteria: • No neck pain for past 2 years • No diabetes, significant musculoskeletal injury or neurological disorder • No chronic PU Participant characteristics: • Mean age 28.2 (SD 4.3) years • Mean weight 63.7 (SD 16.7) kgs • Mean height 1.70 (SD 0.1) m • Mean BMI 22.2 (SD 4,2) kg/m^2 • 100% Asian	• Participants positioned supne on bed on pressure sensor mats • Bed turned each participant from 0° to 0°, 15°, 30° or 45° for 45 mins then returned to supine in following 15 mins at a constant speed • Continuous lateral rotation device consisted of moving parts and a standard mattress 80mm thick polyurethane with 60kg/m^2 density	Interface pressure at occiput, scapulas, sacrum, greater trochanter and heels	• Peak interface pressure was significantly lower at 15° rotation at the occiput, left scapula, sacrum and both heels (compared with an angle 15° lesser) • Peak interface pressure was significantly lower at 30° rotation at the occiput, both scapula, sacrum , right trochanter and both heels (compared with an angle 15° lesser) • Peak interface pressure was significantly lower at 45° rotation at the occiput, both scapula, sacrum , right trochanter and both heels (compared with an angle 15° lesser) **Author conclusions: continuous lateral rotation is associated with lower interface pressure and therefore greater pressure relieving ability than standard supine positioning.**	• Small study with only healthy volunteers • Did not measure incidence of PU	**Indirect evidence (PU not an outcome measure)**
Prone positioning							
Girard, Baboi, Ayzac, Richard, & Guerin, 2014	RCT exploring effectiveness of early long standing prone positioning to supine position in patients with severe acute respiratory distress syndrome (ARDS)	Secondary analysis from an RCT (n=474 included, 466 analysed) Inclusion criteria: Severe ARDS defined as partial pressure oxygen in arterial blood/fraction of inspired oxygen ratio of <150 mmHg	Participants were randomized to receive either: • Supine positioning: not reported in detail (n=229) • Prone positioning: prone-positioning for long periods initiated within 1 hour of randomization, with sessions lasting ≥16 hours, prophylactic dressings also used (n=237)	• Incidence of new patients with Category/Stage II to IV using NPUAP classification • Secondary end points: ○ Incidence of new patients with pressure injury from day 1 to day 7 ○ Incidence of new pressure injury from day 1 to day 7 and from day1 to discharge ○ Mortality in ancillary study	**Pressure injury outcomes** • Incidence of pressure injuries at day 7 was significantly higher in supine group (57.1 versus 42.5, p=0.005) • Incidence of pressure injuries at discharge from ICU was not significantly different between groups (prone 44.4 versus supine 37.8, p=0.151) • Incidence of new patients with pressure injuries was not significantly different between groups when measured by days on mechanical ventilation (prone 20.80 versus supine 14.26/1,000 days of invasive mechanical ventilation, p=0.061) • Incidence of new patients with pressure injuries was significantly higher in prone	• Number of ICUs participating in the study was not included in this report • Not blinded • Secondary analysis without full reporting of methods	**Level of evidence: 1** **Quality: Low**

Ref	Type of Study	Sample	Intervention(s)	Outcome Measures & Length of Follow-up	Results	Limitations and comments	
				Participants followed until discharge from the intensive care unit	group when measured by days in ICU (13.92 vs 7.721,000 of ICU days, p=0.002) **Factors associated with pressure injuries in ARDS patients** • position group (odds ratio [OR] 1.5408, p=0.0653) • age > 60 years (OR 1.5340, p= 0.0019) • female gender (OR 0.5075, p=0.019) • body mass index of >28.4 kg/m2 (OR 1.9804, p=0.0037), and • Simplified Acute Physiology Score II at inclusion > 46 (OR 1.2765, p=0.3158) **Author conclusions: After controlling for confounders, positioning was no longer significant in pressure injury incidence**		
Grisell & Place, 2008	Blinded RCT **comparing different facial pillows for prevention of PU <u>in the OR setting</u>**	Participants were consecutive patients admitted for elective surgery requiring prone position at a surgery in the USA (n=66) Inclusion: • elective thoracic and/or lumbar surgery requiring prone positioning • aged 18 to 65 yrs Exclusion: • existing facial ailment including redness, inflammation, rash, graze, bruising • history of increased intraocular pressure or glaucoma • major language not English	• All participants were positioned using standard prone positioning. • Patients were randomized to receive different facial pillows: ○ Orthopedic Systems Inc (OSI) disposable polyurethane foam positioner (n=22) ○ Dupaco Prone View® Protective Helmet System disposable polyurethane foam head positioner (n=22) ○ ROHO Group neoprene air filled bladder dry flotation device (n=22)	• Facial tissue pressures were measured at the patient's forehead and chin at time 0, 5, 15, and 60 minutes of positioning • The integrity of skin was recorded and classified using NPUAP system staging at the end of surgery	• 10 patients (45%) positioned on the disposable polyurethane foam positioner developed PUs (eight stage I PUs and two stage II PUs) • No patients from the other two groups showed any evidence of PUs • The pressure measurements for the Dupaco Prone View® were lower at all of the time points for both the forehead and the chin in comparison to the disposable polyurethane foam positioner nb and the ROHO ($p<0.05$) • Forehead pressures were significantly less for the ROHO compared with the disposable polyurethane foam positioner ($p<0.05$)	• Patients were not stratified by age, race, or gender and existing risk factors for PU not reported • Risk of PU on entry to study not reported • Length of time in position not recorded (procedures last from 1 to 12 hours)	**Level of evidence: 1** **Quality: low**

Ref	Type of Study	Sample	Intervention(s)	Outcome Measures & Length of Follow-up	Results	Limitations and comments	
		Characteristics: • surgery times from 1 to 12 hours and not reported • no demographic data					
Romero et al., 2009	Case series **investigating the effect of prone positioning ventilation and reporting PU as an adverse effect of positioning**	Participants were recruited from an ICU in Chile (n=15) Inclusion: • aged over 18 years • severe Acute Respiratory Distress Syndrome (ARDS) • ventilation >72hrs Exclusion: • contraindications to prone positioning ventilation • hemodynamic disorders • chronic respiratory insufficiency • likelihood of death in 24hrs Characteristics: • Mean age 46±17 years (range 19 to 69) • Mean time for mechanical ventilation 19±9 days (rang 4 to 64) • 40% died	Prone position ventilation for 48 hours or until the oxygenation index was 10 or less (extended PPV)	Primary: • Barotraumas and/or monobronchial incursion of the orotracheal tube • Arterial and venous blood gas results Secondary: • Development of a new PU as assessed using NPUAP staging	• Prone position ventilation was continuously maintained for 55 ± 7 hours • Two patients (13%) developed grade II PUs (nasal septum, cheek) • All patients experienced facial edema • No patients experienced ventilation complications in prone position	• No control group • Only 20% of the individuals were older than 60 years	**Level of Evidence: 4** **Quality: moderate**
Wu, Wang, Lin, Liu, & Chao, 2011	Observational study	Participants were recruited in a spinal unit in Taiwan (n=30) Inclusion: • spinal surgery • expected surgery duration ≥ 3 hrs • prone positioning Exclusion: • emergency surgery	Participants received either: • 10cm thick high density foam (HDF) • 2cm thick viscoelastic pads(VP) Each participant had VP on the left side of the chest and iliac crest and HDF padding on the right side	• Interface measurement prior to starting surgery Presence of PU as defined by NPUAP classification observed 30mins following surgery and if PU present then again in 24hrs and 48hrs	• Immediately after surgery 75% of participants had nonblanchable skin redness on iliac and chest pressure points (73% of VP pressure points, 77% of HDF pressure points). • At 30mins post-operative overall incidence of PU was higher in HDF group, but not difference was not significant (10% versus 5%, OR=0.47, 95% CI 0.11 to 1.99, p>0.05) • One stage II PU in VP group after 48 hrs	• 48 hours follow up • small sample size • Side that the pad was placed not randomized • Blinding of assessor and statistician not reported • Not designed for the null hypothesis	**Level of Evidence: 4** **Quality: moderate**

Ref	Type of Study	Sample	Intervention(s)	Outcome Measures & Length of Follow-up	Results	Limitations and comments	
		• vascular disease • diabetes • Braden score <18 Characteristics: • Mean age 57.2±19.6 years • Mean weight 62.3±10.5kgs • 6.7% had BMI <18, 26.7% had BMI 18 to 24, 53.3% participants had BMI of 24 to 29, 13.3% had BMI >30 • Mean Braden scale 20.8±1.2 Mean operative time 285.4±73.4 mins			• Interface pressure was significantly lower (p<0.001) with VP pad • Univariate analysis of risk factors for PU at 30mins ○ Female gender(OR=0.04, 95% CI 0 to 0.79, p<0.05) ○ BMI < 18 (OR=21.40, 95% CI 4.11 to 111.51, p<0.05) ○ Body weight <50kgs (OR=18.57, 95% CI 4.06 to 85.03, p<0.05)		
Sitting positions							
Jan & Crane, 2013a	Prospective repeated-measures design to evaluate effect of different seating angle on individuals with spinal cord injury	Participants included in the study are wheelchair users with spinal cord injury (SCI) (n=10) Measures were conducted in a university research laboratory Inclusion criteria were reported in Jan, Jones, Rabadi et al (2010)	Six protocols with various wheelchair tilt-in-space and recline angles randomly assigned to the participants: • 15^0 tilt-in-space and 100^0 recline, • 25^0 tilt-in-space and 100_ recline, • 35^0 tilt-in-space and 100_ recline, • 15^0 tilt-in-space and 120^0 recline, • 25_ tilt-in-space and 120_ recline, and • 35_ tilt-in-space and 120_ recline. Each protocol consisted of a 5-minute upright sitting and a 5-minute tilted and reclined period.	• Skin perfusion over the sacrum and right ischial tuberosity measured using laser Doppler flowmetry. • Each protocol consisted of a 5-minute upright sitting and a 5-minute tilted and reclined period. •	**Skin perfusion** • Sacral skin perfusion did not show a significant difference between protocols of various tilt-in-space and recline angles when changing from an upright to a tilted and reclined position (p>.05) • Ischial tuberosity skin perfusion showed significant increase at 15°, 25°, and 35° tilt-in-space when combined with 120° recline (P<0.01) and a significant increase at 35° tilt-in-space when combined with 100° recline (p<.008) **Author conclusion: wheelchair tilt-in-space and recline enhances skin perfusion over ischial tuberosities without reducing sacral skin perfusion when changing from an upright to a tilted and reclined position.**	• Small number of participants, all with SCI • Only one wheelchair used • No evaluation of impact on pressure injury prevalence or incidence	**Level of Evidence: 4** **Quality: low**

Ref	Type of Study	Sample	Intervention(s)	Outcome Measures & Length of Follow-up	Results	Limitations and comments	
Miller, Aberegg, Blasiole, Parker, & Fulton, 2014	Observation study to evaluate the effect of and two common positions in standard hospital reclining chairs on interface pressure	Healthy volunteers (n=23)	• Volunteers sat in upright position (feet on the floor, and seat back upright) for 6 minutes • Then sat in position 2 (legs elevated and seat back reclined) for 6 minutes then FSA data collected	• Force sensing array was placed on reclining chair • Average pressure, maximum pressure and sensors measuring 60 or 80 mmHg or higher	**Interface pressure** • Legs elevated and reclined position reduced average pressure, and reduced the number of sensors measuring interface pressure as over 60 mmHg • BMI and position were significantly correlated with number of sensors over 80 mmHg and average pressure • Patients with BMI over 29 have decreased sacral pressure when legs are elevated.	• Small sample size • No participants in the underweight category • Use of healthy volunteers, average age 45 •	**Indirect evidence (PU not an outcome measure)**
Taule et al., 2013	To identify factors that predict unsatisfactory seating pressure in spinal cord-injured (SCI) individuals.	Participants recruited in a spinal cord injury clinic in Norway (n=75) Inclusion criteria: • All wheelchair users with traumatic SCI hospitalized between 1 January 2007 and 31 December 2010 Exclusion criteria: • Not reported Participant characteristics: • not reported under risk factors • Mean age 47.2	Using the participant's own wheelchair and cushion, the patient was assessed: • seating in wheelchair without any intervention • change of air level of cushion, use of alternative cushions or • elevation/ lowering of footrest is applied if necessary	• Seating pressure was measured by a 40-by-40 cm computerized seating pad • Possible risk factors collected from records,, through semi-structured interview and observation during the assessment. • Factors such as activity level, procedures of relief, transfer, wheelchair and cushion used during the seating assessment were included to the assessment	• Risk of unsatisfactory seating pressure is significantly high among patients with: o history of pressure injury ($p<0.001$) o use of manually driven wheelchair. • Paraplegia was not a significant factor	• Retrospective methodology and limited to the patients who were hospitalized at the SCI unit	**Indirect evidence (PU not an outcome measure)**
Tederko et al., 2015	Prospective cross sectional study to examine the relationship between the elevation of wheelchair footrests and the pressure and symmetry	Participants were recruited in Poland (n=17) Inclusion criteria: • Paraplegia following SCI ≥ 1 year ago • Daily wheelchair usage • Transfer independently Exclusion criteria:	• Pressures exerted by the ishial tuberosity on the wheelchair cushion were measured at different footplate angles o p0: thighs parallel to seat o p10: footrests elevated by 10% of fibula length (FL)	• Subjects sat in a standard wheelchair with a standard 5cm foam cushion. Pressure exerted by the ishial tuberosities were measured after ten minutes using XSENSOR X3 in mmHg.	• Although there was a proportional rise in the average pressure exerted by the ischial tuberosities with an increase in footplate elevation, when ischial tuberosities exertion pressures were measured individually (right and left) the changes in pressure were random. **Authors conclusions It is important to adequately position footrests in a patient**	• Other factors that affect pressure distribution not examined • Pressure distribution may have been different with different kinds of	**Indirect evidence (PU not an outcome measure)**

Ref	Type of Study	Sample	Intervention(s)	Outcome Measures & Length of Follow-up	Results	Limitations and comments	
	on the ishial tuberosities of individuals with paraplegia	• Presence of pressure injury • Pressure injury in past year • Knee and hip flexion < 120° • Asymmetry of fibula >1cm Participant characteristics: • Average time since disability 19.3years • Average weight 70.7kg • Average height 174.3cm • Average BMI 23.1	○ p20: footrest elevated by 20% of FL		**in a wheelchair with a SCI as footrest elevation may bring about unpredictable pressure injury risk**	cushions commonly used • Small homogenous sample	
Kobara, Takahashi, et al., 2015	To investigate the effect of the timing of leg support elevation on the shear force on the buttocks in a reclining wheelchair.	Sample: healthy men without leg or trunk disease (n= 17) Exclusion criteria: • Back pain • History of surgery • Rheumatism • Neurological disorders Participant characteristics: • Mean age 22.6 (SD 6.6) years • Mean height 170.1 (SD 4.4) cm • Mean weight 62.4 (SD 8.9) kgs	Participants sat in a wheelchair in either the leg up or leg down position. The back support of the wheelchair was reclined at angles increasing from initial upright position to the fully reclined position and then back to the upright position. Horizontal and vertical forces were measured.	• Shear force was measured by using a force plate under the buttocks that measured horizontal and vertical forces. • The back support movement was measured using a video camera and video analysis software	• The horizontal force with the legs elevated was significantly higher than with the legs down in all positions of back support **Authors conclusion: Leg supports should be positioned downwards before reclining the back support a wheelchair the prevent pressure injury formation**	• Small sample of healthy males • Delayed postural collapse and alignment not measured • Footplates not used, affecting horizontal downward force • Factors that interact with friction force not considered such as urinary incontinence and sweat.	**Indirect evidence (PU not an outcome measure)**
Webb, Twiste, Walton, & Hogg, 2017	Observational study to evaluate the impact of three different sling fabrics on the interface pressure over	Participants were wheelchair users from 2 clinics in England (n=32) and healthy students (n=61) Participant characteristics: • Wheelchair users:	• Seated on an adjustable height chair with knees at approximately 90° flexion A six-minute settling time used, after which pressure readings commenced with sensor pad • Measurements were taken in four conditions,	• Pressure readings were recorded every 30 s over ten minutes in each condition such that the participant was seated for 16 min in each condition. Interface pressure mapping was carried out. • Mean pressure at gluteal region (buttocks and thighs)	**Interface pressure** • Sling fabric - Mean gluteal interface pressure, $F(3,29) = 4.78$, $p = 0.008$, compared to the control condition. • Spacer fabric - reduced the mean gluteal interface pressure and this approached significance (spacer $p = 0.06$, 95%CI) • Slipfit and polyester fabrics had no effect ($p = 1$ for both fabrics, 95%CI)	• Pilot data that was included in analysis is from healthy participants • Different sample sizes	**Indirect evidence (PU not an outcome measure)**

Ref	Type of Study	Sample	Intervention(s)	Outcome Measures & Length of Follow-up	Results	Limitations and comments	
	the gluteal region when sitting.	Mean age 55.3±13.9, mean weight 84.2±6.8kg, mean BMI 29.97 • students: mean age 44.3±11.4, mean weight 75.73±17.5, mean BMI 27.43	randomized to reduce systematic carry-over effects: ○ Control - Seated on chair with pressure mapping system only ○ Condition A - Control plus sling in spacer fabric ○ Condition B - Control plus sling in slip-fit fabric ○ Condition C - Control plus sling in polyester fabric	• Peak pressure at left and right ischial tuberosities • Peak pressure at left and right greater trochanters • Peak pressure at the coccyx	**Author conclusions: fabric identified as the most effective in reducing mean and peak pressures in both groups was the spacer fabric, suggesting that a spacer fabric sling is more likely to reduce the risk of pressure ulcer development**	• Range of disabilities for wheelchair group	
Chen et al., 2014	Observational study on tilt and recline seating influence on interface pressure	wheelchair users with SCI (N=13)					**Indirect evidence (PU not an outcome measure)**
Jan, Crane, Liao, Woods, & Ennis, 2013	Lab research to compare the efficacy of wheelchair tilt-in-space and recline on enhancing muscle and skin perfusion over the ischial tuberosities in people with spinal cord injury (SCI)	Power wheelchair users with SCI (N=20) • Inclusion criteria: • traumatic SCI level of C4-T5 with American Spinal Injury Association Impairment Scale grade of A,B, or C • at least 6 months post spinal injury • Power wheelchair • wheelchair seat width 43cm (17in) to 53cm (21in) Exclusion criteria: • cardiorespiratory or other diseases that may affect	• Six protocols of various wheelchair tilt-in-space and recline angles were tested in a random order • Room temperature was maintained at 24 ^{0}C ± 2^{0}C • The participants stayed in the laboratory for at least 30 minutes prior to testing	• Skin perfusion response to 15 degree tilt-in-space combined with 100 degree recline • Skin perfusion response to 35 degree tilt-in-space combined with 120 degree recline. • Muscle perfusion (StO2) response to 15 degree tilt-in-space combined with 100 degree recline • Muscle perfusion response to 35 degree tilt-in-space combined with 120 degree recline • A 5-minute upright sitting was used to induce soft tissue ischemia, and the 5-	**Muscle perfusion** • Muscle perfusion showed a significant increase compared with baseline sitting for 25° protocol and and 35° tilt-in-space combined with 120 degree recline (both p<0.05) • Remaining 4 protocols did not show a significant difference **Author conclusions: a larger angle of tilt-in-space and recline is needed to improve muscle perfusion compared with skin perfusion. A position of 25 degree tilt-in-space combined with 120 degree recline is effective in enhancing muscle and skin perfusion of weight-bearing soft tissues at the ischial tuberosities.**	• Unclear whether this depth was adequate to include the entire muscle thickness between the ischial tuberosity and the skin surface • Muscle perfusion of weight-bearing tissues may require a longer time for recovery • Influence on pressure injury prevalence or	**Indirect evidence (PU not an outcome measure)**

Ref	Type of Study	Sample	Intervention(s)	Outcome Measures & Length of Follow-up	Results	Limitations and comments	
		cardiovascular or circulatory function; • skeletal deformities • active pressure injury Participant characteristics: • Primarily male • 15 Caucasian, 2 dark skin, 3 Hispanic Americans • mean age 41.4±12.6 mean body mass 25.4±3.7kg/m^2 • mean spinal injury duration 7.8 ± 6.1 years		minute tilted and reclined period was used to improve muscle and skin perfusion		incidence is not discussed	
Jan, Liao, Jones, Rice, & Tisdell, 2013	Repeated measures study to compare different durations of wheelchair tilt-in-space and recline on enhancing skin perfusion over the ischial tuberosity in people with spinal cord injury (SCI)	Power wheelchair users with SCI (n=9) Inclusion criteria: • Traumatic SCI between C4 and T5 • ≥6 months after injury • Use powered wheelchair • Wheelchair seat width 0.43cm Exclusion criteria: • cardiorespiratory disease • Other diseases that may affect cardiovascular function • BMI greater than 30kg/m^2 • Active pressure injury Participant characteristics: • Mean age 38 ± 13 years • Mean BMI 24.5± 2.3 kg/m^2 • Duration of SCI 6± 5.	• Each participant sat upright in the wheelchair for 15 minutes, then was reclined and tilted for 0, 1 or 3 minutes. A further 15 minutes sitting upright followed by a 5 minute recovery. • Reclined, tilted and recovery positions were 35° tilt in space and 120° incline	Skin perfusion response was measured using the laser Doppler flowmetry over the ischial tuberosity at a depth of 1mm^3	**Skin perfusion** • Skin perfusion at 3 minute recovery period was significantly higher than at 1 minute recovery (p=0.017) but was not significantly different between the 1 minute and 0 minute durations • Skin perfusion following the 3 minute tilt-in-space recline of the second sitting significantly increased compared with the 1 minute tilt in space recline **Author conclusions: When trying to reduce ischemia to weight bearing tissue it may be more beneficial to tilt-in-space and recline for 3 minutes compared to 1 minute or 0 minutes**	• Skin perfusion only assessed for a short time • Only 9 participants • Influence on pressure injury prevalence or incidence is not discussed	**Indirect evidence (PU not an outcome measure)**

Ref	Type of Study	Sample	Intervention(s)	Outcome Measures & Length of Follow-up	Results	Limitations and comments	
Li et al., 2017	This study examined the four modes of reclining wheelchair without and with different sitting assistive devices in terms of their effects on human wheelchair interface pressure.	Healthy participants were recruited in Taiwan Hospital (n=16) Inclusion criteria: healthy adults Exclusion criteria: identifiable spinal pathologies, musculoskeletal disorders, and movement disorders. Participant characteristics: • Mean age, 22.6±1.5 years • Mean weight, 61.9±12.3 kg • Mean height, 166.4 9.0 cm • Mean body mass index, 22.2±3.0 kg/m2	Four modes were observed in the same way: ○ BRM: the wheelchair backrest was pushed backward to reach a 150° recline ○ LBM: the backrest of the wheelchair was pushed backward to reach a 150° recline, while a lumbar airbag, fully inflated to a thickness of 4 cm, was placed at the L3 spinal segment ○ FBM: the backrest of the wheelchair was pushed backward to reach a 150° recline, and a femur airbag, fully inflated to a thickness of 4 cm, was placed at the midpoint of the thighs • LFBM: the backrest of the wheelchair was pushed backward reach a 150° recline and both lumbar and femur airbags were used, the lumbar airbag, fully inflated to a thickness of 4 cm, was placed at the L3 segment of the participant, whereas the femur airbag, also fully inflated to a thickness of 4 cm, was placed at the midpoint of the thighs • Participants requested to stand for 1 min between four tested modes	• Record and calculate contact area(CA),average pressure(AP),and peak pressure(PP) on the back area (BCA,BAP,BPP),the ischial area(ICA,IAP,and IPP),and the femur area(FCA,FAP,FPP) • Two pressure-mapping mats were used to measure human-wheelchair interface pressure • Interface pressure collected for 5s while participant maintained a stable sitting position	Average pressure on back area (BAP): BRM: 2.59±0.31 (kPa) (P ＞0.05) LBM: 2.39 ± 0.20 (kPa) (P ＞0.05) FBM: 2.53 ± 0.35 (kPa) (P ＞0.05) LFBM: 2.42 ± 0.30 (kPa) (P ＞0.05) Peak pressure on the back area(BPP) BRM: 4.71 ± 1.35(kPa) (P ＞0.05) LBM: 4.10 ± 0.80 (kPa) (P ＜0.05) FBM: 4.44 ± 1.50 (kPa) (P ＞0.05) LFBM: 3.87 ± 1.26 (kPa) (P ＜0.05) Ischial contact area(ICA) of four Modes BRM: 438.06 ± 119.12(cm²) (P ＜0.001) LBM: 417.25 ± 122.13(cm²) (P ＜0.001) FBM: 329.06 ± 118.24(cm²) (P ＜0.001) LFBM: 340.19 ± 134.36(cm²)(P ＜0.001) Average pressure on ischial area(IAP): BRM: 4.05 ± 1.00(kPa) (P ＞0.05) LBM: 3.74 ± 0.95 (kPa) (P ＜0.05) FBM: 3.81 ± 1.01(kPa) (P ＜0.05) LFBM: 3.33 ± 0.89 (kPa) (P ＜0.05) Peak pressure on the ischial area(IPP) BRM: 21.67 ± 11.93(kPa) (P ＜0.05) LBM: 15.19 ± 6.82 (kPa) (P ＜0.05) FBM: 18.97 ± 10.24(kPa) (P ＜0.05) LFBM: 13.18 ± 8.33 (kPa) (P ＜0.001) **Conclusion: LFBM was most effective in reducing stress load on ischial area and shifting stress to the femur. None of the four modes significantly affected the load on the back.**	• Nondisabled participants • Study was a short-term evaluation only • The larger shear force potentially experienced by the back could not be measured; a person's hamstrings pull the pelvis and lead to posterior pelvis rotation, causes the ischial tuberosities to generate a shear that could not be measured. • Unable to provide clear conclusions regarding pressure variations in different areas within one mode	**Indirect evidence (PU not an outcome measure)**

Ref	Type of Study	Sample	Intervention(s)	Outcome Measures & Length of Follow-up	Results	Limitations and comments	
Gabison, Mathur, Nussbaum, Popovic, & Verrier, 2017	To determine relationship between trunk function and offloading ischial tuberosities	Convenience sample Recruited in a rehabilitation institute in Canada (n=20 eligible, n=15 included) Inclusion criteria: • non-ambulatory SCI • AIS class: A-D • medical stable • using wheelchair as primary means of mobility > 2 hr / day • Exclusion criteria: • existing PU • significant musculoskeletal conditions • impaired neurological status affecting sitting balance due to conditions other than SCI • brain injury Participant characteristics: • Age 43 (±16,7); • male 14/17; • H:172±7,7; • W:70±20; • AIS: A=9/17; B=5/17; C=1/17;D=2/17; • Traumatic SCI 13/17 wheelchair manual 15/17	N/A	• Trunk strength (dynamometer in Nm's) reported as reachers and non-reachers. Adequate reaching is the ability to reach in six defined directions without losing balance, measured with a distance meter(laser) and a pressure mat (SensiMAT ™). • Reachers vs non-reachers. During a two hour sample time, activity logs were completed. Cumulative pressure offloading time data were converted to seconds per hour (s/hour). • Offloading=: equivalent in value to that when no pressure was applied (min. 2 sec). • main analysis: associations between trunk strength and pressure offloading times (Spearman's Rank Correlation)	• no statistically significant correlation between trunk strength and pressure offloading times for both groups. • Trunk strength was statistically significantly lower in non-reachers compared with reachers	• Small sample size • The practical implications are difficult to interpret • This study shows that it is possible to differentiate between reachers and non-reachers in SCI patients. •	**Level of evidence: Indirect (PU not an outcome)** **Quality: moderate**
Gebhardt and Bliss (1994)	Cross over RCT investigating effect of a sitting protocol restricted to	Participants underwent fracture repair requiring orthopedic surgery (n=57)	All participants were placed on large-celled alternating mattress		• Significantly fewer pressure ulcers (7%) developed in individuals with fractures who were allowed to sit for two hours or less per session than in those allowed to sit in a chair for unlimited periods (63%) (p<0.001)		**Level of Evidence: 1** **Quality: low**

Ref	Type of Study	Sample	Intervention(s)	Outcome Measures & Length of Follow-up	Results	Limitations and comments	
	two hours per session						
Giesbrecht, Ethans, & Staley, 2011	Repeated measures observational study **measuring reduction in interface pressure associated with tilted seating positions**	Participants were recruited from an outpatient SCI clinic in Canada. (n=18) Inclusion: • aged 18 to 65 yrs • SCI with American Spinal Injury Association (ASIA) A or B level of injury Exclusion: • Substantive scoliosis or deformity preventing central alignment in sitting Characteristics: • 94% sample was male • Mean age 42.6 yrs (SD 8.3 yrs) • Mean weight 74.7 kgs (SD 12.7kgs)	Using a standardized protocol participants seating was tilted in 10° increments between 0° and 50°	• Relative pressure reduction from baseline was calculated and compared between tilt angles using interface pressure (IP) readings obtained at the ischial tuberosities (IT) and sacrum using pressure mapping technology	• No significant difference between IP at left and tight IT • Tilt angles above 20° significantly reduced IP at the ITs F(4,17)=165.1 to 202.7, p=0.000 with each successive tilt producing greater relative IP reduction • Tilt angles above 30° significantly reduced sacral IP (p=0.000 to 0.002), with slight increase in IP at 10° tilt • Pressure reductions were not significantly different between tetraplegic and paraplegic participants **Conclusion: A minimum tilt of 30° is required to initiate unloading the sacrum and to achieve a clinically significant reduction in pressure at the IT**	• Sitting tolerance and the potential for changes in pelvic positioning not considered, IP readings taken after 1 minute • Use of the participants' own seating products may reflect true effects of tilt • Randomizing the application of tilt angle and obtaining multiple measures for test-retest reliability would have been optimal	**Indirect evidence: indirect outcome measure Quality: moderate**
Shabshin, Ougortsin, Zoizner, & A., 2010	Experimental investigation investigating **thickness of fat layer in different seating tilts**	n=10 healthy volunteers	• Subjects underwent sitting MRI in six postures including neutral with/without weight-bearing, 10° and 20° lateral-tilts and 20° and 40° anterior lifts	• Thickness of tissues between the skin and the lowest point of the ischial tuberosity, of fat between the skin and the gluteus muscle and of muscle between the ischial tuberosity and fat • Measurements in weight-bearing positions were compared to the non-weight bearing for calculation of compressive tissue deformations in each trunk tilt	• Muscle and soft tissue compressive deformations from highest and lowest were 20° lateral tilt (87%, 72%), lateral 10° (85%m 70%), anterior 20 (79%, 67%), anterior 40° (74%, 64%) and neutral (72%, 59%) • For the fat highest was anterior tilts (42%), followed by lateral 20° tilt (41%), lateral 10° (39%) and neutral (35%)	• Small sample size of healthy subjects • Did not address potential effects of gender on tissue deformations • Datasets of muscle and fat deformations at the tilted postures were not independent of the neutral-posture data which does not conform the	**Indirect evidence (PU not an outcome)**

Ref	Type of Study	Sample	Intervention(s)	Outcome Measures & Length of Follow-up	Results	Limitations and comments	
						statistical theory of pairwise comparisons in full	
Karatas, Tosun, & Kanatl, 2008	Observational study **investigating the displacement in center of pressure influencing dynamic sitting stability of people with spinal cord injury (SCI)**	n = 34 (16 with SCI, 18 healthy volunteers)	• Participants were seated on an 45 x 45 cm hard chair of appropriate height, without a backrest • Feet were supported in wooden blocks and the height of the foot support was adjusted to each individual to keep the hip, knee and ankles at 90° degrees • Participants were asked to maintain a static position with their hands resting on their thighs without support as a starting position	• Center of pressure displacements measured using a seat sensor placed underneath buttocks •	• Center of pressure displacements in all directions in spinal injured patients were smaller than healthy volunteers ($p < 0.05$) • Center of pressure displacements for high and low thoracic spinal cord injured participants were not significantly different (p=ns) • Mean center-of-pressure displacement during forward leaning and backward leaning were smaller in participants with PU history ($p=0.04$ and $p=0.03$, respectively) **This study suggests that impaired dynamic sitting stability may be associated with PU development due to impaired ability to weight shift in the seated position**	• Small number of participants • PU development was not a direct outcome	**Indirect evidence (PU not an outcome)**
Kobara K et al., 2013	Experimental study **investigating the mechanism of the fluctuation in shear force applied to the buttocks**	Participants were healthy male participants without leg or trunk diseases (n=11) Characteristics: • Mean age 22±5.2 yrs • Mean height 171.1±5.9 cm • Mean body weight 66.1±6.6 kg	• All participants were seated in an experimental chair with an electrical function for reclining the back support The experimental back support was reclined at increasing angles beginning in a full upright position of 10° from the vertical upright position, proceeding to a fully reclined position	• The amount of force applied to the buttocks was measured using a force plate and a pressure and shear force sensor	• The average shear force applied to the buttocks was: ○ 9.4 ± 2.4 (%BW) in the initial upright position (IUP) ○ 9.3 ± 1.2 (%BW) in the fully reclined position (FRP) ○ 15.0 ± 2.9 (%BW) in the returning to an upright position (RUP) • The average normal force on the buttocks was: ○ 78.0 ± 5.0 in the IUP ○ 66.0 ± 8.2 in the FRP ○ 87.0 ± 6.9 in the RUP	• Healthy subjects • Pressure injuries were not a direct outcome measure	**Indirect evidence (PU not an outcome measure)**
Defloor and Grypdonck (1999)	To explore influence of body posture on sitting interface pressure	Healthy volunteers (n=56)	• Participants sat in a support chair (Geriatric Chair 462 Merivaara®, Mertens) with depth of 47cm and width 48cm, angle of backrest was 111°	• Interface pressure measured at	For all cushions, seated pressure is significantly lower ($p < 0.001$) when seated in a reclined position the legs with a rest in elevated position compared with sitting upright with feet on the ground	• Healthy subjects • PUs were not a direct outcome measure	**Indirect evidence (PU not an outcome measure)**

Ref	Type of Study	Sample	Intervention(s)	Outcome Measures & Length of Follow-up	Results	Limitations and comments	
			• Participants were placed in 8 different postures in the chair, including reclines and foot elevations • Four different support cushions were used		Slouching is associated with higher interface pressures (mean 51.3±11.9mmHg) compared to sitting upright with feet on a rest ((mean 43.8±7.19mmHg **Author conclusion: Reclining the backrest of a hospital armchair and placing the legs on a rest reduce the maximum pressure on the seat surface.**		
Manual handling techniques and education							
Powers, 2016	Quasi experiment **comparing standard of care for turning with a patient positioning system for preventing pressure injuries**	Participants were recruited consecutively in a trauma ICU (n=59) Inclusion criteria: • Immobile • Mechanically ventilated for anticipated ≥ 3 days Exclusion criteria: • Mobile • Not mechanically ventilated • Pre-existing PU Participant characteristics: (no significant between group differences) • Mean age 57 yrs (range 18 to 92) • Mean Braden scale 12-13 • Mean BMI 29-30 • Mean time in ICU 7 days	Participants removed from study if discharged or commence active movement Participants randomly assigned to one of two work units in the ICU: • Standard of care with repositioning with pillows (SOC group, n=30) • Repositioning with a device to assist sacral off-loading. System included low friction glide sheet with grip surface, disposable microclimate body pads to control heal and moisture and two body wedges for 30° angle (Prevalon Turn and Position System™, PPS group, n=29)	• Number of time pulled up the bed • Number of staff required for repositioning • Number of PU • Repositioning outcomes determined by observation by researchers and PUs determined by nurse skin assessments	**Number of time pulled up the bed** Significantly more in the standard care group vs turn system group (3.28 versus 2.58, p=0.03) **Number of staff required for repositioning** Significantly more in the standard care group vs turn system group (1.97 versus 1.35, p<0.0001) **Number of PU** Significantly more PU developed in the standard care group vs turn system group (6 versus 1, p=0.04) **Author conclusions: A turn system is more effective in preventing PU than standard care for ventilated patients in the ICU**	• No randomization or blinding • Category/Stage of PUs that developed was not reported • Small sample size • Non-standardised comparator intervention (different types of pillows used)	**Level of evidence: 2** **Quality: Low**
Elnitsky, Lind, Rugs, & Powell-Cope, 2014	Cross sectional study to explore	• Participants were recruited in 153 VA medical centers across the USA (n=51)	• Program manager nurses for the national VA Safe Patient Handling Program completed the	• A survey consisting of 36 closed-ended questions on skin events and falls as adverse events from safe	**Frequency of experiences leading to pressure injuries** • 91.5% of facilities reported never experiencing Category/Stage I and II	• Non-validated survey completed by	**Indirect evidence (PI not an**

Ref	Type of Study	Sample	Intervention(s)	Outcome Measures & Length of Follow-up	Results	Limitations and comments	
	adverse patient events associated with safe patient handling programs	Inclusion criteria: • Program managers Exclusion criteria: Not stated Participant characteristics: • average, 52± 8 years (range 29–65 years old), • 72% Caucasian • 86% female. • 49% had college degrees and 49% reported had Average time working in current facility was for 12± 7 years • Average time of experience with SPH program was an3 years	online questionnaire between November and December, 2011. • All surveys were delivered through a web-based application	manual handling was delivered	pressure injuries when using safe manual handling • 6.4% of facilities rarely experienced • Category/Stage I and II pressure injuries when using safe manual handling • 2.1% of facilities occasionally experienced • Category/Stage I and II pressure injuries when using safe manual handling **Other skin-related adverse outcomes** superficial abrasions were the most frequent event (27%) Lacerations also occurred (7%) **Author conclusions: Organizational factors, human factors and technology factors were associated with patient adverse events from safe manual handling**	self-selected managers • 36% response rate • Self selection may influence the findings • Anonymous VA centers limiting comparability across the nation • Relies on reporting of respondents	**outcome measure)**
B. Crane, Wininger, Strydom, & Hulse, 2015	Single-blinded cross-over RCT **comparing interface pressure with and without transfer sling insitu**	Convenience sample of older adults from long term care settings (n=22) Inclusion criteria: • Able to sit in wheelchair ≥ 60 mins • Tolerate multiple transfers • Ability to follow instructions Exclusion: • Open PU Characteristics: • Mean age 80 years (range 57 to 95) • 21/22 current wheelchair users (including electric, standard and manual-tilt)	• All wheelchairs fitted with a pressure map that was pre-calibrated • Participants were clothed in their normal attire and incontinence aids and transferred to their wheelchair using a sling • All participants were positioned in two conditions for of 2 minutes each (order of conditions was randomized): ○ removable sling (i.e. "no-sling pressure map") that was removed after the transfer ○ Full body mesh sling designed to remain in	Pressure parameters from a pressure map (mmHg) • Minimum interface pressure (IP) • Maximum IP • Average IP • Peak pressure index Pressure measured every second for 2 minutes **Visual clinical analysis** • 3 clinical experts visually analyzed the pressure maps from second half of sitting period (sling and no-sling images were blinded for analysis)	**Pressure mapping parameters** • No significant difference in any values between sling present and sling not present • Most significant difference was seen in maximum pressure (no sling 135.77±41.36mmHg vs 153.77±40.32mmHg, p=0.53) **Clinical analysis of pressure map** • For 12/22 participants the clinical experts nominated the no-sling map as indicating better IP conditions • For 3/22 participants the clinical experts nominated the sling map as indicating better IP conditions • For 6/22 the maps were considered equivalent for IP conditions • For 1/22 there was no agreement on best map	• Small number of participants • Randomization and allocation concealment methods not reported • Sensors reached maximum readings for 5/22 subjects and therefore had inaccurate (under) readings • Reliability and validity of visual pressure map reading has not been established	**Indirect evidence: PU not an outcome measure** **Quality: moderate**

Ref	Type of Study	Sample	Intervention(s)	Outcome Measures & Length of Follow-up	Results	Limitations and comments	
		• 8/22 foam cushions, 6/22 air filled cushions, 4/22 foam anf gel combination cushions, 4/22 other cushion types. Also used other supports e.g. wedges, towels.	place and left under the participant after transfer •	• Agreement on best IP map required at least 2/3 clinicians to agree	**Conclusions: no compelling reason to overturn current general recommendations to remove slings for long sitting durations**		
Kobara, Osaka, et al., 2015	Observational study **investigating shear force applied to buttocks when rotational axis of hip joint is reduced**	Participants were healthy, male volunteers (n=13) Inclusion: Aged over 18 years Exclusion: Pain while seated, back pain, previous surgery, rheumatism, neurological disorders, leg/trunk disease Characteristics: Mean age 22.6±4.2 years Mean height 1.71±0.05 m Body weight 68.3±9.8kg	Participant was seated in experimental chair with sensors at the highest point of pressure with the back support Variations of the chair with different points of rotational axis: • Horizontal axis was with rotation occurring at the same height as the seat base • Upward axis was with rotation occurring approximately 7.5cm above the height base height (i.e. simulating sitting on a pillow).	Measured horizontal and normal forces applied to the buttocks using a force plate	Both horizontal force and normal force were significantly increased on the seat height axis when in fully reclined position and when returning to upright position compared to in the upright position (all $p<0.01$). Both horizontal force and normal force were significantly increased on the 9cm upward axis when in fully reclined position and when returning to upright position compared to in the upright position (all $p<0.01$). **Author conclusions: reclining wheelchairs should possess the function of adjustment of the height of the rotational axis of the back support on the horizontal plane in order to reduce the horizontal force applied to buttocks when returning to upright position.**	• Small study with healthy male volunteers • Unclear if findings can be extrapolated to shorter people • The study did not consider the seating surface, which is significant for wheelchairs and cushion surfaces	**Indirect evidence (healthy volunteers, PU not an outcome measure)**
Gucer, Gaitens, Oliver, & McDiarmid, 2013	Cross-sectional survey investigating **relationship between availability of powered mechanical lifting (PML) aids for manual**	Directors of Nursing (DONs) from 656 Medicare/Medicaid certified LTC facilities in USA were invited to participate (n=271 participant facilities, 41% response rate) Characteristics: • Facilities averaged between 77 to 80 filled beds	• DONs were surveyed on availability of PMLs and the lifting policy of the facility for the years 2005 to 2007 • To this information the authors linked data on mobility-related resident outcomes from the Centers for Medicare and Medicaid Serviced Minimum Data Set	• The authors explored the relationship between resident quality indicators of well-being (including PU incidence while at high risk) and: ○ safe lifting policies and procedures ○ availability of different kinds of PMLs (full lift vs. sit-stand) •	• Significantly more residents at high risk had PUs in facilities with 0-4 PMLs of any sort versus facilities with >8 PMLs of any sort (14.94% versus 9.74%, p=0.000) • Significantly more residents were bed-bound in facilities with 0-4 PMLs of any sort versus facilities with >8 PMLs of any sort (3.44% versus 1.72%, p=0.013) • There was no significant difference in residents with PUs when comparing number of full PMLs in facilities (p=0.866)	• Based upon recall • Based upon self-report (availability of aids) and database review (incidence of PU) • Modest self-selected response rate • Sample may over-represented singly	**Level of Evidence: 4** **Quality: moderate**

Ref	Type of Study	Sample	Intervention(s)	Outcome Measures & Length of Follow-up	Results	Limitations and comments	
	handling/ repositioning and PU incidence in long term care (LTC) facilities	• 54% were owned by for-profit organizations • 59% were located in Middle America • Mean number of full PMLs increased over the 2 year survey time frame to 3.35 per 100 residents • Mean number of sit-stand PMLs over the 2 year survey time frame to 2.65 per 100 residents	Quality Indicators data over 3 years		• There was significantly more residents at high risk had PUs in facilities with 0-1 sit-stand PMLs versus facilities with >3 sit-stand PMLs (16.10% versus 9.62%, p=0.000)	owned and underrepresented large chain facilities • Associations were formed but definitive causality cannot be assigned	
Still et al., 2013	Observational study (quality improvement initiative) investigating **influence of a turn team on rate of PUs**	Study conducted in a surgical intensive care unit in US (n = 20 beds) Characteristics: Routine population includes general surgery, implant patients, ENT, urology Nurse:patient ratio 2:1 with additional 2 patient care attendants (PCAs)	• Prior to intervention introduction nursing staff received an online education intervention on PU prevention, Braden scale scoring • PCAs received training in turn mechanics Turn team initiative required the turn team (2 PCAs) to turn every haemodynamically stable patient every 2 hours, unless the nurse identified contraindications.	• Prevalence surveys conducted over 2 year period, with frequency of data collection ranging from every 3 months to biweekly over the course of the project • Clinical nurse specialist used NPUAP staging system to determine prevalence of PU on audit days.	• **Baseline (15 audits over 2 years)** Average 2.8 PUs per audit 42 PUs in 278 patients Primarily stage II sacral/buttock PU 4 patients had 2 PUs • **After intervention (15 audits over 15 weeks)** 12 patients in 229 patients Average of 0.87 PUs per audit (p<0.0001 compared with baseline) Patients who were ventilated or who had longer stays were more likely to have PU	• Unclear if other changes were made in ward over 2 year period • Data collected more frequently after intervention was introduced, possible Hawthorne effect • If a patient was present for more than one audit, included in only one audit and assigned his/her worst state, reducing prevalence rate in the earlier audit.	**Level of Evidence: 4** **Quality: Low**
Repositioning devices for support							
Bush, Leitkam, Aurino, Cooper, &	Observations study comparing **interface pressure with**	Participants were healthy volunteers recruited in US (n=22)	• Identical sized pressure mapping matts were placed under the sacrum, buttock/thigh and shoulder regions.	• Tissue interface pressures were measured in each position at each inclination of the bed.	• The wedge system was most effective at offloading the sacrum • Tilted positions led to higher loads on the shoulder and buttock regions	• The study was conducted in a laboratory with healthy volunteers	**Indirect evidence (healthy volunteer)**

Ref	Type of Study	Sample	Intervention(s)	Outcome Measures & Length of Follow-up	Results	Limitations and comments	
Basson, 2015	**different positioning devices**	No inclusion/exclusion criteria stated Participant characteristics: • 11 females, 10 males • Females mean body weight 65.1± 7.5 kg • Females mean height 167± 7.9 cm • Females mean BMI 23.3 ± 2.22 • Males mean weight 84.5 ± 21.4kg • Makes mean height 181.4 ± 7.4 cm • Males mean BMI 25.42± 4.92	• The participants were positioned in three different positions: ○ supine position without device support ○ supine position with pillows positioned above and below the sacral region ○ Supine position with wedges positioned above and below the sacral region. • Each position was measured at differing bed inclines of 0°, 20° and 30°.	• Pressures were measured using pressure matts displaying pressure in mmHg.	• Increasing the angle of the bed transferred some of the load from the sacrum and shoulders to the buttock/thigh region	• The size of the pressure mapping was identical for all volunteers despite being different sizes. Custom matts may have different measurements • Shifting of the pillows or wedges with movement was not evaluated	
Edger, 2017	Quasi experiment to determine hospital acquired pressure injury (HAPI) rate associated with a repositioning device	Participants were recruited in an ICU in US (n=717) Inclusion criteria • Body weight < 350lbs • Immobile • Unable to assist with repositioning • Braden scale <15 • Braden mobility subs-score = 1 • Braden moisture subscore <3 Exclusion criteria • Acute agitation Note: parallel group analysis rather than paired tests	• Staff were trained on the use of the device (Prevalon Turn and Position System: Sage Progucts) • Two 30-degree bed wedges with an anchor strap, low friction glide sheet and a body pad. • Algorithm determined when the use of the repositioning device was appropriate for the patient. • Patient repositioned every two hours using this device. Repositioning tracking sheet also implemented	• Point prevalence completed prior to implementation of the device, post implementation patients were monitored for the development of HAPI. If detected wound nurses assessed the client to determine if the wound was on the buttocks or sacrum • study for 15 months • Exertion measured with the Borg Scale of Perceived Exertion • Cost effectiveness was calculated by the facility based on the costs to treat each stage of pressure injury • Followed for 6 months	**Pressure injury incidence at 6 months** There was a statistically significant reduction in pressure injuries associated with using the repositioning device (1.3% versus 0%, p=004) **Staff exertion** Manual repositioning required 88% more exertion over using the repositioning device (p<.001) **Cost effectiveness** Return on investment $16, 961 **Author conclusions: Use of the repositioning device significantly reduced HAPI development and resulted in less perceived exertion than manual repositioning.**	• Single unit in a single facility • No random allocation of participants • Implemented a repositioning tracking tool in addition to the device that may have increased awareness from staff	**Level of evidence: 2** **Quality: High**
Brennan, Laconti, &	Cohort study	Participants were recruited in a	All participants received	Number of pressure	**Number of pressure injuries (unknown number of patients)**	• Comparability of	**Level of evidence:**

Ref	Type of Study	Sample	Intervention(s)	Outcome Measures & Length of Follow-up	Results	Limitations and comments	
Gilchrist, 2014	with retrospective comparator group exploring effectiveness of a conforming fluidized positioning device (FPD) for preventing pressure injuries in ICU	surgical ICU (cardiac and thoracic) in US (total number not reported clearly) Inclusion criteria: • Patients requiring cardiopulmonary bypass Characteristics: • Patients with decreased mobility or unable to independently change position or turn • depending on the procedure some patient may not be moved up to 72 hours after procedure • Patient risk factors and condition is not reported	• All were cared for on a Total Care SpO2RT® Pulmonary Therapy bed (Hill-ROM) • Turning and positioning every 2 hours minimum In addition, participants in experimental cohort: • Conformational positioning using a FPD composed of fluidized medium with a flexible membrane of urethane (Sundance Solutions) • FPD was used for heel lifting and side-to-side turns	injuries/year	• 2007 cohort before introduction of intervention had 49 pressure injuries • After intervention introduction: ○ 2008: 22 pressure injuries ○ 2009: 25 pressure injuries ○ 2010:39 pressure injuries ○ 2011:17 pressure injuries ○ 2012:12 pressure injuries **Other relevant findings** • Staff needed education to use the device appropriately • FPD did not move/slide out from position.	population and management not established • Not clear what classification system used and how incidence was measured • Pressure injuries on admission not addressed • Unclear how many were assessed in each year so rate of pressure injuries is unknown • No statistical analysis • Not clear if the device used in every patient	**3** **Quality: Low**
Clinical question four: Do programs of early mobilization affect pressure injury rates?							
Wood et al., 2014	Pre test/post-test study to determine whether an early mobility program could improve patient outcomes on a general medical unit.	Participants were recruited in a medical unit in US (n=521) All patients included/no exclusion criteria Participant characteristics were not discussed	Participants were assigned to: Intervention: Mobility aide was trained to ensure patients were participating in either, Active ROM, passive ROM, sitting on side of bed, Bed to chair, or ambulating q3times/day (n=234) Intervention 2: Mobility aide was trained to ensure patients were participating in only non-ambulatory activities (n=60)	• Number of falls per month • Incidence of unit-acquired pressure ulcers • Rate of readmission to the hospital within 30 days of unit discharge. • Out of bed to chair • Walking • ROM •	**Activity uptake** On average, patients completed 1.74 (SD 0.34) activity sessions daily, giving the entire unit a daily overall early mobility achievement score of 58% **Pressure injuries** Pressure injury rate was unchanged between pre-intervention period and post implementation period mean 0.33 (SD 0.58) per month and post-intervention mean 0.28 (SD 0.49) per month **Falls**	• Inability to schedule mobility aide every day • Protocol did not address patients admitted late in the day • No blinding, no participant details • Uncertain if confounding factors influenced results	**Level of evidence: 2** **Quality: Low**

Ref	Type of Study	Sample	Intervention(s)	Outcome Measures & Length of Follow-up	Results	Limitations and comments	
					Falls were reduced from 4.33 (SD 3.21) to 3.14(SD2.34) Author conclusions: Mobility program improved patient outcomes		
Klein, Mulkey, Bena, & Albert, 2015	Pretest/posttest to determine if an early mobilization protocol increased mobility and improved clinical and psychological outcomes	Participants were recruited in a Neurological ICU in the US (n=637) Inclusion criteria: • All NICU admissions during data collection period Exclusion criteria: • Diagnosis other than neurologic event/condition Participant characteristics: • Mean age 61-63 years (SD 16) • APACHE III score 59.2-55 • Post-intervention group used fewer walking aids (p=0.006) Pre-intervention group had more gait abnormalities prehospitalization (p<0.001) and were less likely to receive ventilator therapy (p<0.001)	Participants received care as designated in the ward during pre and posttest periods (each period 4 months): • Pretest/control group: Undefined standard procedure (n=260) • Posttest/ intervention group: "Four Progressive Mobility Milestones from 16 Mobility Levels", initiated on NICU admission. The protocol provided criteria for: ○ excluding patients from the progressive protocol ○ Evaluating patient readiness for and tolerance of mobility progression ○ Advancing patient mobility ○ documenting mobility status ○ consulting with physical therapy (n=377)	• Bedside nurses assessed and documented highest level of mobility (16 levels) • Hospital acquired pressure injuries retrieved from databases • Unclear staging system used • Follow up period 13 days	**Hospital acquired pressure injuries** Significantly fewer pressure injuries occurred in the post-intervention group ((3.8% versus 1.1%, p= 0.026) **Author conclusions: A neurological ICU early mobility protocol increased highest neurologic ICU mobility and decreased hospital acquired pressure injuries**	• Not blinded, pre-post design • Relied on database data for pressure injury incidence • Protocol developed after reviewing protocols in critical care literature • Single center study with only neurological patients • People with only a sort NICU stay may not have received sufficient intervention time	**Level of evidence: 2** **Quality: Low**
Azuh et al., 2016	Pre-test post-test study exploring the efficacy of a mobility team in reducing	Participants were recruited in one medical ICU in the US (post-intervention period n=3233) Inclusion criteria:	• Interventions were initiated based on the individual's level of mobility on a 5-point scale and changed as the	• A 5-point mobility scale was developed and used to establish a patients' highest level of activity achievable: mobility level 1 (bed rest) to 5 (complete independence)	**Pressure injury incidence** Following introduction of the intervention, there was a significant reduction in incidence of HAPI (9.2% versus 6.1%, p=0.0405)	• No randomisation or blinded outcome measurement • Minimal details of the pre-intervention cohort	**Level of evidence: 2** **Quality: Low**

Ref	Type of Study	Sample	Intervention(s)	Outcome Measures & Length of Follow-up	Results	Limitations and comments	
	hospital acquired pressure injuries (HAPI)	Admission to medical ICU Braden score <19 Exclusion criteria: None stated Participant characteristics: Approx. 53% male > 45% aged over 65 No significant difference between pre and post cohorts	individual's level of mobility changed • Interventions were implemented by unlicensed, trained personnel • Interventions were promoted through concurrent culture change, adjustment of sedation levels and integrating mobility assistants into the interdisciplinary team • Interventions included: ○ repositioning every 2 hours and ROM every 4 hours for individuals on bed rest ○ For individuals able to sit on bed edge, session up to 3 times daily for 5-30 mins with assisted or active exercises ○ For individuals able to stand to chair, up to 3 times per day for 30 mins ○ For individuals who could walk with assistance, SOOB for all meals and walk 3 times per day	• Skin care nurses performed visual skin assessment on admission and as needed • Hospital acquired pressure injuries documented by Category/Stage	**Safety** No serious incidents associated with intervention 2 minor incidents (IV disconnected, transcutaneous wires disconnected) **Secondary outcomes** Hospital readmission significantly decreased (17.1% versus 11.5%, p=0.001) Mean ICU length of stay decreased (11.7 days versus 10.7 days, p=0.165) 97% (207/213) patients receiving the program who responded to a survey (64% response rate) were satisfied with their interaction with the mobility team **Interventions per patient per day from first quarter to last quarter of intervention** • There was a significant increase in repositioning (0.55±0.61 versus 1.08±0.98, p<0.001) • There was a significant increase in assistance with ADLs (0.28±0.36 versus 0.43±0.46, p<0.001) • There was a significant decrease in bed to chair (0.36±0.43 versus 0.27±0.45, p<0.001) • There was a significant decrease in sitting bedside unsupported (0.19±0.30 versus 0.13±0.28, p<0.001)	(e.g. unclear if there is a significant difference in reasons for admission) • Primary outcome not reported per Category/Stage pressure injury	
Dammeyer, Dickinson, Packard, Baldwin, & Rickleman n, 2013; Dickinson,	Retrospective, Pre-test/post test study **investigating an early mobilization**	• Conducted in a surgical ICU in the US • (pre-implementation phase n=555; post-implementation phase n=557)	• Mobility intervention for patients at least 3 times per day • Early mobility protocol included three separate phases: 0, 1, and 2.	• Incidence of pressure ulcers unstated how these were assessed but appears to be a document review. • PUs were classified according to NPUAP staging system	<u>Data from Dammeyer et al 2013</u> Description of program <u>Data from Dickinson et al. (2013)</u> • Pre-implementation group had a significantly shorted mean hospital length of stay (13.78 days vs 16.58 days,	• Not targeting the intervention to specific populations deemed at risk • Acuity differences between pre and	**<u>Dammeyer</u> Opinion** **<u>Dickinson</u>**

Ref	Type of Study	Sample	Intervention(s)	Outcome Measures & Length of Follow-up	Results	Limitations and comments	
Tschannen, & Shever, 2013; Knoblauch, Bettis, Lundy, & Meldrum, 2013	**protocol in an ICU setting** **nb:** Dickinson et al. (2013)reports the study Dammeyer et al. (2013) describes the intervention Knoblauch et al. (2013) reports cost-effectiveness	Inclusion for protocol: • fractional inspired oxygen saturation less than 605 • positive end-expiratory pressure less than 10cm H_20. • receiving low dose catecholamine drips Exclusion for protocol: • hypoxia, • hemodynamic instability, intercranial pressure monitoring, • unstable cardiac rhythm, or • new cardiac arrhythmia Characteristics: • post-implementation group had a significantly higher risk of PU based on Braden score (15.24 vs 15.66, p<0.001) No significant difference in APACHE scores	• All patients started in phase 0 after physiological stabilization and progress as tolerated • Phase 0: range of motion (active and passive), continuous lateral rotation, HOB at 30 to 45° • Phase 1includes Phase 0 interventions plus chair position or out of bed and dangling (all 3 times daily) • Phase 2 includes phase 1 interventions plus standing, bearing own weight and walking. • The intervention required employment of a nursing tech for 12 hours/day to assist RNs to deliver the intervention. • Medical staff and family education was implemented •		p=0.002) and mean unit LOS 4.02 days vs.. 6.16 days, p<0.001) • Pre implementation group: 20 patients (3.6%) developed unit acquired PU compared with 41 patients (7.4%) in post implementation group • Pre implementation group 30 patients (5.4%) developed facility acquired PU compared with 34 patients (6.1%) in post implementation group • In consideration of extra time spent in the unit, there was a significant increase in PUs associated with the intervention (p=0.009) • 71% staff compliance <u>Data from Knoblauch et al. (2013)</u> • Completion of mobility program requires 20 minute sets x3 per day = 1 hour per patient per day • Calculated for a high acuity 18 bed unit, nursing and support wage was additional $540/day (USD) or $234 for a nursing technician plus $156 for a supervising RN • Including education, the program cost approx. $15,500 for 3 months • Evaluation of a 3-month program found no cost avoidance was achieved due to no reduction in pressure injuries or length of stay	post implementation groups • Staff compliance to the early mobility protocol • Limited variety of exercise	**Level of evidence: 2** **Quality: moderate** <u>**Knoblauch**</u> **Moderate quality economic analysis**
Other information: Economic analyses							
Pechlivanoglou et al., 2018	Economic analysis of costs and effectiveness measured in quality adjusted life	Economic analyses conducted for Canadian aged care facility settings. Costings inflated to 2014 Canadian dollars	All residents in the study had a high-density foam mattress	• Costs only considered direct costs of nursing wages • Informal cost effectiveness threshold of $50,000/QALY • Resident lifetime estimated at average of 102.7 weeks	Lifetime risk of developing pressure injury was 37% higher for people repositioned 2-hourly, and 44% higher for 4-hourly repositioning compared to 3-hourly intervals **Incremental cost-effectiveness**	• Based on evidence of the TURN study (Bergstrom et al 2013) • Findings clarify that residents must	**High quality economic analysis**

Ref	Type of Study	Sample	Intervention(s)	Outcome Measures & Length of Follow-up	Results	Limitations and comments	
	years (QALY) of 2,3 and 4 hourly repositioning				• 3 hourly repositioning total lifetime cost $102,276 and 0.636 (0.118 to 1.172) QALYs • 4 hourly repositioning cost $3296 more than 3 hourly turning, with reduction of 0.009 QALY • 2 hourly repositioning cost $5435 more than 3 hourly turning, with reduction of 0.008 QALY	have high density foam mattress	
Paulden et al., 2014	Economic analysis of reducing frequency of repositioning older adults in aged care	Economic analyses conducted for Canadian aged care facility settings. Costings in 2012 Canadian dollars	All residents in the study had a high-density foam mattress	• Costs only considered direct costs: o Nursing time o Supplies (skin creams, washcloths, briefs) o Hospital visits, physician and surgery services, ambulatory procedures • Per facility cost analysis assumed facilities had 123 residents, 33% at risk of pressure injuries	**Per resident economic benefit** Switching from a 2-hour repositioning to 3 or 4 hour schedule would free up 34.3 mins and 51.4 mins respectively of nursing time/day/resident at pressure injury risk Total economic savings of switching from a 2-hour repositioning to 3 or 4 hour schedule would be $4032 and $6109 respectively annually/per resident at pressure injury risk **Per facility economic benefit** Total annual savings for switching from a 2-hour repositioning to 3 or 4 hour schedule would be $165,321 and $250,453 respectively per resident at pressure injury risk	• Based on evidence of the TURN study (Bergstrom et al 2013) • Findings clarify that residents must have high density foam mattress	**High quality economic analysis**
Z. Moore, Cowman, & Posnett, 2013	Economic analysis to compare pressure injury costs associated with repositioning older individuals in long-term care using two different	Economic analyses conducted using costings from UK in mid-2009		• Costs only considered nursing time performing repositioning • Projected annual facility cost analysis assumed 588 individuals with complete or very limited mobility	**Staff time** • mean daily nurse time for repositioning was 18.5 mins (experimental: 3 hourly repositioning at night with 30° tilt) and 24.5 mins (control: 6 hourly repositioning at night using 90° tilt) (significant over 4 weeks p=0.001, difference of -6.1 mins (95% CI -3.71 to-8.48) • Nurse time cost per patient/day €7.41 (experimental) and €9.80 (control) (significant over 4 weeks, p=0.001) **Per facility economic benefit**	• Based on evidence of from repositioning trial of Moore et al 2011) • Did not consider equipment used	**Moderate quality economic analysis**

Ref	Type of Study	Sample	Intervention(s)	Outcome Measures & Length of Follow-up	Results	Limitations and comments	
	repositioning regimes				• Projected annual annual cost saving from using experimental regimen (3 hourly repositioning at night with 30° tilt) would be €512,800 (21,462 hours of nurse time) **Author conclusions: Repositioning individuals at risk of pressure injuries more frequently using a 30° tilt reduced incidence of pressure injuries and reduced nursing time, leading to cost benefits.**		

Systematic reviews to support discussion

Ref	Type of Study	Sample	Intervention(s)	Outcome Measures & Length of Follow-up	Results	Limitations and comments	
Lying positions							
Wang et al., 2016	Systematic review of RCTs reporting **pressure injuries as a side effect in studies exploring semi-recumbent positioning for ventilated patients**	From the 10 RCTs included in the review, only one RCT (van Nieuwenhoven, 2006) reported PU incidence (n=221 participants) In this study participants were in an ICU in the Netherlands Participant characteristics: • Approx. 75% participants received enteral feeing • No significant difference in baseline conditions between groups	Semi recumbent positioning was 45° incline and control group (supine positioning) was 10° incline	• Backrest elevation was measured automatically every 60 seconds • Patient position was restored to study condition 2-3 times daily	**Pressure injury incidence** • There was no significant difference in PU incidence between semi recumbent positioning (n=31 PU, 27.7%) and supine position (n=33 PU, 30.1%), Risk ratio 0.91 (95% CI 0.60 to 1.38, p=0.67) • Pus that occurred were primarily Stage I or II	• Follow up was 48 hours • RCT was rated as having low confidence in findings • Average recumbent rate achieved was between 23 and 29° rather than the required 45°	**Quality: low** **(result from only one RCT, no meta-analysis)**
Treatment of PU with repositioning							
Z. E. Moore & Cowman, 2015	Systematic review	Consideration of RCTs and controlled clinical trials only	Repositioning to promote PU healing	N/A	• No research on the effectiveness of repositioning in promoting PU healing was identified for inclusion in this review.	• The absence of high level research in this field should be	**Quality: high**

Ref	Type of Study	Sample	Intervention(s)	Outcome Measures & Length of Follow-up	Results	Limitations and comments	
						noted in the guideline	
Gillespie et al., 2014	Systematic review on repositioning to prevent	Considered RCTs – three included Three studies are: DeFloor 2005 Young 2004 Moore 2011	Repositioning to prevent pressure injuries	Pressure injury incidence	**Pressure injury incidence for 2h versus 3h repositioning on standard hospital mattresses** (1 RCT, DeFloor 2005) • There was no significant difference in pressure injury rates for the two regimens (risk ratio [RR] 0.59, 95% CI 0.28 to 1.26, p=0.17) **Category/Stage I to IV pressure injury incidence for 4h versus 6h repositioning on viscoelastic foam mattresses** (1 RCT, DeFloor 2005) • There was no significant difference in pressure injury rates for the two regimens (RR 0.73, 95% CI 0.53 to 1.02, p=0.065) **Category/Stage II to IV pressure injury incidence for 4h versus 6h repositioning on viscoelastic foam mattresses** (1 RCT, DeFloor 2005) • There was significantly fewer Category/Stage pressure injuries for individuals repositioned every 4 hours compared to 6 hours (RR 0.19, 95% CI 0.04 to 0.84, p=0.028) **Pressure injury incidence for 30° tilt 3 hourly vs. 90° tilt overnight** (2 trials, Moore 2011 and Young 2004) • There was no significant difference between the two regimens (RR 0.62, 95% CI 0.10 to 3.97,p=0.62).	• The studies included were moderate and low quality	**Quality: high**
Lifts and transfer equipment to prevent PU							
Canadian Agency for Drugs and	Systematic review	Consideration of RCTs, non-RCTs, reviews, guidelines and economic analyses	Effectiveness of lifts and transfer equipment to prevent PU	N/A	• No research meeting the review question and reporting PU as an	• The absence of high level research in this	**Quality: high**

Ref	Type of Study	Sample	Intervention(s)	Outcome Measures & Length of Follow-up	Results	Limitations and comments	
Technologies in Health (CADTH), 2013					outcome measure was identified for inclusion in this review.	field could be noted in the guideline	

Table 1: Level of Evidence for Intervention Studies

Level 1	**Experimental Designs** • Randomized trial
Level 2	**Quasi-experimental design** • Prospectively controlled study design • Pre-test post-test or historic/retrospective control group study
Level 3	**Observational-analytical designs** • Cohort study with or without control group • Case-controlled study
Level 4	**Observational-descriptive studies (no control)** • Observational study with no control group • Cross-sectional study • Case series (n=10+)
Level 5	**Indirect evidence**: studies in normal human subjects, human subjects with other types of chronic wounds, laboratory studies using animals, or computational models

Table 2: Levels of evidence for diagnostic studies in the EPUAP-NPUAP-PPPIA guideline update

Level 1	Individual high quality (cross sectional) studies according to the quality assessment tools with consistently applied reference standard and blinding among consecutive persons.
Level 2	Non-consecutive studies or studies without consistently applied reference standards.
Level 3	Case-control studies or poor or non-independent reference standard.
Level 4	Mechanism-based reasoning, study of diagnostic yield (no reference standard). Low and moderate quality cross sectional studies.

Table 3: Levels of evidence for prognostic studies in the EPUAP-NPUAP-PPPIA guideline update

Level 1	A prospective cohort study.
Level 2	Analysis of prognostic factors amongst persons in a single arm of a randomized controlled trial.
Level 3	Case-series or case-control studies, or low quality prognostic cohort study, or retrospective cohort study.

APPRAISAL FOR STUDIES PROVIDING DIRECT EVIDENCE (i.e. ELIGIBLE FOR SUPPORTING AN EVIDENCE-BASED RECOMMENDATIONS

Each criteria on the critical appraisal forms was assessed as being fully met (Y), partially met or uncertain (U), not met/not reported/unclear (N), or not applicable (NA). Studies were generally described as high, moderate, or low quality using the following criteria:

- High quality studies: fully met at least 80% of applicable criteria
- Moderate quality studies: fully met at least 70% of applicable criteria
- Low quality studies: did not fully meet at least 70% of applicable criteria

CROSS SECTIONAL/SURVEY/PREVALENCE STUDIES/OBSERVATIONAL

Endnote ID	Author/year	Focussed question	Sampling method	Representative sample	States number invited participants	Clear outcome measures	Valid reliable outcome measurement	Comparable results for multiple sites	Confounders identified and accounted for	Minimal bias	Reliable conclusions	Level of evidence	Quality
6082	Chaboyer et al., 2015	Y	Y	U	Y	Y	U	NA	N	Y	U	indirect	moderate
6429	Kallman et al., 2015	Y	N	U	N	Y	Y	NA	Y	Y	U	4	low
15055	Ceylan et al., 2017	Y	N	Y	Y	Y	Y	U	U	Y	N	4	moderate
16293	Llaurado-Serra et al., 2016	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	4	high
1316	Siddiqui et al., 2013	Y	N	N	Y	Y	N	Y	NA	N	N	4	low
605	Grap et al., 2017	N	U	U	N	N	U	NA	N	N	U	4	low
5866	Jan & Crane, 2013b	Y	U	U	N	Y	Y	NA	N	N	U	4	low

RCTS

Endnote ID	Author/year	Focussed question	Assignment randomised	Adequate concealment method	Subjects and investigators blinded	Groups comparable at commencement	Only difference btw groups was treatment	Valid, reliable outcome measure	% drop out in study arms is reported and acceptable	Intention to treat analysis	Comparable results for multiple sites	Minimal bias	Reliable conclusions	Level of evidence	Quality
6708	Schallom et al., 2015	Y	N	NA	N	Y	Y	Y	N	N	NA	Y	Y	1	low
7803	Bergstrom et al., 2013	Y	Y	Y	N	Y	Y	Y	Y	Y	U	Y	Y	1	High
5447	Girard et al., 2014	Y	U	N	N	U	U	Y	Y	Y	NA	Y	Y	1	Low
14467	Gunningberg, Sedin, et al., 2017	Y	Y	Y	N	Y	Y	Y	Y	Y	NA	Y	Y	1	High
44	Yap et al., 2013	Y	Y	U	N	N	Y	Y	Y	U	Y	Y	Y	1	Moderate
17765	Pickham, Berte, et al., 2018	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	1	High
17848	Manzano et al., 2014	Y	Y	Y	N	Y	Y	Y	Y	N	Y	Y	Y	1	High

CASE SERIES

	Author/year	Focussed question	Participant characteristics reported	Inclusion criteria defined	Consecutive recruitment	Participants entered at same disease stage	Intervention clearly reported	Outcomes relevant and defined apriori	Valid, reliable outcome measurement	Per cent drop out reported and acceptable	Estimates of random variability	Comparable results for multiple sites	Minimal bias	Reliable conclusions	Level of evidence	Quality
10663	Gammon et al., 2016	Y	Y	Y	Y	U	Y	Y	Y	N	N	NA	Y	Y	4	moderate

COHORT STUDIES

	Author/year	Focussed question	Comparable source populations	States number invited	Likelihood of outcome at enrolment considered	Per cent drop out in study arms is reported	Comparison btw drop outs and participants	Clear outcome measures	Assessment blinded, or discuss potential bias	Valid, reliable assessment with supporting reference	More than one measure of exposure	Confounders identified and accounted for	Provides confidence intervals	Minimal bias	Reliable conclusions	Level of evidence	Quality
2810	Brennan et al., 2014	Y	U	N	U	N	N	N	U	U	U	N	N	N	N	3	Low

QUASI EXPERIMENTAL STUDIES

	Author/year	Focussed question	Subjects and investigators blinded	Groups comparable at commencement	Only difference btw groups was treatment	Valid, reliable outcome measurement	Per cent drop out in study arms is reported and acceptable	Intention to treat analysis	Comparable results for multiple sites	Minimal bias	Reliable conclusions	Level of evidence	Quality
10794	Powers, 2016	Y	N	Y	Y	Y	NA	Y	NA	N	Y	2	moderate
13233	Azuh et al., 2016	Y	N	U	Y	U	N	U	NA	U	U	2	low
7882	Behrendt et al., 2014	Y	N	Y	Y	Y	U	Y	NA	Y	Y	2	high
14487	Edger, 2017	Y	N	Y	Y	Y	N	Y	NA	Y	Y	2	high
2729	Klein et al., 2015	Y	N	N	U	U	N	Y	NA	N	N	2	low
7296	Wood et al., 2014	Y	N	U	U	N	N	Y	NA	Y	N	2	low

ECONOMIC EVALUATIONS

	Author/year	Focussed question	Economic importance of question is clear	Choice of study design is justified	All costs are included and measured and valued appropriately	Outcome measures to answer study question are relevant and measured and valued appropriately	Discounting of future costs and outcome measures is performed correctly when appropriate	Assumptions explicit and a sensitivity analysis conducted	Results provide information relevant for policy providers	Minimal bias	Reliable conclusions	Level of evidence	Quality
3209	Paulden et al., 2014	Y	Y	Y	Y	Y	NA	Y	Y	Y	Y	NA	High
7791	Z. Moore et al., 2013	Y	Y	Y	N	Y	NA	N	Y	Y	Y	NA	moderate
17200	Pechlivanoglou et al., 2018	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	NA	High

SYSTEMATIC REVIEWS FOR DISCUSSION

RATING CRITERIA:
1 Partial yes: states review question, search strategy, in/exclusion criteria and risk of bias were a-priori; full yes: meta-analysis/synthesis plan, investigation of heterogeneity and justification for protocol deviation
2 Partial yes: At least 2 databases, provides keywords and search, justifies publication restrictions; full yes: searched reference lists of included studies, searched trial registries, consulted experts in field, searched grey literature, search within 24 months of review completion
3 At least two reviewers independently agreed on selection of studies to include or reviewers achieved 80% agreement on a sample of studies
4 Either two reviewers did data extraction and had >80% agreement, or two reviewers reached consensus on data to extract
5 Partial yes: list of all relevant studies that were read and excluded; full yes: every study that was excluded is independently justified
6 Partial yes: described populations, interventions, comparators, outcomes and research design; full yes: detailed descriptions of same plus study setting and timeframe for follow-up
7 FOR RCTS Partial yes: appraised risk of bias from unconcealed allocation and lack of blinding; full yes: appraised risk of bias on true randomisation, selection of reported result from multiple measurements/analyses
FOR non randomised studies: Partial yes: appraised confounding and selection bias; full yes: appraised methods to ascertain exposures and outcomes, selection of reported result from multiple measurements/analyses
8 Must include reporting of the source of funding of individual studies, or reports that the reviewers considered this even if individual funding sources aren't listed in review

Endnote ID	Author/year	PICO research question and inclusion criteria	Explicitly states a-priori protocol[1]	Rationale for selection of study designs	Comprehensive search[2]	Duplicate study selection[3]	Duplicate data extraction[4]	Excluded studies listed[5]	Adequate description of included studies[6]	Risk of bias assessed[7]	Source of funding reported[8]	Appropriate meta-analysis including weighting and adjustment for heterogeneity	Meta-analysis considers risk of bias of studies	Discussion consider risk of bias of studies	Assessment of publication bias if quantitative analysis is done	Potential conflicts of interest of authors reported and managed	Review Quality	Type of evidence included in review
11070	Wang et al., 2016	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	NA	NA	Y	NA	Y	High	Only 1 RCTs relevant to PU (high risk of bias)
13735	Walia et al., 2016	N	U	N	PY	N	N	N	Y	Y	N	Y	N	Y	N	Y	Exclude	Two RCTs
6707	Z. E. Moore & Cowman, 2015	Y	Y	Y	Y	Y	NA	NA	NA	NA	NA	NA	NA	NA	NA	Y	High	No studies included
7821	Canadian Agency for Drugs and Technologies in Health (CADTH), 2013	Y	N	Y	Y	NA	NA	Y	NA	NA	NA	NA	NA	NA	NA	N	High	No studies included
6524	Gillespie et al., 2014	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	High	3 RCTs

References

Full list of references on data tables

Anderson, R., Kleiber, C., Greiner, J., Comried, L., & Zimmerman, M. (2016). Interface pressure redistribution on skin during continuous lateral rotation therapy: A feasibility study. *Heart & Lung, 45*(3), 237-243

Azuh, O., Gammon, H., Burmeister, C., Frega, D., Nerenz, D., DiGiovine, B., & Siddiqui, A. (2016). Benefits of Early Active Mobility in the Medical Intensive Care Unit: A Pilot Study. *American Journal of Medicine, 129*(8), 866-871.e861

Behrendt, R., Ghaznavi, A. M., Mahan, M., Craft, S., & Siddiqui, A. (2014). Continuous bedside pressure mapping and rates of hospital-associated pressure ulcers in a medical intensive care unit. *American Journal of Critical Care, 23*(2), 127-133

Bergstrom, N., Horn, S. D., Rapp, M. P., Stern, A., Barrett, R., & Watkiss, M. (2013). Turning for Ulcer ReductioN: a multisite randomized clinical trial in nursing homes. *Journal of the American Geriatrics Society, 61*(10), 1705-1713

Best, K., Desharnais, G., Boily, J., Miller, W., & Camp, P. (2012). The effect of a trunk release maneuver on peak pressure index, trunk displacement and perceived discomfort in older adults seated in a high Fowler's position: A randomized controlled trial. *BMC Geriatric, 12*(1), 72

Brennan, M. R., Laconti, D., & Gilchrist, R. (2014). Using conformational positioning to reduce hospital-acquired pressure ulcers. *Journal of Nursing Care Quality, 29*(2), 182-187

Bush, T. R., Leitkam, S., Aurino, M., Cooper, A., & Basson, M. D. (2015). A Comparison of Pressure Mapping between Two Pressure-Reducing Methods for the Sacral Region. *Journal of Wound, Ostomy and Continence Nursing, 42*(4), 338-345

Canadian Agency for Drugs and Technologies in Health (CADTH). (2013). Patient lifts and transfer equipment for preventing pressure ulcers: a review of clinical and cost-effectiveness and guidelines (Structured abstract). *Health Technology Assessment Database*(1)

Ceylan, B., Gunes, U. Y., & Uyar, M. (2017). Examination of sacral tissue oxygen saturation among immobile patients. *Journal of Clinical Nursing, 08*, 08

Chaboyer, W., Mills, P. M., Roberts, S., & Latimer, S. (2015). Physical activity levels and torso orientations of hospitalized patients at risk of developing a pressure injury: An observational study. *Int J Nurs Pract, 21*(1), 11-17

Chen, Y., Wang, J., Lung, C. W., Yang, T. D., Crane, B. A., & Jan, Y. K. (2014). Effect of tilt and recline on ischial and coccygeal interface pressures in people with spinal cord injury. *American Journal of Physical Medicine and Rehabilitation, 93*(12), 1019-1026

Chung, C. H. K., Lau, M. C. H., Leung, T. Y. C., Yui, K. Y. S., Chan, S. H. S., Chan, S. L. S., & Chan, P. L. (2012). Effect of head elevation on sacral and ischial tuberosities pressure in infirmary patients. *Asian Journal of Gerontology and Geriatrics, 7*(2), 101-106

Crane, B., Wininger, M., Strydom, E., & Hulse, J. (2015). The effects of sitting on a mechanical lift sling on interface seat pressure: A pilot study. *Topics in Geriatric Rehabilitation, 31*(1), 67-73

Crane, B. A., Wininger, M., & Kunsman, M. (2015). Proxy study on minimizing risk of sacral pressure ulcers while complying with ventilator-associated pneumonia risk reduction guidelines. *Advances in Skin and Wound Care, 28*(12), 541-550

Dammeyer, J., Dickinson, S., Packard, D., Baldwin, N., & Ricklemann, C. (2013). Building a protocol to guide mobility in the ICU. *Critical Care Nursing Quarterly, 36*(1), 37-49

Defloor, T. (2000). The effect of position and mattress on interface pressure. *Applied Nursing Research, 13*(1), 2-11

Defloor, T., De Bacquer, D., & Grypdonck, M. H. F. (2005). The effect of various combinations of turning and pressure reducing devices on the incidence of pressure ulcers. *International Journal of Nursing Studies, 42*(1), 37-46

Defloor, T., & Grypdonck, M. H. (1999). Sitting posture and prevention of pressure ulcers. *Applied Nursing Research, 12*(3), 136

Dickinson, S., Tschannen, D., & Shever, L. L. (2013). Can the use of an early mobility program reduce the incidence of pressure ulcers in a surgical critical care unit? *Critical Care Nursing Quarterly, 36*(1), 127-140

Do, N. H., Kim, D. Y., Kim, J. H., Choi, J. H., Joo, S. Y., Kang, N. K., & Baek, Y. S. (2016). Effects of a continuous lateral turning device on pressure relief. *Journal of Physical Therapy Science, 28*(2), 460-466

Edger, M. (2017). Effect of a Patient-Repositioning Device in an Intensive Care Unit On Hospital-Acquired Pressure Injury Occurences and Cost: A Before-After Study. *J Wound Ostomy Continence Nurs, 44*(3), 236-240

Elnitsky, C. A., Lind, J. D., Rugs, D., & Powell-Cope, G. (2014). Implications for patient safety in the use of safe patient handling equipment: A national survey. *International Journal of Nursing Studies*

Gabison, S., Mathur, S., Nussbaum, E. L., Popovic, M. R., & Verrier, M. C. (2017). Trunk Function and Ischial Pressure Offloading in Individuals with Spinal Cord Injury. *Journal of Spinal Cord Medicine*, 1-10

Gammon, H. M., Shelton, C. B., Siegert, C., Dawson, C., Sexton, E., Burmeister, C., . . . Siddiqui, A. (2016). Self-turning for pressure injury prevention. *Wound Medicine, 12*, 15-18

Gebhardt, K., & Bliss, M. R. (1994). Preventing pressure sores in orthopaedic patients. Is prolonged chair nursing detrimental? *Journal Of Tissue Viability, 4*, 51-54

Giesbrecht, E. M., Ethans, K. D., & Staley, D. (2011). Measuring the effect of incremental angles of wheelchair tilt on interface pressure among individuals with spinal cord injury. *Spinal Cord, 49*(7), 827-831

Gillespie, B. M., Chaboyer, W. P., McInnes, E., Kent, B., Whitty, J. A., & Thalib, L. (2014). Repositioning for pressure ulcer prevention in adults. *Cochrane Database Syst Rev, 4*, CD009958

Girard, R., Baboi, L., Ayzac, L., Richard, J. C., & Guerin, C. (2014). The impact of patient positioning on pressure ulcers in patients with severe ARDS: Results from a multicentre randomised controlled trial on prone positioning. *Intensive Care Medicine, 40*(3), 397-403

Grap, M. J., Munro, C. L., Wetzel, P. A., Schubert, C. M., Pepperl, A., Burk, R. S., & Lucas, V. (2016). Backrest elevation and tissue interface pressure by anatomical location during mechanical ventilation. *American Journal of Critical Care, 25*(3), e56-e63

Grap, M. J., Munro, C. L., Wetzel, P. A., Schubert, C. M., Pepperl, A., Burk, R. S., & Lucas, V. (2017). Tissue interface pressure and skin integrity in critically ill, mechanically ventilated patients. *Intensive Crit Care Nurs, 38*, 1-9

Grisell, M., & Place, H. M. (2008). Face tissue pressure in prone positioning: a comparison of three face pillows while in the prone position for spinal surgery. *Spine, 33*(26), 2938-2941

Gucer, P. W., Gaitens, J., Oliver, M., & McDiarmid, M. A. (2013). Sit-stand powered mechanical lifts in long-term care and resident quality indicators. *Journal of Occupational and Environmental Medicine, 55*(1), 36-44

Gunningberg, L., Baath, C., & Sving, E. (2017). Staff's perceptions of a pressure mapping system to prevent pressure injuries in a hospital ward: A qualitative study. *Journal of Nursing Management, 29*, 29

Gunningberg, L., & Carli, C. (2014). Reduced pressure for fewer pressure ulcers: can real-time feedback of interface pressure optimise repositioning in bed? *Int Wound J*

Gunningberg, L., Sedin, I. M., Andersson, S., & Pingel, R. (2017). Pressure mapping to prevent pressure ulcers in a hospital setting: A pragmatic randomised controlled trial. *Int J Nurs Stud, 72*, 53-59

Hultin, L., Olsson, E., Carli, C., & Gunningberg, L. (2017). Pressure Mapping in Elderly Care: A Tool to Increase Pressure Injury Knowledge and Awareness Among Staff. *J Wound Ostomy Continence Nurs, 44*(2), 142-147

Jan, Y. K., & Crane, B. A. (2013a). Wheelchair tilt-in-space and recline does not reduce sacral skin perfusion as changing from the upright to the tilted and reclined position in people with spinal cord injury. *Archives of Physical Medicine and Rehabilitation, 94*(6), 1207-1210

Jan, Y. K., & Crane, B. A. (2013b). Wheelchair tilt-in-space and recline does not reduce sacral skin perfusion as changing from the upright to the tilted and reclined position in people with spinal cord injury. *Archives of Physical Medicine and Rehabilitation, 94*(6), 1207-1210

Jan, Y. K., Crane, B. A., Liao, F., Woods, J. A., & Ennis, W. J. (2013). Comparison of muscle and skin perfusion over the ischial tuberosities in response to wheelchair tilt-in-space and recline angles in people with spinal cord injury. *Archives of Physical Medicine and Rehabilitation, 94*(10), 1990-1996

Jan, Y. K., Liao, F., Jones, M. A., Rice, L. A., & Tisdell, T. (2013). Effect of durations of wheelchair tilt-in-space and recline on skin perfusion over the ischial tuberosity in people with spinal cord injury. *Archives of Physical Medicine and Rehabilitation, 94*(4), 667-672

Källman, U., Bergstrand, S., Ek, A. C., Engström, M., Lindberg, L. G., & Lindgren, M. (2013). Different lying positions and their effects on tissue blood flow and skin temperature in older adult patients. *Journal Of Advanced Nursing, 69*(1), 133-144

Källman, U., Bergstrand, S., Ek, A. C., Engström, M., & Lindgren, M. (2015). Nursing staff induced repositionings and immobile patients' spontaneous movements in nursing care. *International Wound Journal*

Kallman, U., Engstrom, M., Bergstrand, S., Ek, A. C., Fredrikson, M., Lindberg, L. G., & Lindgren, M. (2015). The Effects of Different Lying Positions on Interface Pressure, Skin Temperature, and Tissue Blood Flow in Nursing Home Residents. *Biological Research in Nursing, 17*(2)

Karatas, G. K., Tosun, A., & Kanatl, U. (2008). Center-of-pressure displacement during postural changes in relation to pressure ulcers in spinal cord-injured patients. *American Journal of Physical Medicine and Rehabilitation, 87*(3), 177-182

Klein, K., Mulkey, M., Bena, J. F., & Albert, N. M. (2015). Clinical and Psychologic Effects of Early Mobilization in Patients Treated in a Neurologic ICU: A Comparative Study. *Critical Care Medicine, 43*, 865-873

Knoblauch, D. J., Bettis, M. A., Lundy, F., & Meldrum, C. (2013). Financial implications of starting a mobility protocol in a surgical Intensive Care Unit. *Critical Care Nursing Quarterly, 36*(1), 120-126

Kobara K, Fujita D, Osaka H, Ito T, Yoshimura Y, Ishida H, & S., W. (2013). Mechanism of fluctuation in shear force applied to buttocks during reclining of back support on wheelchair. *Disabil Rehabil Assist Technol, 8*(3), 220-224

Kobara, K., Osaka, H., Takahashi, H., Ito, T., Fujita, D., & Watanabe, S. (2015). Influence of rotational axis height of back support on horizontal force applied to buttocks in a reclining wheelchair. *Prosthetics and Orthotics International, 39*(5), 397-404

Kobara, K., Takahashi, H., Fujita, D., Osaka, H., Ito, T., Suehiro, T., & Watanabe, S. (2015). Investigation of effect of leg support elevation timing on the horizontal force acting on the buttocks in a reclining wheelchair. *Journal of Physical Therapy Science, 27*(8), 2605-2610

Li, C. T., Huang, K. Y., Kung, C. F., Chen, Y. N., Tseng, Y. T., & Tsai, K. H. (2017). Evaluation of the effect of different sitting assistive devices in reclining wheelchair on interface pressure. *BioMedical Engineering Online, 16 (1) (no pagination)*(108)

Lippoldt, J., Pernicka, E., & Staudinger, T. (2014). Interface pressure at different degrees of backrest elevation with various types of pressure-redistribution surfaces. *American Journal of Critical Care, 23*(2), 119-126

Llaurado-Serra, M., Ulldemolins, M., Fernandez-Ballart, J., Guell-Baro, R., Valentí-Trulls, T., Calpe-Damians, N., . . . Vargas-López, C. (2016). Related factors to semi-recumbent position compliance and pressure ulcers in patients with invasive mechanical ventilation: An observational study (CAPCRI study). *International Journal of Nursing Studies, 61*, 198-208

Manzano, F., Colmenero, M., Pérez-Pérez, A. M., Roldán, D., Jiménez-Quintana Mdel, M., Mañas, M. R., . . . Fernández-Mondéjar, E. (2014). Comparison of two repositioning schedules for the prevention of pressure ulcers in patients on mechanical ventilation with alternating pressure air mattresses. *Intensive Care Med, 40*(11), 1679-1687

McInnes, E., Chaboyer, W., Allen, T., Murray, E., & Webber, L. (2013). Acute care patient mobility patterns and documented pressure injury prevention -- an observational study and survey. *Wound Practice & Research, 21*(3), 116-125

Miller, S. K., Aberegg, L., Blasiole, K., Parker, M., & Fulton, J. (2014). A prospective assessment of sacral pressures in healthy volunteers seated upright and reclined with legs elevated in a recliner. *Ostomy Wound Management, 60*(9), 52-59

Moore, Z., Cowman, S., & Conroy, R. M. (2011). A randomised controlled clinical trial of repositioning, using the 30° tilt, for the prevention of pressure ulcers. *Journal Of Clinical Nursing, 20*(17/18), 2633-2644

Moore, Z., Cowman, S., & Posnett, J. (2013). An economic analysis of repositioning for the prevention of pressure ulcers. [DE]. *Journal of Clinical Nursing, 22*(15-16), 2354-2360. http://onlinelibrary.wiley.com/o/cochrane/clcentral/articles/070/CN-00872070/frame.html doi:10.1111/j.1365-2702.2012.04310.x

Moore, Z. E., & Cowman, S. (2015). Repositioning for treating pressure ulcers. *Cochrane Database Syst Rev, 1*

Oomens, C. W., Broek, M., Hemmes, B., & Bader, D. L. (2016). How does lateral tilting affect the internal strains in the sacral region of bed ridden patients? - A contribution to pressure ulcer prevention. *Clinical Biomechanics, 35*, 7-13

Paulden, M., Bergstrom, N., Horn, S. D., Rapp, M., Stern, A., Barrett, R., . . . Krahn, M. (2014). Turning for ulcer reduction (TURN) study: An economic analysis. *Ontario health technology assessment series, 14*(12), 1-24

Pechlivanoglou, P., Paulden, M., Pham, B., Wong, J., Horn, S. D., & Krahn, M. (2018). Turning High-Risk Individuals: An Economic Evaluation of Repositioning Frequency in Long-Term Care. *Journal of the American Geriatrics Society, 66*(7), 1409-1414

Pepperl, A. A., Rooney, M. B., Parker, A., Burk, R. S., Kabban, C. S., Wetzel, P. A., & Grap, M. J. (2014). Effect of alertness level and backrest elevation on skin interface pressure. *Wounds, 26*(12), 334-341

Peterson, M., Schwab, W., McCutcheon, K., van Oostrom, J. H., Gravenstein, N., & Caruso, L. (2008). Effects of elevating the head of bed on interface pressure in volunteers. *Critical Care Medicine, 36*(11), 3038-3042

Peterson, M. J., Gravenstein, N., Schwab, W. K., van Oostrom, J. H., & Caruso, L. J. (2013). Patient repositioning and pressure ulcer risk: Monitoring interface pressures of at-risk patients. *J Rehabil Res Dev, 50*(4)

Pickham, D., Berte, N., Pihulic, M., Valdez, A., Mayer, B., & Desai, M. (2018). Effect of a wearable patient sensor on care delivery for preventing pressure injuries in acutely ill adults: A pragmatic randomized clinical trial (LS-HAPI study). *International Journal of Nursing Studies, 80*, 12-19

Pickham, D., M., P., Valdez, A., Mayer, B., Duhon, P., & Larson, B. (2018). Pressure Injury Prevention Practices in the Intensive Care Unit: Real-world Data Captured by a Wearable Patient Sensor. *Wounds, 30*(8), 229–234

Pompeo, M. (2013). Pressure Map Technology for Pressure Ulcer Patients: Can We Handle the Truth? *Wounds: A Compendium of Clinical Research & Practice, 25*(2), 34-40

Powers, J. (2016). Two Methods for Turning and Positioning and the Effect on Pressure Ulcer Development: A Comparison Cohort Study. *Journal of Wound, Ostomy, & Continence Nursing, 43*(1), 46-50

Rich, S. E., Margolis, D., Shardell, M., Hawkes, W. G., Miller, R. R., Amr, S., & Baumgarten, M. (2011). Frequent manual repositioning and incidence of pressure ulcers among bed-bound elderly hip fracture patients. *Wound Repair and Regeneration, 19*(1), 10-18

Romero, C. M., Cornejo, R. A., Galvez, L. R., Llanos, O. P., Tobar, E. A., Berasain, M., . . . Castro, J. (2009). Extended prone position ventilation in severe acute respiratory distress syndrome: A pilot feasibility study. *Journal of Critical Care, 24*(1), 81-88

Schallom, M., Dykeman, B., Metheny, N., Kirby, J., & Pierce, J. (2015). Head-of-Bed Elevation and Early Outcomes of Gastric Reflux, Aspiration and Pressure Ulcers: A Feasibility Study. *Am J Crit Care, 24*(1), 57-66

Scott, R. G., & Thurman, K. M. (2014). Visual feedback of continuous bedside pressure mapping to optimize effective patient repositioning. *Advances in Wound Care, 3*(5), 376-382

Shabshin, N., Ougortsin, V., Zoizner, G., & A., G. (2010). Evaluation of the effect of trunk tilt on compressive soft tissue deformations under the ischial tuberosities using weight-bearing MRI. *Clinical Biomechanics, 25*(5), 402-408

Siddiqui, A., Behrendt, R., Lafluer, M., & Craft, S. (2013). A continuous bedside pressure mapping system for prevention of pressure ulcer development in the medical ICU: A retrospective analysis. *Wounds, 25*(12), 333-339

Sonenblum, S. E., Sprigle, S. H., & Martin, J. S. (2016). Everyday sitting behavior of full-time wheelchair users. *Journal of Rehabilitation Research and Development, 53*(5), 585-598

Still, M. D., Cross, L. C., Dunlap, M., Rencher, R., Larkins, E. R., Carpenter, D. L., . . . Coopersmith, C. M. (2013). The Turn Team: A Novel Strategy for Reducing Pressure Ulcers in the Surgical Intensive Care Unit. *Journal of the American College of Surgeons*

Taule, T., Bergfjord, K., Holsvik, E. E., Lunde, T., Stokke, B. H., Storlid, H., . . . Rekand, T. (2013). Factors influencing optimal seating pressure after spinal cord injury. *Spinal Cord, 51*(4), 273-277

Tederko, P., Besowski, T., Jakubiak, K., Łyp, M., Bobecka-Wesołowska, K., & Kiwerski, J. (2015). Influence of wheelchair footrest height on ischial tuberosity pressure in individuals with paraplegia. *Spinal Cord, 53*(6), 471-475

Vanderwee, K., Grypdonck, M. H., De, B. D., & Defloor, T. (2007). Effectiveness of turning with unequal time intervals on the incidence of pressure ulcer lesions. *Journal Of Advanced Nursing, 57*(1), 59-68

Walia, G. S., Wong, A. L., Lo, A. Y., Mackert, G. A., Carl, H. M., Pedreira, R. A., . . . Sacks, J. M. (2016). Efficacy of Monitoring Devices in Support of Prevention of Pressure Injuries: Systematic Review and Meta-analysis. *Adv Skin Wound Care, 29*(12), 567-574

Wang, L., Li, X., Yang, Z., Tang, X., Yuan, Q., Deng, L., & Sun, X. (2016). Semi-recumbent position versus supine position for the prevention of ventilator-associated pneumonia in adults requiring mechanical ventilation. *Cochrane Database of Systematic Reviews, 1*, CD009946

Webb, J., Twiste, M., Walton, L. A., & Hogg, P. (2017). The impact of hoist sling fabrics on interface pressure whilst sitting in healthy volunteers and wheelchair users: A comparative study. *Journal of Tissue Viability.*

Wininger, M., & Crane, B. A. (2015). Prevalence of Sensor Saturation in Wheelchair Seat Interface Pressure Mapping. *Assistive Technology, 27*(2), 69-75

Wood, W., Tschannen, D., Trotsky, A., Grunawalt, J., Adams, D., Chang, B., . . . Diccion-MacDonald, S. (2014). A Mobility Program for an Inpatient Acute Care Medical Unit. *American Journal of Nursing, 114*(10), 34-42

Woodhouse, M., Worsley, P. R., Voegeli, D., Schoonhoven, L., & Bader, D. L. (2015). The physiological response of soft tissue to periodic repositioning as a strategy for pressure ulcer prevention. *Clin Biomech, 30*(2), 166-174

Wu, T., Wang, S. T., Lin, P. C., Liu, C. L., & Chao, Y. F. (2011). Effects of using a high-density foam pad versus a viscoelastic polymer pad on the incidence of pressure ulcer development during spinal surgery. *Biological Research For Nursing, 13*(4), 419-424

Yap, T. L., Kennerly, S. M., Simmons, M. R., Buncher, C. R., Miller, E., Kim, J., & Yap, W. Y. (2013). Multidimensional team-based intervention using musical cues to reduce odds of facility-acquired pressure ulcers in long-term care: a paired randomized intervention study. *J Am Geriatr Soc, 61*(9)