THE DISPERSION INDEX AS A METRIC FOR MEASURING PRESSURE DISTRIBUTION ON SEAT SURFACES: A PILOT STUDY

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ABSTRACT

Individuals with a spinal cord injury (SCI) are at a high risk for the development of a pressure ulcer at some point in their life. Therefore, there is a need to predict and prevent the development of pressure ulcers. Besides pressure, a significant risk factor is the nutritional status of the individual. The purpose of this study is to describe the effectiveness of seat surfaces based on the pressure distribution characteristics for individuals with a SCI. The dispersion index (DI) was measured for seven individuals with a spinal cord injury while on six different seating surfaces. The DI was less than 50 for all individuals when on their own cushion. The differences between the plinth and all other seating surfaces were significant. Furthermore, the differences between the foam/air cushions and the foam/honeycomb cushions were significant. Given the small sample size, the DI may be an appropriate metric for characterizing the pressure distribution, and may be useful when developing models describing the development of pressure ulcers.

INTRODUCTION

According to researchers, 24% of individuals with a spinal cord injury (SCI) experience a pressure ulcer during their rehabilitation hospital stay, 15% experience a pressure ulcer within the 1st year, and between 5% and 85% will develop a pressure ulcer in their lifetime (Chen, Devivo, & Jackson, 2005; McKinley, Jackson, Cardenas, & DeVivo, 1999; Richardson & Meyer, 1981; Salzberg et al., 1996; Young, Railton, Harrower, & Brookes, 1981). Furthermore, adults who lack adequate calories, protein, or other nutrients needed for tissue maintenance and repair will experience undernutrition. In acute, chronic, and transitional care settings, recognition and treatment of adult undernutrition is a primary concern (Jensen et al., 2010; Tappenden et al., 2013; White et al., 2012). The Academy of Nutrition and Dietetics provides nutrition recommendations for the individuals with a spinal cord injury within their evidence analysis guidelines (Thompson, Paison DiTucci, & Barton, 2013) Therefore, there is a clinical need to characterize the wheelchair seating system in terms of pressure at the seat cushion interface and nutritional status of individuals with a spinal cord injury.

The long-term goal of this study includes describing the nutritional status of individuals with a SCI, the pressure relieving characteristics of an individual's seat cushion, and the risk of pressure ulcer development. The purpose of the pilot study described in this paper is to start addressing the second long term goal: characterize the pressure distribution properties of seat cushions using the dispersion index for individuals with a SCI.

METHODS

A pilot exploratory study was used with a cross-sectional descriptive design to describe the characteristic of pressure at the seating surface for individuals who have a spinal cord injury and use a wheelchair as their primary mode of mobility. The study was approved by The Ohio State University Institutional Review Board. This study used a sample of convenience of individuals with a spinal cord injury who used a wheelchair as their primary mode of mobility. All participants were 18 years old or older, were at least one-year post injury, and had a spinal cord injury at the level of C5 or lower.

Study Procedures

Research was conducted at the Assistive Technology Center, The Ohio State University Wexner Medical Center. All data was collected at a single appointment. The same physical therapist completed the pressure mapping assessment, an ASIA scale assessment, and interview for participant demographics and history. As part of the pressure mapping assessment, pressure was measured at the seat cushion interface via the Boditrak pressure measurement system [Figure 1](Vista Medical, Winnipeg, Manitoba, CA; www.pressuremapping.com). The dispersion index was the primary variable of interest for this pilot study (Sprigle et al., 2003). The dispersion index was determined by creation of a 3x3 box around the ischial tuberosities, and the sacrum. The area for defining the dispersion index was then determined as the area circumscribing the three boxes utilized to define the ischial

tuberosities and the sacrum [Figure 2]. The dispersion index is then calculated as the sum of the pressure in this area divided by the sum of all pressure measurements.

The measurement of pressure took place on the individuals own seat cushion and five other seating surfaces: a plinth, a foam cushion, an air cushion, a gel cushion and a honeycomb composite cushion. Pressure and temperature measurements were recorded at 30 seconds, 60 seconds and 120 seconds. Measurements were repeated 3 times for each seating surface totaling nine measures for each seating surface. The individual remained in their own wheelchair for all measurements, except those on the plinth.

Data Analysis

Descriptive statistics were used to summarize the dispersion index data. A two way repeated measures ANOVA was conducted using SPSS Version 21 with the mean difference significant at the .05 level and a Bonferroni adjusted pairwise comparison of cushion material mean dispersion index. [IBM Corp. Released 2012. IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY: IBM Corp].

Figure 1. Boditrak pressure measurement mat.

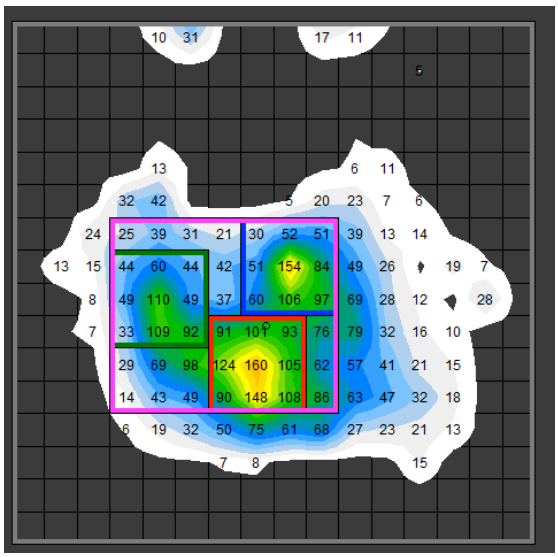

Figure 2. Presure mapping for one of the participants. The top/bottom and left/right represent that anterior/posterior and left/right positions of the participant. The area (magenta rectangle) used to calculate the dispersion index circumscribes the three squares used to define the left/right ischial tuberosiities (green square, blue square) and the sacrum (red square).

RESULTS

Seven individuals provided informed consent to participate in the study (6 men, 1 women) with a mean age of 35.6 years (12 st. dev., range 23-53 years). The individuals had a mean height and weight of 176.7 cm (4.4 st. dev., range 170.2 – 182.9 cm) and 84.2 kg (13.7 st. dev., range 65.8 – 104.0 kg). The mean time since injury was 10.9 years (st. dev. 12.0, range 0.5 -28.5 years). In terms of their primary mode of mobility, 6 used power wheelchairs and 1 used manual wheelchairs. Three individuals used a gel based seat cushion, and four individuals used an air based seat cushion. Six individuals had a cervical spinal cord injury, and one had a thoracic spinal cord injury.

The DI was calculated for each individual on each seating surface. The mean and standard error for the individuals own seat cushion in displayed in Figure 3. The DI for each individual is displayed in Figure 4. The mean and standard error were calculated across all 54 trials for each individual. The DI mean and standard error fore each cushion across all individuals is displayed in figure 5. The mean and standard error were calculated across all 63 trials fore each seating surface. Based on the statistical analysis, significant differences were found between the plinth and all other seating surfaces (Figure 5). Furthermore, significant differences were found between the following combination of seating surfaces: foam/air and foam/honeycomb.

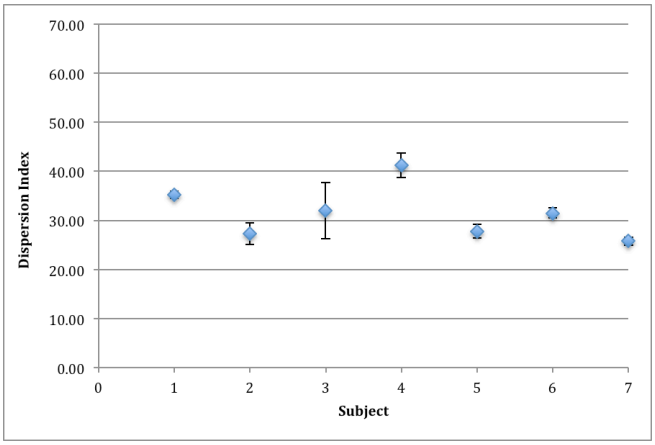

Figure 3. The dispersion index mean and standard error for each participant for their own seat cushion.

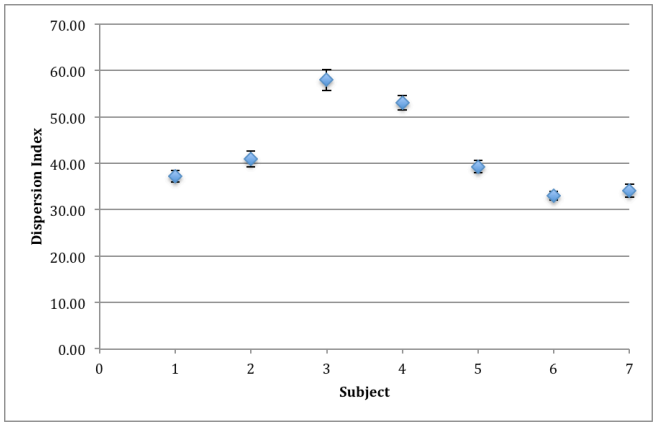

Figure 4. The dispersion index mean and standard error for each participant across all seating surfaces

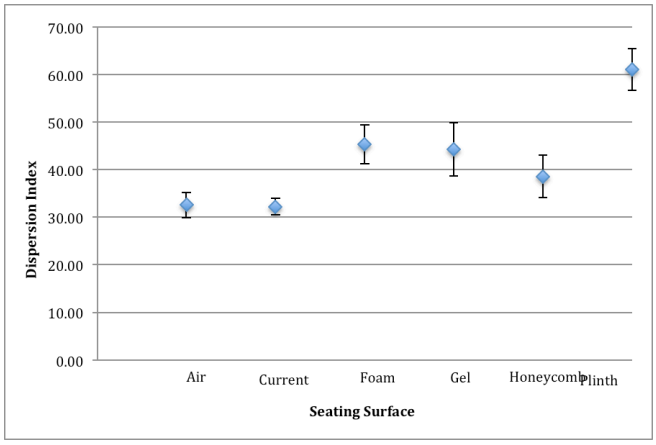

Figure 5. The dispersion index mean and standard error for each seat cushion across all participants.

DISCUSSION

The characteristics of the pressure at the interface of the individual and the seat cushion were described using the dispersion index. The mean and st. error of the dispersion index was less than 50 for all individuals on their own cushion (Figure 3). Overall, the mean and st. error for the current cushion was 32.25±1.8 across all subjects (Figure 3). A dispersion index of less than 50 has been identified as a potential threshold for effective pressure distribution (Davis & Sprigle, 2008). This indicates that greater than 50% of the loading occurs outside the region of the ischial tuberosities and sacrum, which have been identified as areas at high risk for the development of pressure ulcers. In terms of pressure distribution, the trans-disciplinary team, including the consumer, selected a cushion that meets the consumers needs in terms of pressure distribution. However, the pressure distribution is not the only area of concern when selecting a seat cushion, as many factors such as the postural support and transfers are also important.

The dispersion index as a metric for differentiating between groups of individuals and the effectiveness of seat cushions seems reasonable based on the data collected for the pilot study. Differences in the mean DI were observed across the subjects (Figure 4). Specifically, the DI was above 50 for participant #3 and #4. Whether this has specific implications as it relates to the nutritional status of the individual, the past history of pressure ulcers, or the development of pressure ulcers is not known at this time based on this data. However, this pilot study is a first step in further addressing the specific correlation between pressure, nutrition and past history of pressure ulcers.

We were also able to differentiate between the seating surfaces based on the dispersion index. Based on our clinical knowledge we would expect the plinth to have the highest dispersion index, which we observed in figure 5. Furthermore, even with only seven individuals, we observe that the difference in the dispersion index between the plinth and the other seating surfaces is significant. The mean DI for the plinth is well above 50, while the mean of all of the other seating surfaces is below 50. This provides supporting evidence that 50 may be a good starting point for identifying effective seating surfaces. However, further stratification of the DI to describe the effectiveness is still necessary.

Differentiation among the seat cushions was observed between the foam/air combination and the foam/honeycomb combination. This demonstrates the potential to differentiate effectiveness of seat cushions for individuals with a spinal cord injury. The differentiation of the seat cushions based on the DI could allow for the stratification of seating surfaces which is necessary to begin developing pressure ulcer development models that also include the individual's nutritional status.

The limitations to this study include the small number of participants, and the fact that we only looked at a single metric. Furthermore, this is a cross-sectional study, therefore we did not measure the pressure over a long period time to determine if the dispersion index would work outside the clinical setting. Each individual used his or her own wheelchair and seating system which may have affected the results, however, we used their own system in order to minimize postural changes. Finally, the individuals were positioned in their ideal seating position (e.g. hips back, pelvic belt properly positioned), which may not accurately represent how a person utilizes a wheelchair in the community.

Future studies include examining other pressure related variables, and examining correlations between past history of pressure ulcers and nutritional status. The combination of pressure and nutritional status may lead to a reduction in the development of pressure ulcers for individuals with a spinal cord injury, an improved healing when one occurs.

CONCLUSION

The effectiveness of seating surfaces to distribute pressure was examined for seven individuals with a spinal cord injury. The dispersion index, a measure to describe seating surface effectiveness, was below 50 for each individual on their own seat cushion, thereby indicating a minimum threshold is met in terms of pressure distribution. Differences in the pressure distribution were observed from subject to subject and cushion to cushion. This indicates that the dispersion index may be a useful dependent variable when identifying relationships with other pressure ulcer risk factors. Future, research will focus on developing models that include pressure, pressure ulcer history and nutritional status in the prediction and prevention of pressure ulcer development.

ACKNOWLEDGEMENTS

We would like to acknowledge Hannah Oakley, Division of Medical Dietetics, School of Health and Rehabilitation Sciences, The Ohio State University for her assistance is collecting and synthesizing the data. We would also like to acknowledge the School of Health and Rehabilitation Sciences, The Ohio State University for funding this project.

REFERENCES

Chen, Y., Devivo, M. J., & Jackson, A. B. (2005). Pressure ulcer prevalence in people with spinal cord injury: age-period-duration effects. *Archives of Physical Medicine and Rehabilitation*, *86*(6), 1208–1213. doi:10.1016/j.apmr.2004.12.023

Davis, K., & Sprigle, S. (2008). The Science of Interface Pressure Mapping - Updates for Clinical Application. In M. Story & D. Cooper (Eds.), (Vol. Vancouver, BC Canada, pp. 197–200). Presented at the 24th International Seating Symposium, Interprofessional Continuing Education - The University of British Columbia.

Jensen, G. L., Mirtallo, J., Compher, C., Dhaliwal, R., Forbes, A., Grijalba, R. F., … International Consensus Guideline Committee. (2010). Adult starvation and disease-related malnutrition: a proposal for etiology-based diagnosis in the clinical practice setting from the International Consensus Guideline Committee. *JPEN. Journal of Parenteral and Enteral Nutrition*, *34*(2), 156–159. doi:10.1177/0148607110361910

McKinley, W. O., Jackson, A. B., Cardenas, D. D., & DeVivo, M. J. (1999). Long-term medical complications after traumatic spinal cord injury: a regional model systems analysis. *Archives of Physical Medicine and Rehabilitation*, *80*(11), 1402–1410.

Richardson, R. R., & Meyer, P. R., Jr. (1981). Prevalence and incidence of pressure sores in acute spinal cord injuries. *Paraplegia*, *19*(4), 235–247. doi:10.1038/sc.1981.47

Salzberg, C. A., Byrne, D. W., Cayten, C. G., van Niewerburgh, P., Murphy, J. G., & Viehbeck, M. (1996). A new pressure ulcer risk assessment scale for individuals with spinal cord injury. *American Journal of Physical Medicine & Rehabilitation / Association of Academic Physiatrists*, *75*(2), 96–104.

Sprigle, S., Dunlop, W., & Press, L. (2003). Reliability of bench tests of interface pressure. *Assist Technol*, *15*(1), 49–57.

Tappenden, K. A., Quatrara, B., Parkhurst, M. L., Malone, A. M., Fanjiang, G., & Ziegler, T. R. (2013). Critical role of nutrition in improving quality of care: an interdisciplinary call to action to address adult hospital malnutrition. *Medsurg Nursing: Official Journal of the Academy of Medical-Surgical Nurses*, *22*(3), 147–165.

Thompson, K., Paison DiTucci, A., & Barton, V. (2013). Spinal Cord Injury and Nutrition Evidence Analysis Project. *Academy of Nutrition and Dietitcs. Evidence Analysis Library*. Retrieved from http://andevidencelibrary.com/topic.cfm?cat=1407

White, J. V., Guenter, P., Jensen, G., Malone, A., Schofield, M., Academy of Nutrition and Dietetics Malnutrition Work Group, … A.S.P.E.N. Board of Directors. (2012). Consensus statement of the Academy of Nutrition and Dietetics/American Society for Parenteral and Enteral Nutrition: characteristics recommended for the identification and documentation of adult malnutrition (undernutrition). *Journal of the Academy of Nutrition and Dietetics*, *112*(5), 730–738. doi:10.1016/j.jand.2012.03.012

Young, K. C., Railton, R., Harrower, A. D., & Brookes, R. W. (1981). Transcutaneous oxygen tension measurements as a method of assessing peripheral vascular disease. *Clinical Physics and Physiological Measurement: An Official Journal of the Hospital Physicists' Association, Deutsche Gesellschaft Für Medizinische Physik and the European Federation of Organisations for Medical Physics*, *2*(2), 147–151.