# DEVELOPMENT AND EVALUATION OF IT-BASED ADJUSTABLE PRESSURE RELIEF AIR CUSHION FOR PERSONS WITH SPINAL CORD INJURY

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## ABSTRACT

This study intends to introduce not only the technology to monitor and control the pressure of the air-type pressure relief cushion in real-time using a smartphone, but also a related pilot study. This study conducted preliminary research using the developed product targeting one person with spinal cord injury. Pressure was measured with the pressure mapping system, and the result data was converted to 5 indexes and analyzed. As a result, peak pressure index and IT peak pressure turned out to be 93.7mmHg and 78.0mmHg, respectively. In addition, dispersion index was 12.2%, showing that pressure was well dispersed, not being concentrated on ischial tuberosity or coccyx. The study results confirmed the possibility to develop an IT-based adjustable pressure relief air cushion and its technology.

## INTRODUCTION / BACKGROUND

A wheelchair is the most important assistive device for persons with spinal cord injury in their daily life, and they spend most of their time on it during the day(Burns & Betz, 1999). They have a higher risk of pressure ulcer than others due to sensory loss, paralysis of motor function, change in autonomic nervous system, and vasoconstriction loss(Bromely, 2006). Although their life expectancy has improved owing to the advance of modern medical science, 30% of them still have to stay at hospital for the rest of their life due to the problems related to pressure(Krousop, 1983; Rosenthal, Felton, Hileman, Lee, Friedman, & Navach, 1996). They easily come to have a pressure ulcer because of their physical characteristics, but it takes much time to treat it, so it is a direct cause that reduces their participation in community, workplace, or school(Cutajar & Roberts, 2005).

The major strategy for persons with spinal cord injury to prevent a pressure ulcer is to avoid concentrated pressure on a certain spot and re-disperse pressure throughout the seat(Jan & Brienza, 2006). To do so, they use a pressure relief cushion to maintain a stable and safe posture(Aissaoui, Boucher, Bourbonnais, Lacoste, & Dansereau, 2001). As a pressure relief cushion can disperse excessively concentrated pressure, it is an essential assistive device for persons with spinal cord injury that have difficulties in proper posture change and movement(Ragan, Kernozek, Bidar, & Matheson, 2002).

Various types of pressure relief cushions are being developed and commercialized depending on the needs of those using a wheelchair. Although preceding research reported that an air-type cushion should be the most effective for pressure dispersion(Gil-Agudo et al, 2009; Yuen & Garret, 2001), a large number of persons with spinal cord injury still develop a pressure ulcer(Brienza et al., 2010). Thus, pressure relief cushions are now being developed using various materials and technologies(Kim & Kim, 2016).

In this sense, this study intends to introduce not only the technology to monitor and control the pressure of the air-type pressure relief cushion in real-time using a smartphone, but also a related pilot study.

## METHOD

### PARTICIPANTS

This study conducted preliminary research using the developed product targeting one person with spinal cord injury(Male, 47years, Cervical 6 Level of injury).

## IT-BASED ADJUSTABLE PRESSURE RELIEF AIR CUSHION

An IT-based adjustable pressure relief air cushion has a sensor able to measure pressure, temperature, and humidity in real-time as well as a fan capable of air circulation within the cushion. In addition, each air cell has an air-controlling valve, which is connected to an external air injector to control the pressure of air cells individually. All these sensors and control functions are linked to a smartphone by Bluetooth to enable real-time monitoring and pressure controlling through an application. That is, those using the IT-based adjustable pressure relief air cushion can use the application on a smartphone to monitor the pressure value of their seat. In addition, if the pressure on a certain spot is high or increasing, they can control pressure themselves by clicking the air cell shown on a smartphone. If moisture and temperature increase, they can operate the air circulation fan to enable air circulation around the front, rear, and upper sides of the cushion.

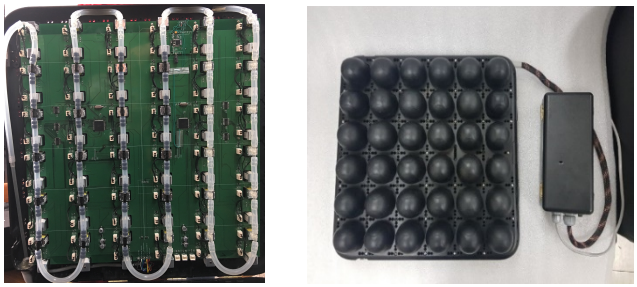

Figure 1: Adjustable pressure relief air cushion

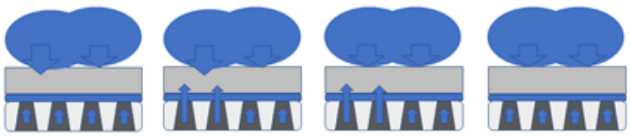

Figure 2: Method of adjust in air cell

Figure 3: The process of controlling a adjustable air cushion using the application

## OUTCOME MEASURE

Pressure was measured with the pressure mapping system, and the result data was converted to 5 indexes (Average pressure, Contact area, Peak Pressure Index, IT peak pressure, Dispersion index) and analyzed(Crane, Wininger, & Call, 2016).

## RESULT

As a result, peak pressure index and IT peak pressure turned out to be 93.7mmHg and 78.0mmHg, respectively. In addition, dispersion index was 12.2%, showing that pressure was well dispersed, not being concentrated on ischial tuberosity or coccyx(Table 1).

Table 1: Result of 5 indexes for IT-based adjustable pressure relief air cushion

| **Outcome measures** | | |
|---|---|---|
| ***Descriptor*** | ***Units*** | ***Data*** |
| Average pressure | mmHg | 42.9 |
| Contact area | $cm^2$ | 1508.8 |
| Peak Pressure Index | mmHg | 93.7 |
| IT peak pressure | mmHg | 78.0 |
| Dispersion index | % | 12.2 |

## DISCUSSION / CONCLUSION

According to a study dealing with a pressure ulcer and the pressure value, the flow in the capillary vessel decreases for the skin at 55mmHg and the subcutaneous tissue at 80mmHg, and change in the bloodstream of muscles occurs at over 100mmHg(Herrman, Knapp, Donofrio, & Salcido, 1999; Patel, Knapp, Donofrio, & Salcido, 1999). The values above were lower than 100mmHg that should be the risk factor of pressure ulcer, which could be considered to be a meaningful result for prevention of pressure ulcer. However, as this study targeted only one person with spinal cord injury and measured the values for just 10

minutes, it is hard to generalize the results related to the effectiveness of the product.

The study results confirmed the possibility to develop an IT-based adjustable pressure relief air cushion and its technology. This study has a meaning in that it suggested the research design and direction needed to verify the pressure ulcer-preventing effects of this product in the future.

## ACKNOWLEDGEMENTS

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## REFERENCES

Aissaoui, R., Boucher, C., Bourbonnais, D., Lacoste, M., & Dansereau, J. (2001). Effect of seat cushion on dynamic stability in sitting during a reaching task in wheelchair users with paraplegia. *Archives of Physical Medicine and Rehabilitation, 82*(2), 274–281.

Burns, S. P., & Betz, K. L. (1999). Seating pressures with conventional and dynamic wheelchair cushions in tetraplegia. *Archives of physical medicine and rehabilitation, 80*(5), 566-571.

Bromley, I. (2006). Tetraplegia and paraplegia: a guide for physiotherapists. Elsevier Health Sciences.

Crane, B., Wininger, M., & Call, E. (2016). Orthotic-Style Off-Loading Wheelchair Seat Cushion Reduces Interface Pressure Under Ischial Tuberosities and Sacrococcygeal Regions. *Archives of Physical Medicine and Rehabilitation, 97*(11), 1872-1879.

Cutajar, R., & Roberts, A. (2005). The relationship between engagement in occupations and pressure sore development in Saudi men with paraplegia. *British Journal of Occupational Therapy, 68*(7), 307-314.

Gil-Agudo, A., De la Peña-González, A., Del Ama-Espinosa, A., Pérez-Rizo, E., Díaz-Domínguez, E., & Sánchez-Ramos, A. (2009). Comparative study of pressure distribution at the user-cushion interface with different cushions in a population with spinal cord injury. *Clinical Biomechanics, 24*(7), 558-563.

Herrman, E. C., Knapp, C. F., Donofrio, J. C., & Salcido, R. (1999). Skin perfusion responses to surface pressure-induced ischemia: implication for the developing pressure ulcer. *Journal of Rehabilitation Research and Development, 36*(2), 109.

Jan, Y. K., & Brienza, D. (2006). Technology for pressure ulcer prevention. *Topics in Spinal Cord Injury Rehabilitation, 11*(4), 30-41.

Kim, J. H., & Kim, J. B. (2016). Research trends in pressure ulcer prevention cushions for the people with disabilities using wheelchair: a systematic review. *Journal of Korean Society of Occupational Therapy, 24*(2). 1-18.

Krouskop, T. A. (1983). A synthesis of the factors that contribute to pressure sore formation. *Medical Hypotheses, 11*(2), 255-267.

Patel, S., Knapp, C. F., Donofrio, J. C., & Salcido, R. (1999). Temperature effects on surface pressure-induced changes in rat skin perfusion: Implications in pressure ulcer development. *Journal of Rehabilitation Research and Development, 36*(3), 189.

Ragan, R., Kernozek, T. W., Bidar, M., & Matheson, J. W. (2002). Seat-interface pressures on various thicknesses of foam wheelchair cushions: A finite modeling approach. *Archives of Physical Medicine and Rehabilitation, 83*(6), 872-875.

Rosenthal, M. J., Felton, R. M., Hileman, D. L., Lee, M., Friedman, M., & Navach, J. H. (1996). A wheelchair cushion designed to redistribute sites of sitting pressure. *Archives of Physical Medicine and Rehabilitation, 77*(3), 278-282.

Yuen, H. K., & Garrett, D. (2001). Comparison of three wheelchair cushions for effectiveness of pressure relief. *American Journal of Occupational Therapy, 55*(4), 470-475.