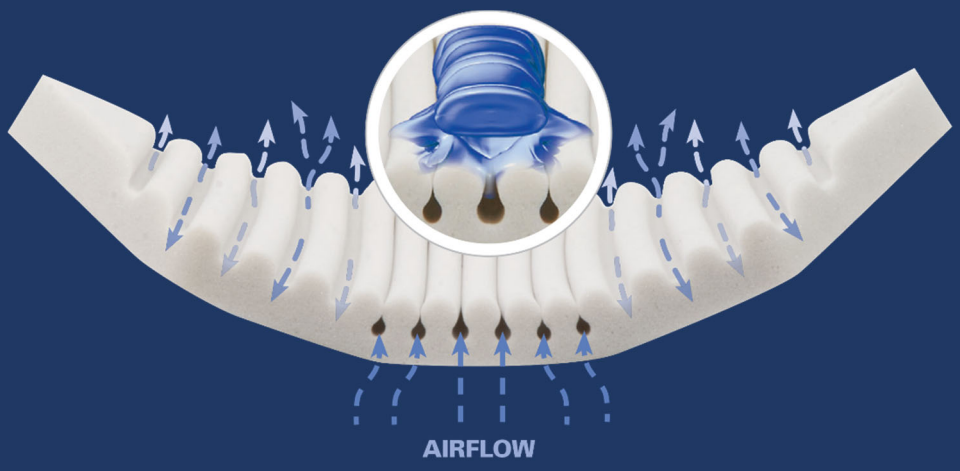


The Ripple Effect – Evaluation of Foam Configuration in Temperature and Moisture Control

Prepared for:
Motion Concepts
84 Citation Dive Unit 1
Concord, Ontario L4K 3C1
CANADA

Prepared by:
Anna Sokol, RN, MN, BScKin
Clinical Education Specialist
Motion Concepts
July 15, 2020

Temperature and Humidity

There are a variety of rigid back supports on the market. Usually, the clinician's choices are influenced by the degree of postural support and stability offered by each product. Recently, however, we hear more and more questions related to temperature and humidity. As more literature describes the links between microclimate and pressure injury, prescribers are looking for ways to address skin safety by reducing the build-up of heat and moisture. Health care systems across the world recognize the financial burden of pressure injuries and expect clinicians to recommend preventative solutions.

For people using wheelchairs, regulating body temperature can have significant benefits in addition to skin health. Some individuals with spinal cord injury experience thermoregulation issues that make them limit the type and duration of activities[1]. During hot summer days, they may abandon the idea of going outside, because they may experience hyperthermia or heat stroke.

Conditions Associated with Heating Up

For people with spinal cord injury, heating up is attributed to a loss of ability to thermoregulate through sweating. Pritchett et al.[2] found that athletes with SCI had half the density of sweat glands below the level of lesion compared to able-bodied athletes. While the sweat response of the glands was similar between the groups, having a smaller number of sweat glands reduced athletes' ability to thermoregulate effectively through sweat evaporation. The higher the level of the SCI, the greater the degree of thermoregulatory impairment and thermal strain[3,4]. Loss of sweating impacts the bodies' ability to normalize core temperature and may lead to dangerous complications. For individuals with SCI, overheating can even provoke autonomous dysreflexia.

Elevated body temperature is also a trigger for Uhthoff's phenomenon experienced by almost 80% of patients with multiple sclerosis (MS) and about half of individuals living with neuromyelitis optica (NMO)[5]. The German ophthalmologist Uthoff in 1890 described loss of vision, muscle weakness and loss of sensation in his patients with MS after they exercised, stood near a stove, or had dinner. MS is a progressive neurologic condition marked by a defect in the structure of the myelin sheath and subsequent loss of saltatory conduction function. As in SCI, impairment of a sweating response is associated with structural changes in eccrine sweat glands caused by altered function of the peripheral nerves and lesions in the brain. Loss of ability to sweat results in ineffective thermoregulation and increased sensitivity to heat. For individuals living with MS, elevation of core temperature by just 0.8 °C can result in thermal stress, fatigue, and loss of vision and function[6].

To prevent hyperthermia, many individuals pre-cool their body before going outside in hot and humid weather or before high intensity activity. From ice packs over the neck and gulping crushed ice to using special garments with sophisticated cooling technology, patients with impaired thermoregulation try every possible method to control temperature increase.

New Matrx E2 back

Many clinicians are familiar with the Matrx Elite Back-support. It is a lightweight, rigid back compatible with most manual and power wheelchairs, and featuring the popular Easy-Set hardware. The Matrx Elite Back has been a popular choice for pediatric, adult, and bariatric users due to its anatomical contour providing great postural support for every size.

Many active wheelchair users are familiar with the Matrx MX2 carbon fiber back. It is an ultra-lightweight back support designed primarily for highly active wheelchair users. The Spacetex cover and unique cutouts of the MX2 shell are designed to maximize airflow and prevent heat build-up.

Motion Concepts has always been mindful of the temperature and humidity issues of the wheelchair users. With understanding of the impaired thermoregulation, both the Matrx Elite Back and MX2 back offer an optimal thickness of foam – enough to ensure comfort and durability and not so thick to cause overheating of the user.

Motion Concepts is currently launching the Matrx E2 Series of backs. The design of the E2 combines the best features of the Elite and MX2 backs, with the addition of something unique - Ripple Foam. Ripple Foam features channels for airflow that cool the surface of the back support with the slightest movements of the occupant and we are excited to share some data from our observations of the E2 functionality.

Temperature and Humidity Comparisons – Participants

We wanted to compare temperature and humidity performance of the Matrx Elite and E2 back-supports. Five females and five males with the most sedentary job descriptions were asked to sit in a wheelchair of an appropriate size. The Elite and E2 backs were fitted to each user and adjustments to the back angles were completed for maximum sitting comfort. Matrx Vi cushions fitted to each subject were used for the study. Participants are described in Table 1 below.

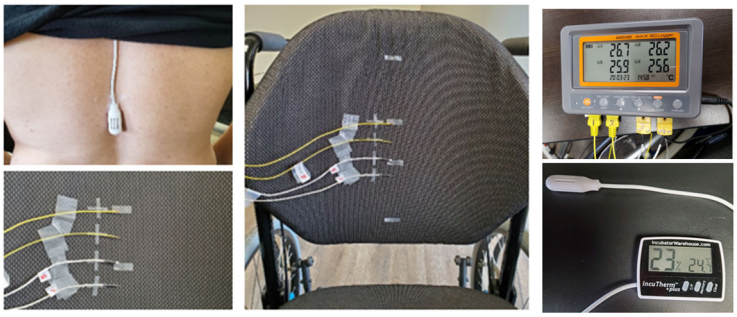
List of subjects	f/m	Age	BMI	Wheelchair	Wheelchair width	E2 and Elite Backrest size
Subject 1	f	30-39	18.5-24.9	Kuschall K4 Pro	16"	16"x 16"
Subject 2	f	40-49	18.5-24.9	Kuschall K4 Pro	16"	16"x 16"
Subject 3	m	40-49	18.5-24.9	Kuschall K4 Pro	16"	16"x 16"
Subject 4	f	50-59	18.5-24.9	Kuschall K4 Pro	16"	16"x 16"
Subject 5	m	20-29	18.5-24.9	Kuschall K4 Pro	16"	16"x 16"
Subject 6	f	30-39	18.5-24.9	Kuschall K4 Pro	16"	16"x 16"
Subject 7	m	20-29	18.5-24.9	Kuschall K4 Pro	16"	16"x 16"
Subject 8	m	40-49	30-39.9	Freedom Designs PRO CG	18"	18"x 16"
Subject 9	m	50-59	25.0-29.9	Freedom Designs PRO CG	18"	18"x 16"
Subject 10	f	30-39	25.0-29.9	Freedom Designs PRO CG	18"	17"x 16"

Table 1. Description of study participants and wheelchair systems used.

Temperature and Humidity Comparisons - Methods

Temperature probes (see Appendix A for specific information about instrumentation used) were placed midline on the back-support surface in a way that they would align with the spine on the level between T8/T9 and L2. To ensure consistent location of the temperature probes, the cover of the back support stayed the same, and the foam and the back-support shell were changed for different conditions. For each participant, the backs were properly fitted with angle and height adjusted as needed, and the probes adjusted to be positioned between T8/T9 and L2. Four probes were positioned one inch apart which allowed for the variation of temperatures to be captured and averaged later. The temperature logger recorded back-support surface measurements every minute for the duration of 40 min.

A separate humidity and skin temperature probe was placed directly on the skin at the level just above probe #1 of the back-support surface. The readings from the skin probe were taken every 10 min.



Participants were asked to complete 4 trials:

C1 – continuous 40 min on Matrx Elite, maintaining constant contact with the back-support
C2 – 40 min on Matrx Elite, with a 30-sec 'off-loading' break at 20 min
C3 – continuous 40 min on Matrx E2, maintaining constant contact with the back-support
C4 – 40 min on Matrx E2, with a 30-sec 'off-loading' break at 20 min

A literature search revealed that despite recommendation to shift weight every 15-20 min, more than half of wheelchair users struggle with following this advice[7]. People without the ability to move or shift their weight could frequently be in a situation of continuous contact with the back support. For this reason, it was decided to imitate the best scenario and the scenario of limited movement. The position of the temperature and humidity probes was also strategic; to catch the highest temperatures and sweating rates at the locations considered 'hot spots' of the human body.

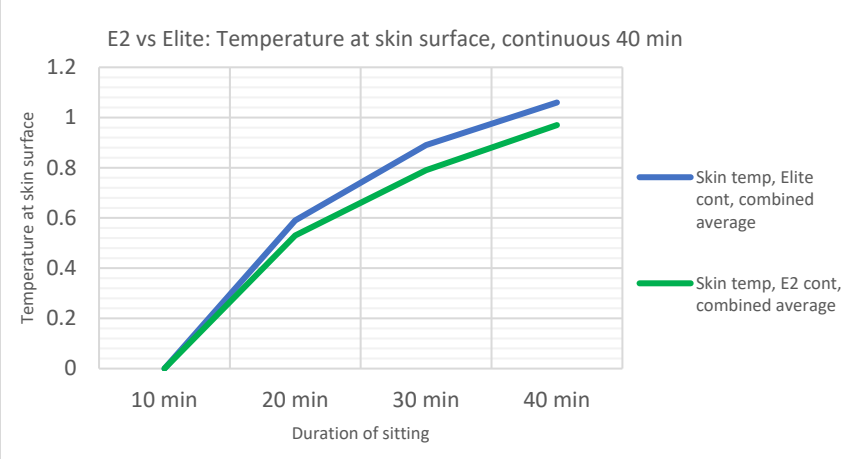
Prior to engaging the participants, our pilot test recorded temperatures from different locations on the back. The area between T8/T9 and L2 demonstrated the highest readings in both humidity and heat. We also learned that the temperature is the lowest at the area laterally from midline, at the flank area, 2 inches away from the paraspinals. The heat travels up along the spinal column and gets 'trapped' just below the apex of kyphosis. Mindful of the fact that people with SCI or MS have impaired ability to thermoregulate using sweating, we focused on the hottest spot of the back.

Skin Surface Temperature Comparisons - Results

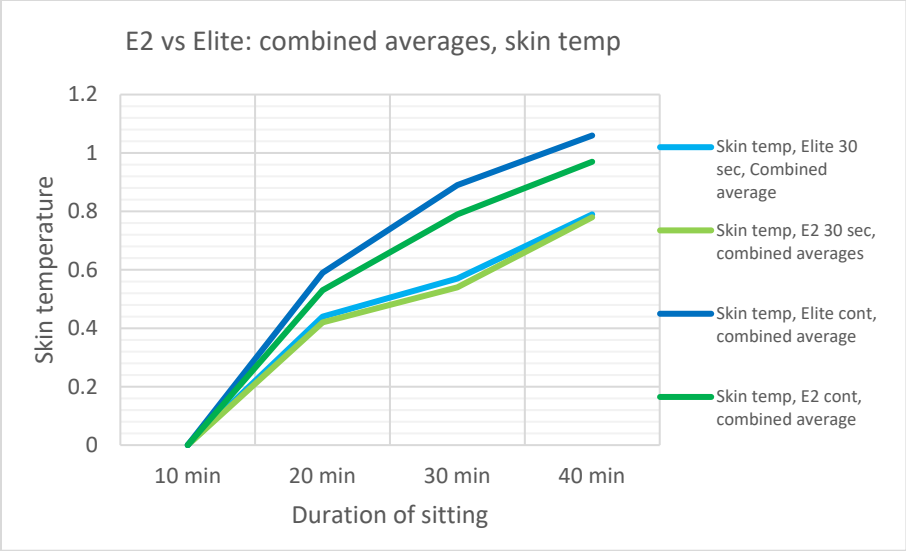
When all the data was gathered and processed, it was found that using the Matrx E2 back resulted in 0.1 – 0.3 °C lower skin surface temperatures compared to the Elite back. In the scenario, where the user would not shift weight at all, being 'glued' to the back-support showed superior performance of the E2 and consistently lower temperatures by 0.1 °C.

The graphs show the performance of the Matrx Elite back in blue, and E2 back in green.

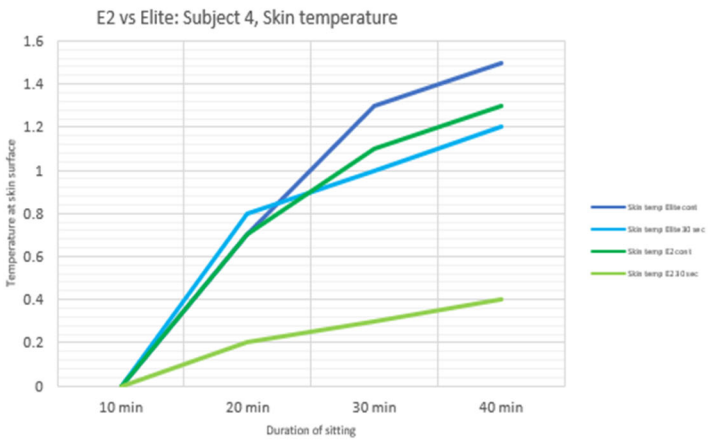
Dark Blue = Non-moving continuous contact with Elite back-support
Light Blue = Elite back-support for 40 min with a 30-sec break at 20 min
Dark Green = Non-moving continuous contact with E2 back-support
Light Green = E2 back-support for 40 min with a 30-sec break at 20 min

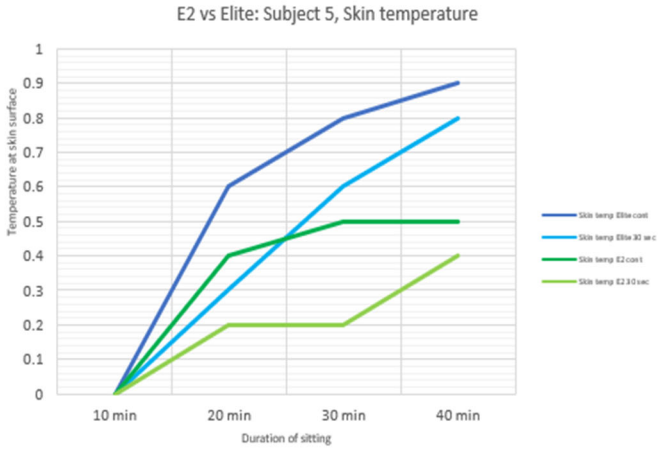


In the scenario where the off-loading was performed by bending forward for 30 sec, averaged results showed almost no changes between the back-supports. Both Elite and E2 backs were effectively dissipating the heat and lowering skin temperature.

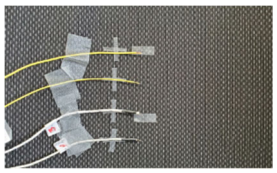


It was interesting to observe a variety of thermo-regulation patterns and individual responses to different conditions. For some people, the difference in the performance of a back-support was most prominent in the non-moving scenario. For others, off-loading produced the largest difference in the temperature drops.

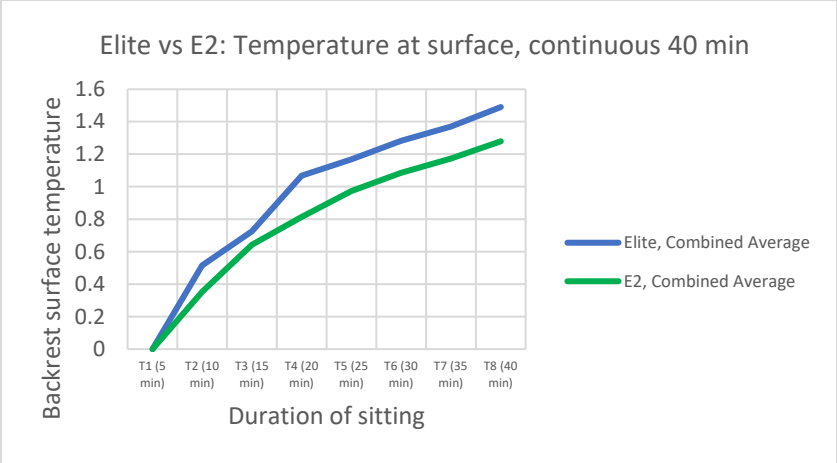


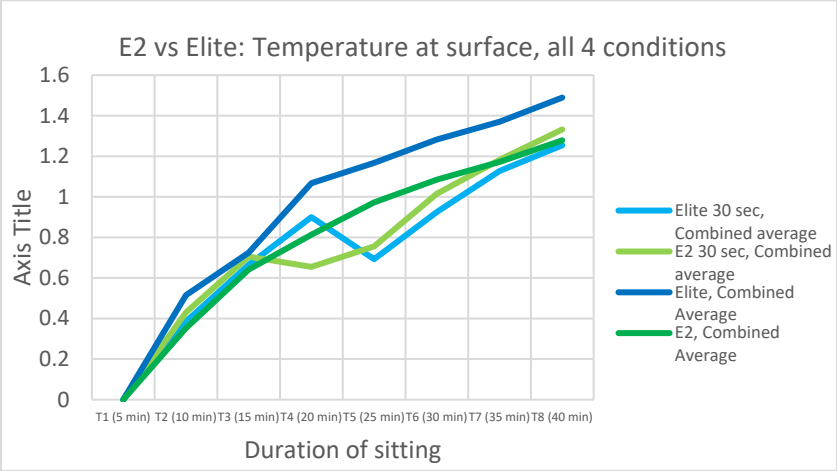


Back Support Surface Temperatures – Results



At the backrest surface, continuous 40-minute contact resulted in lower surface temperatures on the E2 Back by an average of 0.2°C. The difference was much smaller during the off-loading condition. Weight shifting for 30-seconds was an effective intervention for thermoregulation on both the Elite and E2 backs.



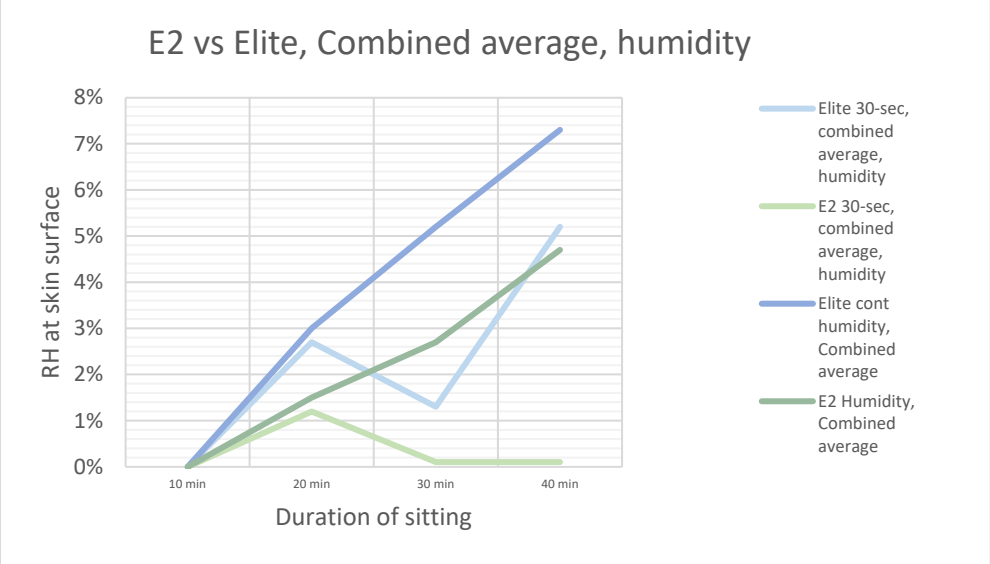


Humidity Comparisons – Results

Originally, humidity measurements were not our major focus. We knew that many people with degenerative or traumatic neuro-muscular conditions lose ability to effectively thermoregulate through sweat evaporation. However, we noticed that for one person, sweating was dramatically reduced on the E2 back-support. While the rest of the participants had skin RH (relative humidity) fluctuations between 25% and 49%, Subject #8 had an initial skin RH of 72-95% in all four conditions. His experience on E2 was a great relief, even during continuous contact and non-moving for 40 min.

	10 min	20 min	30 min	40 min
Humidity, Elite cont	92%	99%	99%	99%
Humidity Elite 30 sec	72%	69%	49%	57%
Humidity, E2 cont	76%	65%	56%	60%
Humidity E2 30 sec	95%	94%	84%	65%

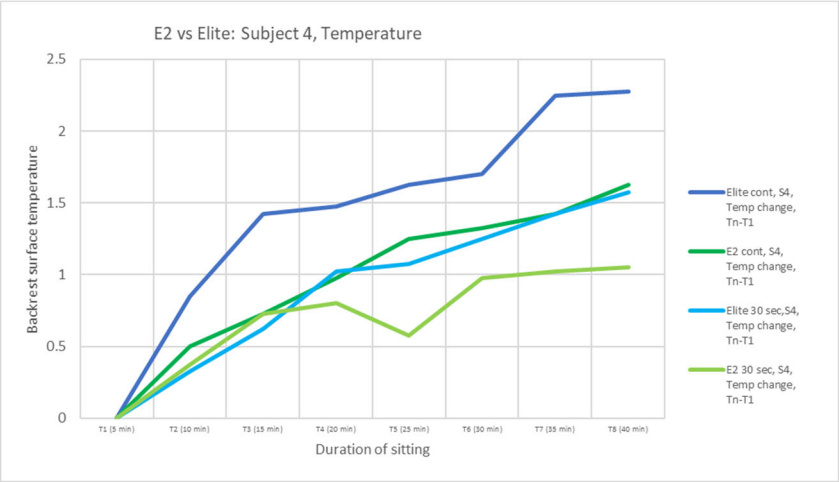
For wheelchair users with hyperhidrosis (generalized or local excessive sweating), the relative humidity (RH) reduction effect of the Matrx E2 back could be very valuable. It was decided to compare the humidity results for all the participants and all the conditions. On the E2 back, participants demonstrated on average 2.5% lower skin RH during the 40 min continuous contact and 5.2% lower RH in the 30-second off-loading scenario compared to the RH readings on the Elite Back.



Ambient Conditions During the Study

It was noted that the ambient temperatures in the test site were rather warm. Room temperatures fluctuated between 23.1°C and 26.2°C, which is considered slightly warm by many. In a clinical sense, such ambient temperatures result in moderate heat formation, which serves as a mild physiological stressor[8]. The relative humidity (RH) of the ambient air fluctuated between 27% and 31%.

Additional Observations – 'Self-cooling' of Matrx E2



It was noted that one of the subjects was very fidgety. She explained that normally it is hard for her to stay still. While she was maintaining contact with the backrest throughout all four conditions, lateral micromovements of the trunk were noticeable every 15-30 seconds and ranged within ½''-1'' distance.

Later analysis of the data for subject #4 showed that the E2 back-support surface temperatures were much lower compared to Elite. The E2 back appeared to demonstrate a 'self-cooling' effect: the temperatures decreased during the 30 seconds of non-contact, and for 4 minutes after, when full contact was resumed.

Even during the 40-minute continuous contact, the E2 temperature line was 'broken' with a lower rate of temp increases at 10, 25, and 35 minutes. Overall, subject #4 gained 2.25°C of heat on the Elite Back, while the E2 back-support surface was 0.65°C cooler after 40 minutes of continuous contact. When the deliberate 30-second break was added, the surface of the E2 warmed up only by 1.0°C.

Comfort

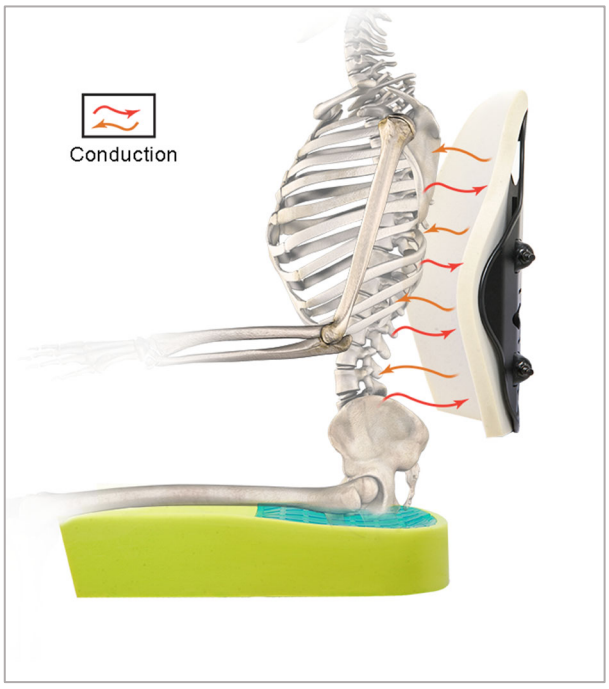
While participants knew about the project, we did not let them know which back support model was used during the temperature and humidity measurements. After each condition, each person was asked about the feeling of comfort and whether he/she perceived any differences in temperature. All ten participants commented about the E2 as the most comfortable back. With respect to temperature, half of the subjects felt buildup of heat on Elite Back. The other half did not notice any temperature differences. Several people commented that they wished their office chairs were as comfortable as the wheelchairs they were on.

Benefits of E2 Back

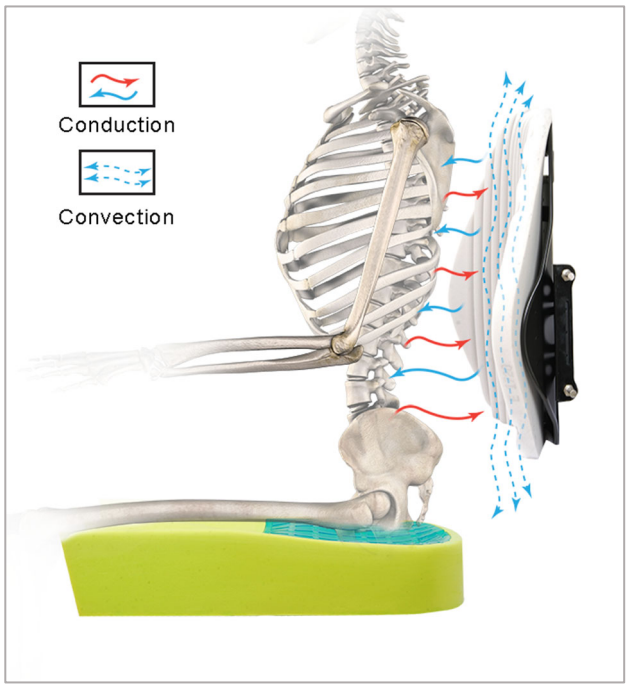
Ripple Foam increases immersion while controlling the skin temperature. It utilizes both convection and conduction mechanisms of transferring heat. Convection is the mechanism of air traveling upwards as it heats up. Conduction is the ability of solid materials to accept the heat of the object via direct contact. The bigger the mass of the solid material, the longer it takes for heat to be transferred to it. Smaller mass allows the heat to travel faster through the material towards the cooler side.

While in contact with the body, the E2 back surface takes up body heat quicker, but thanks to the cooler air inside the channels, it cools down quicker as well. Slight body movement helps air move through the Ripple Foam channels, and further propels the air. That explains the most dramatic cooling effect occurring during the condition with 30-second off-loading.

Matrx Elite Back



Matrx E2 Back



Wheelchair User Feedback

Dean is an Assistive Technology Technician at a Children's Centre. He has used a wheelchair regularly throughout his life to manage his work and daily activities. With a diagnosis of CP, Dean uses his manual wheelchair for long distances and work, but can walk short distances, so he does get out of his chair regularly during the day. His priorities when choosing a mobility system are to have a lightweight maneuverable wheelchair (he uses a rigid chair) and seating system to address the issue of temperature management as he is always hot and sweats profusely.

Dean has been using the Matrx MX2 Back for 2 years. The lightweight carbon fibre shell and low height (6") allow him greater functionality and freedom of movement. Flex in the carbon fibre has reduced the impact of vibration on his spasticity and reduced the discomfort in his back. The sporty look of the MX-2 is also important to him as the overall aesthetics of his chair is essential to his self-image as an independent, productive individual.

While searching for a solution to the sweating issues, Dean was able to try a ‘fan' system integrated to his MX2 back, which he found extremely beneficial as it actually cooled his skin. However, it was challenging to find a way to mount it in a way that would not interfere with his movement and he had to develop a routine to keep the fan charged.

Recently, Dean was able to try the new ripple foam on his MX2 back for about 6 months. On inspection, he noted the ripples in the foam and had concerns that he would feel them. He was pleased that he did not notice them at all, nor did they limit his movement. He also commented that the back seemed thicker but was happy to note that there was no impact on seat depth as he immersed well into the foam. Dean is very active and reported improved comfort while working and propelling. The Ripple Foam did not limit his movement and in fact seem to reduce the friction of his back against the foam.

Dean states that his number one benefit of the Ripple Foam is temperature control, although he has not stopped sweating completely, he feels a significant improvement. He commented "If I can't have a fan then this is the next best thing. Please don't make me go back to my original foam as this is so much cooler and more comfortable!"

During the previous six months, several consumers have been using the new Ripple Foam and have provided feedback on the comfort and durability of this exciting new design. Michael G. has been living with a C-6 level SCI for 30+ years and began using Ripple Foam in the back support of his power wheelchair for more than eight months ago. He immediately noticed an increase in his overall stability with the new foam. He described it as providing “more griptіon” for his upper body; a result of the increased immersion vs the slab foam, we suspect.

Allen is a high-level paraplegic who began using Ripple Foam on his existing MX2 Back almost 10 months ago. He also noted increased immersion and stability with the new foam.

Summary

Improvements in temperature and humidity have been found with the Ripple Foam technology used in the Matrx E2 back support. Volunteers in the study had a variety of thermoregulation responses. Some were quick to sweat with 0.1°C of temperature increase. Others stayed dry even when the ambient temperatures and back support surfaces felt warmer than usual. The Matrx E2 back-support appears to perform its comparative 'cooling' feature in both extremes.

Consumers and clinicians are eagerly awaiting the release of the new Matrx E2 Back support. It is expected to be a welcome option to wheeled mobility users with impaired thermoregulation and people living in warmer climates. We hope that improved seating tolerance and temperature control on E2 Back will offer more time outside and more freedom to remain active and socially engaged.

References:

1. Price, M.J. (2006). Thermoregulation during exercise in individuals with spinal cord injuries. *Sports Medicine, 36*(10), 863-879. doi: 10.1249/MSS.0000000000001978
2. Pritchett, R. C., Al-Nawaiseh, A. M., Pritchett, K. K., Nethery, V., Bishop, P. A., & Green, J. M. (2015). Sweat gland density and response during high-intensity exercise in athletes with spinal cord injuries. *Biology of Sport, 32*(3), 249-254. doi: 10.5604/20831862.1163370
3. Griggs, K. E., Leicht, C. A., Price, M. J., & Goosey-Tolfrey. (2015). Thermoregulation during intermittent exercise in athletes with a spinal cord injury. *International Journal of Sports Physiology & Performance, 10*(4), 469-475.
4. Peta, F., Miller, J., Pumpa, K., Thompson, K. G., & Jay, O. (2019). Independent influence of spinal cord injury level on thermoregulation during exercise.
5. Park, K., Tanaka, K., & Tanaka, M. (2014). Uhthoff's phenomenon in multiple sclerosis and neuromyelitis optica. *European Neurology, 72*, 153-156. doi: 10.1159/000361045
6. Davis, S. L., Wilson, T.E., White, A. T., & Frohman, E. M. (2010). Thermoregulation in multiple sclerosis. *Journal of Applied Physiology, 109(5)*, 1531-1537. doi:10.1152/japplphysiol.00460.2010
7. Wounds Canada (2018). Norton, L., Parslow, N., Johnston, D., Ho, C., Afalavi, A., Mark, M., O'Sullivan-Drombolis, D. & Moffat, S. Best Practice Recommendations for the Prevention and Management of Pressure Injuries. In: Foundations of Best Practice for Skin and Wound Management. A supplement of Wound Care Canada; 2018 [cited 2019 Sept 4]. 64 p. Available from: https://www.woundscanada.ca/docman/public/health-care-professional/bpr-workshop/172-bpr-prevention-and-management-of-pressure-injuries-2/file
8. Nouri, A. S., Charalampopoulos, I., & Matzarakis, A. (2018). Beyond singular climatic variables – identifying the dynamics of wholesome thermo-physiological factors for existing/future human thermal comfort during hot dry Mediterranean summers. *International Journal of environmental Research and Public Health, 15,* 2362.

Appendix A

Tekcoplus 4 Channel K Thermocouple SD Card Temperature Data Logger was used on a back-rest surface:

- Temp. Range: -200°C (-328°F) to +1370°C (+2498°F)
- Resolution: 0.1°C (0.1°F)
- Accuracy under +18°C (64.4°F) to +28°C(82.4°F) ambient temp.: ± 0.3%rdg
- Sampling Rate: Programmable frequency of reading from 1 second to 5 min.
- LCD Size: 47 mm High x 104 mm Wide
- Operating Temp.: 0°C (32°F) to 50°C (122°F)

IncuTherm™ Plus Digital incubator monitor was used on a skin surface

Measures and displays temperature in Celsius or Fahrenheit and relative humidity (measures humidity readings between 10 to 99% +/-5%). Memory function to recall minimum and maximum humidity and temperature readings.