

FINAL REPORT

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Threats to Skin Integrity Associated with Use of Patient Handling Slings in Veterans with SCI IRB Study # Pro00003983

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Background

The use of ceiling lifts and other safe patient technologies have been shown to reduce the risk of musculoskeletal injuries for healthcare providers and reduce the risks of immobility such as falls, pressure ulcers and urinary function for patients. No evidence to date has been published that suggests the use of slings and lifts result in pressure ulceration. A pressure ulcer is a localized injury to the skin or underlying tissue usually over a bony prominence, as a result of pressure, or pressure in combination with shear or friction.¹ Mechanical loading is the main cause of pressure ulcer formation; however, the pathophysiological responses to this loading are inconclusive.² This research was offered in response to concerns regarding the possible contribution that patient handling slings may play in pressure ulcer development in vulnerable populations, specifically Veterans with spinal cord injury (SCI).

Research Aims

The main goals of this study were to quantify risks associated with pressure ulceration due to normal forces and to identify the at-risk anatomical locations that are generated at the sling-participant interface while sitting or lying on a sling and during typical transfers for various sling designs (e.g., universal, repositioning, hygiene, disposable).

Study results will be disseminated via podium and poster presentations at national conferences and published in peer-reviewed journals. Findings will be shared with Veterans with SCI, care providers, and clinicians with the goal of minimizing skin integrity risks while using safe patient handling slings.

Methods

Study Design

A descriptive, observational study was conducted at a VA clinical research institution. Twenty-three patient handling slings (18 seated, 5 supine) were examined to represent a wide variety of sling styles (e.g., slings with and without head support), materials, and manufacturers. The sample was not exhaustive, but is a representation of slings currently on the market and used in clinical settings. Slings were selected from three international manufacturers: ArjoHuntleigh (Addison, IL), Guldman (Tampa, FL), and Liko (Franklin, MA) (Table 1).

Table 1. Patient Handling Slings Evaluated.

	Sling	Manufacturer	Type	Material	Feature
A	General purpose loop sling with head support	ArjoHuntleigh	Seated	Polyester	---
B	Toilet sling with head support	ArjoHuntleigh	Seated	Polyester	---
C	Mesh sling with head support	ArjoHuntleigh	Seated	Polyester	Hygiene
D	Large hammock sling	ArjoHuntleigh	Seated	Polyester	---
E	Loop flites	ArjoHuntleigh	Seated	Polyester	Disposable
F	Active micro plus	Guldmann	Seated	Polyester	---
G	Basic basic sling	Guldmann	Seated	Polyester	---
H	Basic basic sling	Guldmann	Seated	Polyester Net	Hygiene
I	Basic high	Guldmann	Seated	Polyester	---
J	Basic high	Guldmann	Seated	Polyester Net	Hygiene
K	Uni-D	Guldmann	Seated	Nylon	---
L	Uni-D high back	Guldmann	Seated	Nylon	---
M	Uni-D high back Disposable	Guldmann	Seated	Polyester	Disposable
N	Original highback	Liko	Seated	Polyester	---
O	Original highback	Liko	Seated	Plastic Coated Net	Hygiene
P	Universal sling	Liko	Seated	Polyester	---
Q	Universal sling	Liko	Seated	Plastic Coated Net	Hygiene
R	Solo highback	Liko	Seated	Non-Woven Polypropylene	Disposable
S1	Repositioning sling w/ stretcher frame	ArjoHuntleigh	Supine	Polyester	---
S2	Stretcher sling	ArjoHuntleigh	Supine	Polyester	---
S3	Disposable repositioning w/ horizontal lifting support	Guldmann	Supine	Polyester	Disposable
S4	Octo lift sheet w/ Octo stretch	Liko	Supine	Polyester	---
S5	Repositioning sheet	Liko	Supine	Polyester, Cotton	---

Participants

Twelve individuals participated and provided written informed consent (Table 2).

Table 2. Study Participants.

	N	Age	Height	Weight	BMI
Nondisabled participants	4 (3 M, 1 F)	21 to 42 years (30.0 ± 8.8 years)	1.70 m to 1.83 m (1.75 m ± 0.06 m)	59.1 kg to 87.3 kg (76.9 kg ± 12.6 kg)	20.4 to 28.4 (25.2 ± 3.4)
Veterans with SCI*	8 (7 M, 1 F)	34 to 64 years (51.9 ± 9.0 years)	1.68 m to 1.91 m (1.75 m ± 0.07 m)	61.2 kg to 104.8 kg (77.6 kg ± 13.9 kg)	20.9 to 37.3 (25.4 ± 5.6)

BMI = body mass index; F = female; M = male; *SCI ranged from MS to quadriplegia

Instrumentation

Interface pressure measurements were recorded at 5 Hz with a high-resolution pressure-mapping system, X3 PRO (XSENSOR Technology Corp, Calgary, Canada). The pressure sensor is a flexible, thin sensor array comprised of 16,000 sensors (0.2" x 0.2") in a 32-inch x 20-inch array (25 sensors per square inch). The sensor array was calibrated by the manufacturer to measure pressures from 0-200 mmHg, with a reported accuracy of $\pm 10\%$.

A modern hospital bed with low air loss technology was used for all measurements (VersaCare A.I.R., Hill-Rom, Batesville, IN). The head of bed (HOB) elevation was measured with the bed's ball-bearing indicator located in the side rail of the bed. A Maxi Sky 600 (ArjoHuntleigh) ceiling lift system was used in a clinical laboratory setting for all participants and slings. The lift system has a safe working load of 272 kg and a 2.3 m strap length. A standard, 2-point spreader bar was used for all seated slings. The manufacturer-recommended spreader bar (either 8- or 10-point) was used for each of the respective supine slings.

Data Collection Protocol

After the consent process, participants were dressed in hospital scrubs or loose fitting clothing (e.g., sweatpants) and positioned supine on the bed that was laid flat. The sensor array was placed between the participant and the sling, spanning from the sacrum to the lower-thighs to ensure data collection of the predominant weight-bearing tissue areas. The sling and sensor array were positioned on the hospital bed prior to the participant lying on the bed to ensure proper placement beneath the patient, without wrinkles.

Participants underwent a series of positions, transfers, and transports with each sling. The positioning sequence for the seated slings was as follows: supine on a hospital bed (0-degree HOB), HOB raised to 30-degrees, sling installation onto the ceiling lift (for an upright, seated position), suspension in sling and transport (bed to wheelchair), seated in wheelchair, suspension in sling and transport (wheelchair to bed), and supine on hospital bed (30-degree HOB) with sling uninstalled from the ceiling lift. The positioning sequence for the supine slings was as follows: supine on a hospital bed (0-degree HOB), sling installation onto the ceiling lift, suspension in sling and transport, and supine on hospital bed (0-degree HOB) with sling uninstalled from the ceiling lift.

Interface pressure measurements were recorded at 5 Hz for the duration of the protocol. Patients were monitored for 5 minutes in each position. This time frame was chosen to allow the subject to settle into the position, to allow enough time for transport if prescribed, and to limit prolonged exposure to potentially high pressures while suspended in the sling. The entire protocol was completed in 30 minutes for each of the seated slings and 20 minutes for each of the supine slings. During sling installation and suspension, care was taken to ensure the sensor array was positioned beneath the participant's weight-bearing tissue areas and was not bunched up.

Data Processing and Analysis

The interface pressure profiles from the positions of interest were used to determine how each of the patient handling slings affected the participants' interface pressures. MATLAB (The MathWorks, Natick, MA) and Excel (Microsoft, Redmond, WA) were used to image, analyze, and compare the interface pressure data. Each pressure profile provided the interface pressure (mmHg) at each of the 16,000 discrete sensors. Interface pressure distributions across the slings were analyzed and the anatomical locations of high pressures were determined.

For each position for each sling, a representative sample was selected for analysis. Each representative sample consisted of 40 consecutive seconds of interface pressure data (200 profiles) with

the least variance. The pressure distributions were analyzed by dividing the calibrated range of pressures into 10 divisions (>0, >20, >40, >60, >80, >100, >120, >140, >160, >180) and calculating the number of sensors that corresponded to each value.

The seated and supine slings were ranked overall according to their performance *while suspended* (this position was selected as it resulted in the greatest interface pressures and potential for skin integrity risks). The evaluation criteria minimized the amount of sensors exposed to high interface pressures [seated slings (>100, >180); supine slings (>60, >80)] and maximized the amount of sensors consisting of lower, or supportive, interface pressures [seated slings (average of (>40,>60,>80) and all sensors ≤ 80); supine slings (average of (>20,>40,>60) and all sensors ≤ 40)]. Slings were ranked for each participant, and the average rank for each criterion was calculated for each sling. Combining all four criteria determined the overall rank for each sling.

The nondisabled participants evaluated all 23 slings, and the Veterans with SCI evaluated the 5 best-performing slings (4 seated, 1 supine) to limit subject burden in this vulnerable population.

Results

Seated Slings

Sling-participant interface pressures (Table 3) were greatest while suspended in the sling compared to seated in the wheelchair or lying on the bed. Interface pressure magnitudes exceeded 200 mmHg for all participants, for all slings, while suspended in the seated slings. Sling-patient interface pressures, regardless of position or type of sling, were greatest along the sling seams. The back of the upper and lower thighs, towards the groin and knee respectively, were the anatomical areas exposed to these high pressures. See Figure 1 for examples of interface pressure profiles of seated slings. Trends in performance were not identified for particular materials, manufacturers, or sling styles.

Supine Slings

Sling-participant interface pressures (Table 3) were greatest while suspended in the sling compared to lying on the bed. The anatomical areas exposed to high interface pressures were the tissues of the peri-sacral area, buttocks, and greater trochanters. Additionally, the presence of additional sling seams (support straps) on the underside of some of the supine slings greatly increased interface pressures over these load bearing areas. Trends in performance were not identified for particular materials, manufacturers, or sling styles.

Veterans with SCI

Interface pressure results for Veterans with SCI were similar to the nondisabled participants (Table 4). Again, the interface pressures were greatest while suspended in the sling compared to other positions. Interface pressures exceeded 200 mmHg for all Veterans with SCI while suspended. Sling-participant interface pressures were greatest along the sling seams. And, the anatomical areas at risk were also the back of the upper and lower thighs, towards the groin and knee respectively. However, Veterans with SCI tended to have more high pressure areas than nondisabled participants.

Shear Force

An exploratory aim was to measure shear forces at the sling-participant interface during typical patient handling transfers. Four 1-cm x 1-cm investigational, prototype shear sensors (Novel Electronics, Inc., Saint Paul, MN) were used in attempt to measure shear forces at 20 Hz. The shear sensors worked in controlled, laboratory evaluations; however, the data collected with study participants did not reveal

meaningful data. The shear sensors were fastened to the sling seams where the greatest interface pressures were expected to occur, but very minimal shear forces were recorded and measures were inconsistent across participants.

Table 3. Mean interface pressure data. Data represents the mean number of sensors that exceed the interface pressure thresholds (mmHg) while suspended in the sling. The slings are ranked from best performing (lower number) to least (higher number).

Seated Slings. Suspended.

Sling	>0	>20	>40	>60	>80	>100	>120	>140	>160	>180	Rank
A	8257.4	5665.9	1765.1	818.4	467.0	325.8	246.2	186.6	148.2	121.8	1
B	4945.6	3853.5	1892.3	1082.0	721.7	556.8	449.1	373.7	320.4	276.0	10
C	7495.3	4989.8	1769.6	1014.1	682.1	514.8	392.9	303.7	239.7	189.9	5
D	9621.7	7372.3	2879.2	1191.9	492.6	232.5	133.2	77.1	42.3	26.0	3
E	8345.5	5887.6	2000.4	1018.9	565.4	390.4	279.7	205.5	153.5	113.3	2
F	4261.2	3512.6	1891.7	1230.4	760.8	506.5	368.0	264.6	191.6	136.5	6
G	7992.9	5373.8	2301.3	1495.0	1054.7	810.4	649.5	522.3	437.1	365.9	14
H	6983.7	4124.0	1774.8	1385.0	1153.1	980.9	851.4	731.4	631.8	550.5	17
I	7879.1	5399.8	2336.6	1464.1	975.9	693.5	507.2	365.0	259.4	183.2	11
J	7699.0	4425.7	1603.6	1180.8	882.8	676.8	514.9	399.4	312.7	247.2	9
K	7819.5	5141.0	2055.9	1367.3	1032.0	844.7	705.3	589.8	503.0	434.1	16
L	7692.7	5280.3	2022.7	1098.9	722.1	537.2	412.8	314.5	245.1	190.2	4
M	6803.1	4612.7	2130.5	1418.6	1052.9	825.4	661.3	519.3	413.7	332.9	15
N	7085.1	4727.6	2088.1	1406.2	1008.2	774.1	626.7	506.4	411.1	335.0	17
O	7182.0	4846.6	1905.6	1167.1	761.1	548.9	415.8	318.9	251.5	195.3	7
P	6522.9	4408.8	1968.9	1266.6	868.8	667.0	528.0	428.2	355.7	300.9	12
Q	6614.2	4284.0	1764.1	1181.8	881.3	713.1	591.3	487.3	406.1	335.7	12
R	7895.1	5574.9	2229.8	1336.1	871.7	616.0	463.3	357.3	284.0	229.5	7

Supine Slings. Suspended.

Sling	>0	>20	>40	>60	>80	>100	>120	>140	>160	>180	Rank
S1	6042.7	3969.3	581.8	73.7	13.8	5.1	1.1	0.5	0.3	0.3	2
S2	5329.9	3784.1	696.6	188.6	46.1	15.8	5.2	2.4	1.3	0.5	4
S3	6575.9	4399.6	324.5	21.4	3.2	0.3	0.0	0.0	0.0	0.0	1
S4	5516.7	4167.9	659.7	138.8	30.5	6.9	2.6	0.6	0.3	0.3	3
S5	4922.4	3187.7	620.6	400.5	281.5	208.8	158.5	121.2	98.9	77.8	5

Table 4. Mean interface pressure data for Veterans with SCI. Data represents the mean number of sensors that exceed the interface pressure thresholds (mmHg) while suspended in the sling.

Sling	>0	>20	>40	>60	>80	>100	>120	>140	>160	>180
A	10006.0	6029.8	1890.1	880.6	519.3	356.7	259.6	192.0	147.1	118.1
D	10544.2	7542.7	3006.1	1203.0	497.5	263.5	149.1	88.1	55.4	40.1
E	10597.3	6314.3	1962.9	970.0	576.5	397.2	293.7	226.6	176.3	144.1
L	11026.1	6453.9	2087.7	1153.4	748.8	545.1	417.3	319.7	244.0	198.9
S3	7226.0	4651.7	809.5	113.5	25.7	9.9	3.8	1.8	0.9	0.7

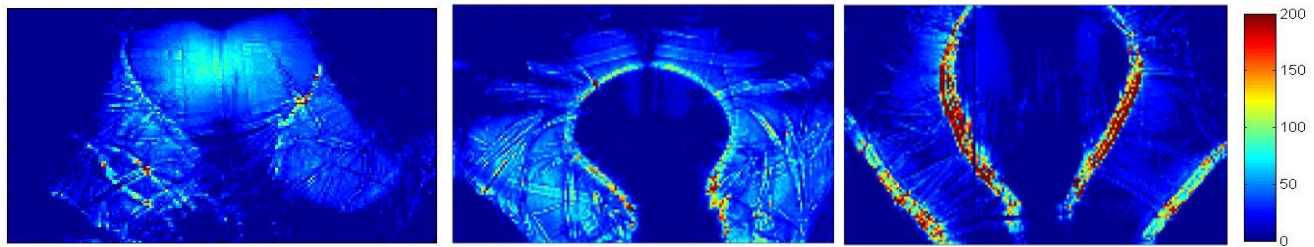


Figure 1. Interface pressure images. The colorbar represents interface pressure magnitude in mmHg. Left: Example of a participant seated on a sling (E) in a wheelchair. Middle and Right: Examples of suspended positions in a high performing sling (D) and a low performing sling (H), respectively. Note the high pressures densely localized along the seams.

Discussion

Skin Integrity Risks

For the seated slings, the anatomical areas exposed to elevated interface pressures were primarily the back of the upper and lower thighs, towards the groin and knee respectively. Despite the extremely high pressures at the sling seams (>200 mmHg), these pressures were not over the bony prominences where pressure ulcers typically develop (e.g., sacrum, coccyx, greater trochanters). While the high pressure areas are not typical areas for pressure ulcer formation, it would be prudent to limit the duration of these pressures as much as possible. For the supine slings, despite lower magnitude interface pressures, the anatomical areas exposed to the highest interface pressures were over the peri-sacral area, buttocks, and greater trochanters (and tissue areas across any support straps). Therefore, regardless of the sling type, the amount of time suspended in the sling should be limited. Regarding distances traveled with a ceiling lift system, again, the amount of time suspended in the sling is what should be monitored and limited, not the distance traveled. In this study, participants were safely suspended for 5 minute durations, but were closely monitored to limit exposure to high interface pressures. Based on study results, we would recommend, if possible, that sling suspension times be limited to approximately 5 minutes. However, we recognize that we have only evaluated a select number of patient handling slings.

Recommendations to Reduce Sling Interface Pressures

Care should be taken so that when an individual is seated or lying on a sling (not suspended) that the seams are not beneath the patient or that they have been smoothed out to minimize high interface pressures. However, when lifting an individual, one should ensure that the fabric (or seams) does not fold over itself to avoid unnecessarily high interface pressures. If a sling seam folded over itself, it essentially doubled or tripled the size of the sling seams, thus doubling or tripling the tissue area exposed to elevated interface pressures. This tended to be an issue for slings made of thinner materials and slings with more material. Additionally, providing a slight recline while suspended in the seated position can provide some weight support onto the back, which can help alleviate high interface pressures on the thighs. However, care must be taken so the individual does not “fall through” the sling.

Shear Force

Due to the small size (dimensions) of the sensors compared to the surface area of the sling and human body, it is difficult to determine whether they were appropriately placed to accurately measure shear forces. Perhaps the results are accurate and there are only minimal shear forces at the sling seam

and participant interface; however, further investigation is warranted with these shear sensors (or others) and for data collection in clinical scenarios vs. controlled laboratory conditions.

Future Work

This research was the first to provide interface pressure data of nondisabled adults and Veterans with SCI while suspended in safe patient handling slings. Due to the preliminary yet promising nature of this work, future research is warranted before extrapolating these results to the clinical setting to further elucidate skin integrity threats to Veterans with SCI and others using of patient handling slings.

Additional research approaches that are needed include:

- Evaluation of additional patient handling slings with a variety of manufacturers, materials, and sling types.
- A larger study (more participants) of Veterans with SCI to evaluate sling performance in the clinical setting.
- Sling design improvements (e.g., materials, construction, etc.) to minimize the seam areas or provide seams that more evenly distribute high interface pressures.

Conclusions

- Transferring individuals with patient handling slings expose them to high interface pressures.
- Interface pressures are maximal while suspended in a sling.
- Interface pressures are prominent and elevated along the sling seams, independent of the sling type or manufacturer.
- Prolonged suspension in a sling should be limited.
- Veterans with SCI appear to be at greater risk for skin integrity risks while suspended in a patient handling sling than nondisabled participants due to greater tissue areas exposed to elevated interface pressures.

Dissemination

- This research was presented as a podium presentation at the Academy of Spinal Cord Injury Professionals (ASCIP) Annual Meeting in Las Vegas, NV on September 2-4, 2013.
- This research was presented as a poster presentation at the Safe Patient Handling Conference East Annual Meeting in Orlando, FL on March 24-28, 2014.
- This research has been accepted for a podium presentation at the ESM Annual Meeting in Boston, MA on July 2-6.
- A manuscript is in preparation to the Journal of Rehabilitation Research and Development with the results from the healthy, nondisabled adult participants with all 23 patient handling slings.
- Another manuscript is in preparation to the Journal of Spinal Cord Medicine with data from Veterans with SCI with the 5 better-performing slings.

References

1. National Pressure Ulcer Advisory Panel (NPUAP). Pressure Ulcer Stages Revised by NPUAP. 2007. Available at: www.npuap.org/pr2.htm. Accessed February 13, 2013.
2. Bouten CV, Oomens CW, Baaijens FP, Bader DL et al. The etiology of pressure ulcers: skin deep or muscle bound? Arch Phys Med Rehabil. 2003;84:616-619.