Bodytrak

Validation studies

Heat stress: The burning risk impacting workers and organisations globally

Over the past decade references to weather condition phrases such as “record-breaking” and “unprecedented” are becoming far too common, especially during the warmer months. As temperatures continue to rise year-on-year this is putting both indoor and outdoor workers at greater risk of heat-related illnesses. According to the Bureau of Labour Statistics, heat exposure causes over 170,000 work-related injuries and more than 2000 fatalities every year. [1]

When core body temperature (CBT) exceeds 38.0°C / 100.4°F it starts to impair physical and cognitive functions and lead to the onset of heat-related illnesses such as dehydration, heat exhaustion and heat stroke. As a result this decreases productivity, increases errors, and incidents on the job. A single heat-related incident in the workplace can cost an employer around $79,081.[2] While heat stress in the workplace can have damaging effects on the short- and long-term health and wellbeing of employees, the implications can extend beyond those directly involved in the incident. The UN estimates that heat-related illnesses and increasing temperatures will cost the global economy $2.4 trillion every year by 2030. [3]

Traditional approaches to workplace safety that were once effective now have limited capacity as environments become more challenging

The ability to measure CBT is one of the best ways to detect the early signs of heat stress however, the challenges of measuring CBT in uncontrolled and industrial environments exposes the shortcomings of traditional methods. The gastro-intestinal (GI) pill, often used is research labs and controlled environments, is the gold standard for measuring CBT in ambulating individuals; however, it’s expensive, invasive and can be affected by food and beverage consumption. Other reliable methods, such as rectal probes, are also invasive and impractical for work environments.

Alternatives that are more consumer-focused include skin-based (ie. head thermometers, smart watches and armbands); however, these are prone to external interferences while the data captured can also be compromised by movement affecting accuracy and rendering readings unreliable. While such methods may suffice in controlled environments or when the stakes are not a matter of life and death, these approaches fail to address the dynamic and unpredictable conditions workers face, leading to the delayed detection of heat stress — when early intervention is crucial. As global temperatures rise and workplace demands intensify, the limitations of these outdated methods can put lives at risk, leaving workers vulnerable to the devastating impacts of heat-related illnesses.

Bodytrak, the world’s most comprehensive and reliable smart safety solution

Bodytrak’s in-ear monitoring solution redefines what is possible in occupational safety by providing continuous, real-time measurement of CBT with exceptional accuracy and reliability. Unlike traditional methods, the in-ear approach is non-invasive, unaffected by external variables and seamlessly integrates into a worker’s routine without hindering movement and performance.

This innovation empowers organisations to detect heat stress early, enabling preventative action to protect lives and minimise disruptions. With the ability to monitor physiological data in real time, Bodytrak offers a life-saving solution that ensures heat stress no longer goes unnoticed, safeguarding the health and productivity of workers in even the most challenging environments.

How does Bodytrak capture CBT accurately and prevent heat-related incidents?

Bodytrak captures real-time physiological data from a wearable earpiece with multiple sensors, analysed by machine learning (ML) on the device and in the cloud. The in-ear solution fits comfortably in the ear, taking an internal reading of the body’s temperature. Due to its proximity to the hypothalamus, the body’s temperature control organ, the ear is an excellent place to measure CBT and heart rate. Nestled securely in the concha of the ear, Bodytrak is unaffected by abrupt changes in environmental conditions and movement, delivering consistent and accurate data unique to the wearer.

Immediate alerts are triggered to the wearer (via audio) and supervisor (via Dashboard, email, text and WhatsApp) when preset thresholds have been exceeded – detecting early signs of heat stress and enabling immediate intervention before it becomes a serious risk.

Monitoring CBT: In-ear vs skin-based solutions

Measurement location and accuracy
An in-ear solution fits securely in the ear, taking an internal reading of the body's temperature. Due to its close proximity to the temperature control center of the body, the hypothalamus, the ear is an excellent site to measure CBT and heart rate. Skin-based methods only measure the skin's surface temperature, rather than what's happening internally. Whilst this can be reasonably effective in, for example, an air-conditioned hospital environment, it is a problem when monitoring active workers wearing personal protective equipment (PPE) in warm ambient conditions. Consider a steel or metal worker, surrounded by furnaces and an environment with varying temperatures. Measuring the worker's temperature using a skin-based solution is likely to be influenced by the hot air radiated from the surrounding furnaces as well as body heat trapped under PPE, but won't necessarily account for the metabolic heat production within the body due to physical activity. These compounding factors make it very difficult for skin-based solutions to provide an accurate measurement of the individual's heat stress level and their overall level of risk.

Ambient interference
Industrial environments in the workplace are often susceptible to many diverse and hazardous conditions that may be regularly changing, with workers having to constantly adapt. Limb-worn skin-based devices are exposed to high levels of movement artefact, which can compromise the reliability of the data collected.
An in-ear device is nestled securely inside the ear with low levels of movement, delivering consistent and accurate data. Picture a firefighter in training battling a blaze, who is very active moving around an area but also operating hoses and machinery, as well as being surrounded by varying degrees of heat and doused by water at different intervals. An in-ear device will reliably monitor the internal body temperature of the wearer regardless of the conditions while a skin-based solution will be influenced by the excessive motion and temperature of the air, heat trapped under the PPE, water from the hose and even smoke.

Comfort
Just like a pair of well-fitted headphones, the Bodytrak earpiece has been ergonomically designed for maximum comfort and wearability, especially alongside existing PPE. For employees on long shifts, comfort isn't a luxury – it's a necessity. An in-ear solution respects this, removing any discomfort when fitted correctly. While skin-based solutions might seem suitable, over extended periods they can cause skin irritation from rubbing, friction and salt deposits from perspiration, along with discomfort from unevenly dispersed weight. In some instances, the fibers from skin-based harnesses can trigger allergic reactions.

Validation studies

Environmental chamber study (2024)

Method

Nine physically active, healthy participants (age: 32.7 ± 6.0 years, height: 176.8 ± 6.7 cm, weight: 75.9 ± 13.1 kg) completed the study. Each participant completed the protocol four times, with the exception of four sessions being removed as a result of the GI pill reading being affected by external sources such as fluid consumption.

The study began with a 15-minute rest period in a neutral environment (~ 18°C). The participants then entered the environmental chamber (35°C and 40% relative humidity) where they completed 60 minutes of intermittent cycling on a cycle ergometer at 80W, i.e., 5 minutes sitting then 5 minutes cycling, repeatedly. The final stage of the study was a 30-minute seated recovery period in the neutral environment.

Findings

The Bodytrak 1 device had a mean bias of 0.173°C , mean absolute error (MAE) of 0.260°C and root mean square error (RMSE) of 0.398°C, when compared to the GI pill. There was a strong positive correlation between the GI pill and the Bodytrak 1 device, which was statistically significant ($r(204,217) = 0.652$, $p < 0.001$).

When the temperature recorded from the GI pill was greater than 38°C the mean bias reduced to 0.006°C, the mean absolute error (MAE) to 0.185°C and root mean square error (RMSE) to 0.261°C.

During this study the heart rate of four of the participants was monitored using the Bodytrak 1 device and the ECG Holter monitor. The Bodytrak 1 device had a mean bias of 0.39 bpm and mean absolute error (MAE) of 2.80 bpm. There was a strong positive correlation between the ECG Holter monitor and the Bodytrak 1 device, which was statistically significant ($r(18,017) = 0.988$, $p < 0.001$).

Measuring core body temperatures using wearable technology (2024)

Method

10 physically active, healthy participants completed sessions comparing Bodytrak to a rectal probe.

Participants spent 30-minutes at rest in a semi-supine position at temperate conditions (25°C). This was followed by 60-minutes at rest in a temperature controlled environmental chamber set at 50°C and 25% relative humidity. The session ended with 20-minutes cycling at 1.7W for every kilogram of body weight on a cycle ergometer.

Findings

The Bodytrak 1 device had a mean bias of 0.067°C, mean absolute error (MAE) of 0.201°C, and root mean square error (RMSE) of 0.240°C, when compared to a rectal probe.

NavAir pilot helmet and PPE testing (2019)

Method

Two physically active, healthy participants completed three sessions in a controlled environmental chamber (35°C and 55-60% relative humidity).

Participants completed an interval cycle session of 90 seconds at 25% of their VO_{2max} followed by 60 seconds of rest. Participants completed this for a duration of 60 minutes or until they reached volitional exhaustion.

Findings

The Bodytrak 1 device had a mean bias of 0.181°C, mean absolute error (MAE) of 0.227°C, and root mean square error (RMSE) of 0.330°C when compared to the GI pill. There was a strong positive correlation between GI pill and the Bodytrak 1 device, which was statistically significant ($r(11,889) = 0.658$, $p < 0.001$).

During this study the heart rate of the two participants was monitored using the Bodytrak 1 device and the Polar Chest Strap. The Bodytrak 1 device had a mean bias of 0.183 bpm and mean absolute error (MAE) of 2.874 bpm. There was a strong positive correlation between the Polar Chest Strap and the Bodytrak 1 device, which was statistically significant ($r(11,889) = 0.948$, $p < 0.001$).

Summary of methods and findings for core body temperature

	Duration	No. of sessions	Temp.*	Humidity*	MAE	Mean bias	RMSE
Environmental chamber study (2024)	56 hrs 43 m	32	35°C	40%	0.260°C	0.173°C	0.398°C
Measuring core body temp. using wearable technology (2024)	17 hrs 05 m	10	50°C	25%	0.201°C	0.067°C	0.240°C
NavAir pilot helmet and PPE testing (2019)	03 hrs 18 m	3	35°C	55 - 60%	0.227°C	0.181°C	0.330°C

** The temperature and humidity specified were based on the observed readings inside the environmental chamber.*

Insights into the findings

Bodytrak has conducted extensive validation studies to ensure the accuracy and reliability of its wearable smart safety solution in measuring CBT as well as heart rate. The validation studies spanned a diverse range of ambient environments, participants, and personal protective equipment (PPE), reinforcing Bodytrak's commitment to precision and worker safety.

The industry-accepted standard for CBT measurement accuracy is within a mean absolute error (MAE) of 0.30°C. The solution from Bodytrak demonstrates an overall weighted MAE of 0.245°C, highlighting its accuracy and reliability. The validation studies covered a total monitoring duration of over 77 hours (4626 minutes), providing robust data to support the solution's accuracy claims.

Additionally, the Bodytrak device was exposed to ambient temperatures up to 50°C, showcasing its ability to withstand tough and challenging conditions.

The accuracy of heart rate monitoring from Bodytrak has also been validated against leading industry benchmarks, including medical-grade 3-lead ECG monitors commonly used in hospitals and the Polar Chest Strap monitor. The studies demonstrate that the Bodytrak device provides heart rate measurements with a high degree of precision, making it a reliable solution for continuous physiological monitoring.

Conclusion

The tools available to monitor CBT are changing, especially within the industrial environment. While many organisations may be accustomed to external environmental measures (i.e. WBGT) or skin-based methods (i.e. smart watches and armbands), the innovative in-ear solutions from Bodytrak are challenging their accuracy and suitability in real-life settings.

Designed with comfort and ease of use, Bodytrak is one of the most comprehensive smart safety solutions that is leading the way when it comes to real-time physiological monitoring in industrial environments. With over 77 hours of collected data, the accuracy of CBT measurements is validated across the range of studies.

Bodytrak has been implemented across various sectors to enhance workplace health and safety measures and protect workers in a range of environments.

To arrange a trial, please email us at: sales@bodytrak.co

Sources

1 https://www.ishn.com/articles/113397-heat-safety-rule-cant-come-fast-enough
2 OSHA Estimated Total Cost of a Heat Prostration Injury or Illness, https://www.osha.gov/safetypays/estimator
3 https://news.un.org/en/story/2019/07/1041652