SLATE SAFETY™

Third-Party Validation Studies

Proving the efficacy of our solution through independent, scientific studies.

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PROBLEM: THE HEAT

With record high temperatures every year, the risk of heat-related illnesses such as heat exhaustion and heatstroke is at an all-time high for workers exposed to hot environments and those who wear insulative PPE. High ambient temperatures can result in decreased productivity, increased risk of accidents, and in severe cases, fatalities. An article from The Citizen suggests that heat contributes to around 170,000 worker injuries per year, which often go unreported. Heat injuries would be the third-highest occupational injury if they were accurately reported. Additionally, OSHA estimates that each injury costs around $80,000 from direct and indirect costs.

OSHA® Occupational Safety and Health Administration

"**Heat is the leading cause of death** among all weather-related phenomena, and it is **becoming more dangerous** as 18 of the last 19 years were the hottest on record."

Existing Solutions are Inadequate, Invasive or Inaccurate for measuring Core Body Temperature

When workers know their core body temperature is too high, they can take a break and cool off. However, the “gold standard” methods for measuring core body temperature, such as ingested pills or rectal thermometers, are invasive and not suitable outside a controlled setting.

Ingestible pills (left) and a thermometer.

Other thermometers, such as forehead scanners, are inaccurate because they only measure skin temperature which is heavily affected by external factors such as ambient temperature. Non-invasive methods take the temperature from the body’s surface or naturally open places, like the mouth, armpit or ear. These methods are more comfortable and practical for frequent use. Still, their accuracy can be influenced by factors such as recent eating or drinking (mouth), the surrounding temperature (armpit) or not placing the thermometer correctly (ear). Inaccurate readings lead to distracting false positives and dangerous false negatives.

A forehead scanner thermometer (left) and an ear thermometer.

SlateSafety's Solution

SlateSafety has created the BAND V2, an arm-worn physiological monitor, to fill this gap. Equipped with a sensor that simply needs skin contact, the BAND V2 measures core body temperature in an accurate, non-invasive, user-friendly way. This enables workers to quickly see early signs of heat stress and take necessary steps, like reducing physical work, moving to a cooler place, or drinking more fluids.

How can core body temperature be measured from the arm?

The BAND V2 does not directly measure core body temperature from the arm. Instead, it uses state-of-the-art methods developed to estimate and closely track core body temperature from accelerometry and sequential heart rate readings. Historically, similar methods have been applied by researchers in the U.S. Army.

Scientific Validation

In addition to the US Army studies that have corroborated this method for estimating core temperature, SlateSafety's devices have undergone validation studies. These studies were conducted by third parties without input or stake from SlateSafety. **Note:** If you are a researcher who is interested in conducting a study with SlateSafety devices, please contact us.

To our knowledge, SlateSafety has the only non-invasive core body temperature monitor that has been validated in studies by third-party university research teams. SlateSafety also has its own internal dataset for testing and internally validating its core body temperature estimation, but it's more important to analyze the results from externally conducted studies.

To date, there have been three third-party conducted studies involving SlateSafety devices, which are summarized here:

Texas A&M and the University of Alabama Core Body Temperature Study (2023)

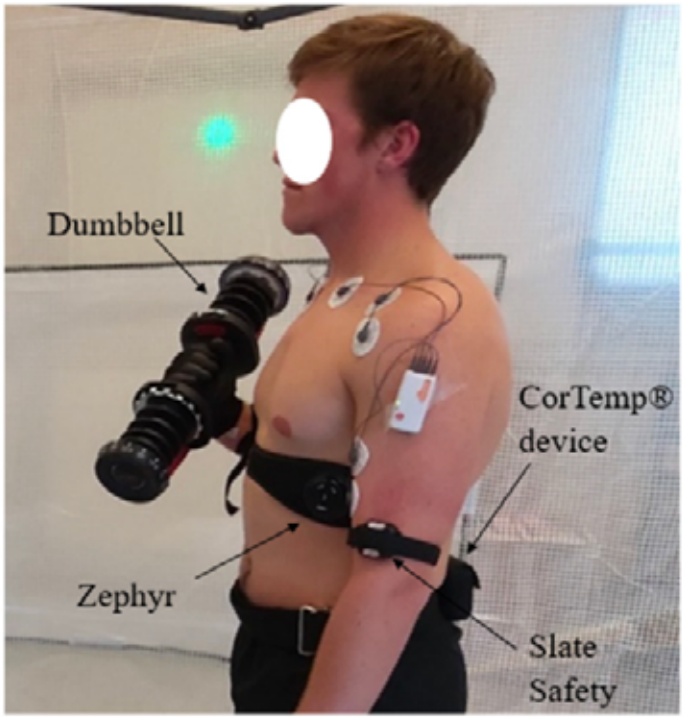
View Study

Participants: 10 male volunteers without confounding medical issues between the ages of 18 and 30.

Environment: lab experiment with ten participants performing a dumbbell curling task in hot temperature conditions (temperature = 33 °C; humidity = 50%). PPE = none.

Results: showed that the SlateSafety device had a bias of 0.20 °C and a MAE of 0.33 °C. There was a strong positive correlation between the Ingestible Core Body Temperature Sensor and the SlateSafety device, which was statistically significant (ρ (421) = 0.543, $p < 0.001$).

(a)



(b)

University of Alabama Core Body Temperature and Comfortability Study (2023)

View Study

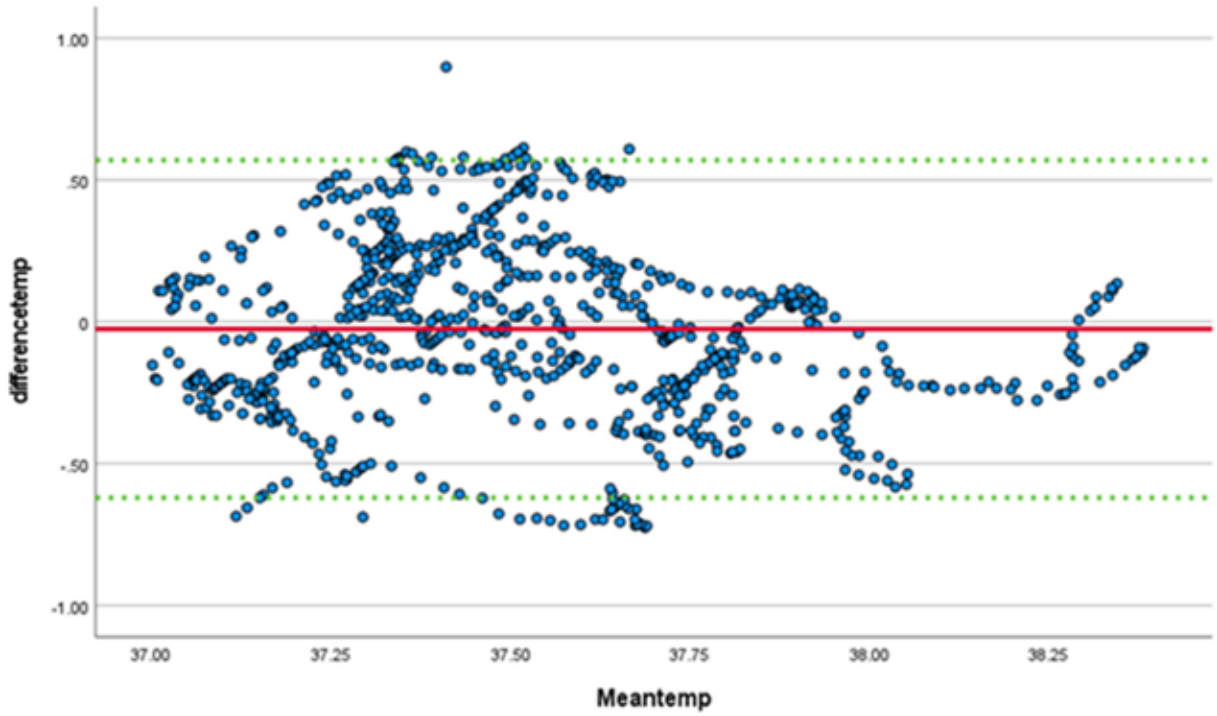
Participants: 20 nurses (17 female, 3 male), average age of 31.45 years.

Environment: The simulation occurred in a room equipped as a hospital room with the temperature controlled to either 71 °F (moderate condition) or 85 °F (hot condition) and at a humidity of approximately 40%. CPR was performed. Participants in the hot room also wore splash-resistant gowns for the collection to simulate the occupational conditions more accurately.

Results:

- **Comfort:** All participants reported a high level of comfort with the SlateSafety system, with a mean score of 9.8, with ten representing the highest level of comfort. The mean comfort rating for the ingestible pill was 6.5.

- **Accuracy:** Aggregated data demonstrated a mean error bias of 0.04 C higher for the SlateSafety system with an RMSE of 0.27 C and an MAE of 0.25 C. The mean difference in temperature between the ingestible pill and the SlateSafety system was −0.03 (meaning the SlateSafety temperature is on average 0.03 C higher) with a standard deviation of 0.3 (95% confidence interval −0.62, 0.57)



Above: *Bland-Altman test for temperature comparing SlateSafety device to ingestible pill. Mean noted in red, 95% confidence interval in green.*

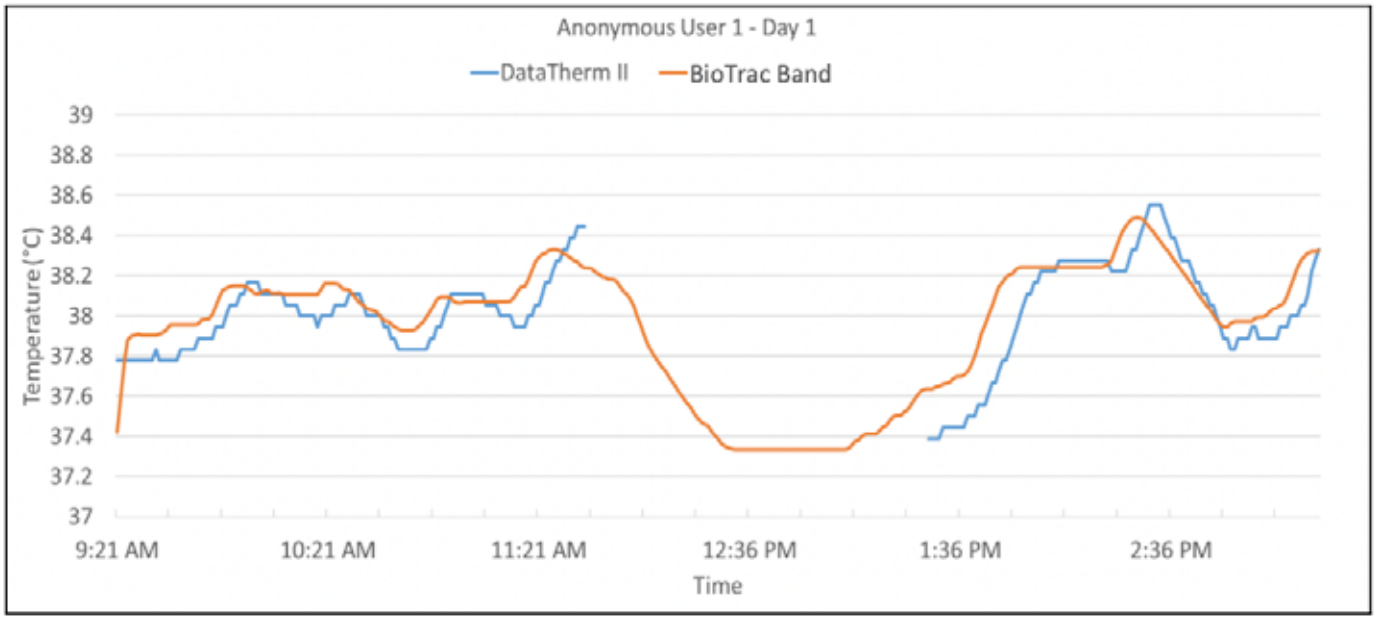
Lee University Core Body Temperature Study (2020)

View Study

Participants: 5 recruits at a local firefighting training facility (4 Male, 1 Female).

Environment: This study was an augment to an already planned local fire departments training exercise. Data was captured during the 2-day training event where subscribed activities are intended to test a firefighter recruit's ability to perform simulated implementation of tactical operations. Activities captured during this training consisted of live fire fighting technique training and heavy calisthenics in full PPE load out. Outdoor Temperature = 18 to 27 °C; humidity = 50% to 90%.

Results: With 95% confidence, any given SlateSafety core temperature reading will be between +0.25 C and -0.39 C of the DataTherm II's reading (a rectal thermometer).



STUDY SUMMARY TABLE

Third-Party Research Team	Total Minutes of Activity	Participants (n=)	Environment	Mean Absolute Error (˚C)	Mean Bias (˚C)
Texas A&M / Univ of Alabama	235	10	temp = 33 °C humidity = 50% PPE = none	0.33	0.20
Univ of Alabama	884	20	temp = 21 to 29 °C humidity = 40% PPE = medium	0.25	0.04
Lee University	948	5	temp = 18 to 27 °C humidity = 50 to 90% PPE = heavy	0.23	0.07
Total/Range/ Weighted Avg.	**2,067**	**35**	**temp = 18 to 33 °C humidity = 40 to 90% PPE = none, medium, and high**	**0.25**	**0.07**

Analyzing the Results

The studies above covered a wide range of individuals, ambient environments, and PPE. With a Mean Absolute Error (MAE) of 0.25 °C, SlateSafety's device accuracy is not far removed from those of rectal and ingestible thermometers and is well within the industry-accepted standard of 0.30 °C. Notably, SlateSafety's algorithm consistently overestimates core body temperature since it was designed to be used across the spectrum of PPE — including heavier PPE — which could explain the higher accuracies for the studies involving heavier PPE. With a Mean Bias of 0.07 °C, SlateSafety's core body temperature estimation appears to have a very minor bias over the ingestible/rectal temperature. This can be explained by SlateSafety's use case — SlateSafety would rather estimate slightly higher temperatures to be on the safe side and protect workers.

Conclusions

Despite being much more reliable and easy to use, SlateSafety's device is nearly as accurate as a rectal or ingestible thermometer throughout a range of activities and environments. This has been proven from over 2,000 minutes of data comparison with gold-standard thermometers by third-party researchers in various occupational environments.

Lastly, SlateSafety is constantly undergoing new studies with university researchers; if that is you or you have any questions, contact us at info@slatesafety.com.

References

1. Callihan, M.; Cole, H.; Stokley, H.; Gunter, J.; Clamp, K.; Martin, A.; Doherty, H. Comparison of Slate Safety Wearable Device to Ingestible Pill and Wearable Heart Rate Monitor. Sensors 2023, 23, 877. https://doi.org/10.3390/s23020877

2. Ibrahim, A.A.; Khan, M.; Nnaji, C.; Koh, A.S. Assessing Non-Intrusive Wearable Devices for Tracking Core Body Temperature in Hot Working Conditions. Appl. Sci. 2023, 13, 6803. https://doi.org/10.3390/app13116803

3. Lawler, R. Industrial Athlete Core Temperature Accuracy Analysis of Commercial Arm Worn Device vs Rectal Thermometry. 2020. Athletic Training Education, Lee University.