Seat Interface Pressures of Individuals With Paraplegia: Influence of Dynamic Wheelchair Locomotion Compared With Static Seated Measurements

Thomas W. Kernozek, PhD, Jeff E. Lewin, MS


Objective: To provide a comparison of the seat interface pressures between static seating and dynamic seating during wheelchair locomotion of individuals with paraplegia.

Design: Repeated measures multivariate analysis of variance (MANOVA) comparing two conditions: static seat and dynamic seat interface pressures.

Setting: University campus and clinic.

Participants: Fifteen participants, each of whom propelled a manual wheelchair for at least 5 hours per week over the previous 6 months and functioned with a spinal cord injury/disability level of T1 or below.

Main Outcome Measures: Peak pressure (PP) and pressure-time integral (PTI) as measured by the Novel Pliance System, which consists of a flexible 32 x 32 capacitive sensor mat (each sensor 1.5 cm²) interfaced with a PC, was sampled at 10 Hz. The participants were measured in their own wheelchair with a new Jay Active seat cushion.

Results: The repeated measures MANOVA showed a difference in the PP and PTI between the static and dynamic measurements (Wilks’ = .00, p < .05). Follow-up dependent t-tests yielded a difference in PP (t = 5.40, p < 0.025) and no difference in the PTI between static and dynamic conditions (t = 1.45, p > 0.025). The PP during static seating (mean = 16.2 ± 5.0 kPa [121 ± 37.5 mmHg]) was less than during dynamic seat interface pressures during wheelchair locomotion (20.03 ± 6.6 kPa [152.3 ± 49.5 mmHg]). PP varied by up to 42% during the wheelchair locomotion cycle. The PTI was similar between static (30.1 ± 9.3 kPa [225.7 ± 69 mmHg]) and dynamic conditions (36.2 ± 18.1 kPa [271 ± 135.7 mmHg]).

Conclusions: The results from this study are consistent with some of the previous work on the nondisabled and a single case study, but with greater external validity because of the nature of the sample chosen and the methodology employed. PPs were greater during dynamic wheelchair locomotion compared with static seating interface pressures, with the peak varying up to 42% during the wheelchair locomotion cycle. The PTI indicates that the cumulative effect of the loading was comparable between conditions. The question that remains is whether this dynamic loading, resulting in a change in PP throughout the cycle, has a significant effect on tissue health.

SEAT INTERFACE PRESSURE assessment is of interest to both researchers and clinicians because 25% to 85% of all persons with spinal cord injury (SCI) develop pressure ulcers that result in more than 2.3 million Medicare hospital days (1987) and approximately $1.1 billion in direct insurance costs. Complications associated with pressure ulcers are attributed to between 4% and 8% of deaths. While both intrinsic and extrinsic risk factors are associated with the etiology of pressure ulcers, pressure is thought to be one of the key extrinsic factors in the development of sores. Some of the other risk factors include shear forces, skin temperature, the nutritional status of the patient, existence of moisture, body build and anatomic structure, and local perfusion. Skin breakdown usually occurs in the areas of the ischial tuberosities because of the concentration of load due to bony structure and the amount of time loaded.

Currently, seat interface pressure distributions are measured—if they are measured at all—statically in a clinical or research environment with the patient in a fixed position on various cushions or in various body positions. Measuring static seat pressures provides a baseline, but it is likely that the seat interface is loaded differently throughout the day with dynamic loading, resulting in a change in PP throughout the cycle. The results from this study are consistent with some of the previous work on the nondisabled and a single case study, but with greater external validity because of the nature of the sample chosen and the methodology employed. PPs were greater during dynamic wheelchair locomotion compared with static seating interface pressures, with the peak varying up to 42% during the wheelchair locomotion cycle. The PTI indicates that the cumulative effect of the loading was comparable between conditions. The question that remains is whether this dynamic loading, resulting in a change in PP throughout the cycle, has a significant effect on tissue health.
pressures of individuals with paraplegia during wheelchair locomotion. The purpose of our study was to investigate the peak pressure (PP) and pressure time integral (PTI) during static seating in comparison with the ADL skill of wheelchair locomotion in a group of SCI participants. The hypothesis was that PPs and the peak PTI would be greater during the wheelchair locomotion cycle compared with static measures.

METHODS

A convenience sample of 15 patients was selected, each of whom had been using a manual wheelchair for at least 5 hours a week for 6 months and was functioning with an SCI/disability of T1 or below. The average time between a subject’s injury and testing was 17.5 ± 10.25 years; the mean body weight of this sample was 77.5 ± 22.4 kg (170.5 ± 49.31 lbs). Thirteen men and 2 women were involved in the study. The Novel Pliance System™, which consists of a flexible 32 × 32 capacitive sensor mat (each sensor, 1.5 cm²) interfaced with a PC sampling at 10 Hz, was used to measure seat interface pressures. The system is hardwired, requiring that cabling be tethered between the external analog-to-digital converter hardware and PC. This configuration seemed to have little effect on patients’ performances. The sensor mat was calibrated by homogenous air pressure throughout the measurement range before data collection. Within a pressure chamber, verification of pressures from the sensor mat was performed between data collection sessions at 15 ± 1.0 kPa (112.5 ± 7.5 mm Hg). If measured pressures deviated by more than this criterion, the sensor mat was recalibrated. This sensor technology was chosen over other sensor technologies because of its excellent reliability as shown in the analysis of gait. The participants were measured in their own wheelchair with a new Jay Active™ seat cushion that was prescribed for each participant. The order of measurements was randomized (static versus dynamic) with the pressure-sensitive mat placed between the patient and the cushion. To identify a wheeling cycle from the data, a deformable hand switch interfaced with a light-emitting diode (LED) on the wheelchair was placed in the participant’s right hand. When the participant made contact with the push rim, the switch closed, illuminating the LED. From the Pliance System™ a synch pulse was discharged from the analyzer, illuminating a second LED on the chair. Both LEDs were captured on videotape with a camcorder (30 Hz) to determine the onset (right hand on push rim) and termination (right hand on push rim for the second time) of a wheeling cycle and onset of pressure mat sampling. The dependent variables obtained from the sensor mat were PP and PTI. PP was the peak value that occurred from any single sensor during the static and dynamic trials. This PP value occurred in the region of one of the ischial tuberosities in all trials. PTI was calculated by integrating the PP time curve for each trial, about 40% from the peak to the minimum PP throughout the wheelchair locomotion cycle. Minimum PP decreased below the PP during static loading in all trials for each subject. However, PP varied throughout the wheeling cycle by 35% to 42% below the static loading conditions.

DISCUSSION

There is no agreement on a pressure threshold for tissue damage. Some researchers have indicated that tissue damage can occur with a PP of 6 kPa (45 mm Hg) with friction, and with PPs ranging from 1 to 9 kPa (7.5 to 67.5 mm Hg) both pressure and dynamic pressures were found with an air-filled cushion compared with foam. Static PPs were 18 kPa (135 mm Hg) on the air cushion and 25 kPa (187.5 mm Hg) on foam. The maximum PP was approximately 40% greater for the foam cushion than for the air. While Kalpen reported the same instrumentation as in our study, differences in the PP were much greater comparing static and dynamic pressures during wheeling. Figure 1 shows the mean and 95% confidence interval from a single wheelchair locomotion trial of three consecutive locomotion cycles. The three trials were interpolated and ensemble-averaged to obtain the resulting curve. Note that PP varies by about 40% from the peak to the minimum PP throughout the wheelchair locomotion cycle. Minimum PP decreased below the PP during static loading in all trials for each subject. However, PP varied throughout the wheeling cycle by 35% to 42% below the static loading conditions.

Table 1: Means and Standard Deviations for Peak Pressure and Pressure Time Integral for Static and Dynamic (Wheeling) Trials (n = 15)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Static</th>
<th>Dynamic</th>
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<tr>
<td>Peak pressure (kPa)</td>
<td>16.2 ± 6.0</td>
<td>20.3 ± 6.6</td>
</tr>
<tr>
<td>Pressure time integral (kPa/sec)</td>
<td>30.1 ± 9.3</td>
<td>36.2 ± 18.1</td>
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*p < .025.
cycle, the question remains whether these interface pressures are as damaging to tissue health as the static loading. To answer, we must first recognize and heed Brand’s warning that we do not know enough about the etiology of pressure sores to speculate on the direct causes of tissue breakdown. Much more research is needed on the etiology of sore development and on the development of a threshold for injury. Even during wheelchair locomotion, seat interface pressures do not decrease below the pressure thresholds discussed in the literature.

Conversely, does the fluctuation in PP facilitate a sort of “pumping mechanism” as suggested by Eckrich and Patterson? Since there are other therapeutic techniques that use external manipulation of the skin to stimulate blood and lymphatic activity, it seems logical that this fluctuation in PP throughout the wheelchair locomotion cycle could promote this activity. Thus, the cycling loading may be beneficial to the patient rather than a risk factor for tissue damage. Further research needs to examine these factors.

A notable fact is that the sensor mat was sampled at 10Hz. The ability to capture the peak may be diminished because of this sampling rate. As a result, the PPs that were measured may have been less than what was actually occurring. Three cycles and four trials were used to obtain these PP measurements. Standard deviations were similar between trials of dynamic wheelchair locomotion measures, providing some merit to the protocol sample chosen and the protocol used. PPs were greater during dynamic wheelchair locomotion compared with static seating, greater external validity because of the size and nature of the sample chosen and the protocol used. PPs were greater during dynamic wheelchair locomotion compared with static seating, with the peak varying up to 42% during the wheelchair locomotion cycle. The PTI indicated that the cumulative effect of the loading was comparable between the two conditions. The question remains as to how this dynamic loading affects tissue health in comparison with static loading.

**CONCLUSIONS**

Our results are consistent with the results of some previous work on the nondisabled and in a single case, but our study has greater external validity because of the size and nature of the sample chosen and the protocol used. PPs were greater during dynamic wheelchair locomotion compared with static seating, with the peak varying up to 42% during the wheelchair locomotion cycle. The PTI indicated that the cumulative effect of the loading was comparable between the two conditions. The question remains as to how this dynamic loading affects tissue health in comparison with static loading.

**References**


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