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BRIEF REPORT

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Wearable Technology for Feedyard Safety

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ABSTRACT

Objectives: Cattle feedyard workers are at high risk of heat stress and illness due to being outdoors for long hours in high heat and humidity. Wearable technology has the potential to provide a warning system so that at-risk workers can take a break, move into a shaded area, and hydrate before heat illness results in lost work time.
Methods: The MākuSafe wearable device was used to monitor heat warnings in 15 cattle feedyard workers. We collected environmental temperatures and heat warnings from wearable devices at a single feedyard from June 1 through September 30, 2023. We assessed the number of heat warnings and the maximum temperature where they were most likely to occur using segmented logistic regression to model the nonlinear relationship between temperature and heat warning and to understand the threshold at which heat warnings occurred. The Pseudo Score Test was used to assess for a changepoint in the logistic regression model with temperature predicting a heat warning for the number of days the wearable device was used in 15 workers.
Results: The Pseudo Score Test identified a single statistically significant changepoint ($p < .0001$). The Davies test confirmed the result and estimated the change at 78°F. The covariates worker role or hours worked that day were not significantly associated with the probability of a heat warning.
Conclusion: These findings revealed that the probability of a heath warning occurring at a relatively low temperature of 78°F, which can aid workplace management with heat stress management and preparedness to protect worker health.

KEYWORDS
Agriculture; feedyard; heat stress management; safety; wearables

Introduction

Over half of all feedyards are located within the central states region of the United States (US).[1] This economically vital industry comes with a high risk of injury, illness, and fatality to its workers. In 2020, livestock agriculture had a "days away from work, job restriction or transfer rate" of 29/1000 FTE workers.[2] Farm workers are particularly susceptible to heat stress due to many factors including physiological strain and exposure to hot environments.[3] Agriculture has more than 35 times the risk of heat-related mortality compared to all other industries.[4] Heat safety is at the forefront of highly concerning occupational health risks. Recently, the Occupational Safety and Health Administration (OSHA) proposed a new rule that will protect agricultural industries who employ seasonal workers from heat hazards.[5] Though this is a great stride, there is still a need for monitoring not only the environment but the individual worker.

The use of internet of things (IoT) combined with wearable technology has been deployed by many industries to monitor worker health and safety. Construction workers have been the most studied due to the risks of musculoskeletal disorders in this occupation.[6,7] Wearable devices can capture data that can be used to analyze trends and insights about the worksites and their workers. Measures can be used to assess strain; exertion; ergonomic risk; slips, trips, and falls; heart rate; and core body temperature. Environmental monitoring for heat, sound, air quality, and light combined with physiological monitoring of heart rate, skin temperature, and sweat rate can provide enhanced data for informed decision-making. Agricultural workers would benefit from knowing when their body temperature and exertion levels put them at risk of a heat-related illness. Supervisors can be made aware of the situation and can urge workers to move to the shade, hydrate, and rest until the situation improves. This data can be used to provide an early warning system for cattle feedyard workers who are at risk of a heat-related illness.

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This brief report aims to examine associations between environmental temperature and heat warnings from wearable device monitoring in cattle feedyard workers. The specific objectives were to (1) characterize heat warning events in 15 cattle feedyard workers from June 2023 to September 2023, using the MakuSafe wearable device and (2) assess heat warning frequencies at daily maximum temperatures. The benefits and challenges of employing this technology on a cattle feedyard are discussed.

Methods

Device

The MākuSafe wearable device is a commercially available environmental monitoring device that is worn with an elastic armband on the upper arm as seen in Figure 1. It carries an array of IoT-enabled sensors which gather data on environmental conditions, potentially hazardous human motion, proximity, and location. The device uses proprietary sensors to collect heat and humidity information that it then sends to the MākuSmart cloud-based software platform which uses proprietary algorithms to create heat advisory alerts. More information on the device can be found at https://makusafe.com/.

Figure 1. MākuSafe wearable device worn on feedyard worker. Photograph provided by Athena Ramos, Central States Center for Agricultural Safety and Health (CS-CASH).

Sample

MākuSafe wearable devices were piloted on a feedyard in Nebraska and heat warning data was obtained for 15 workers from June 1, 2023, through September 30, 2023, from the MākuSmart dashboard. Workers don the wearable technology at the beginning of their shift and return it at the end of their shift, although a few inadvertently wore it home. We also collected the hours worked for each worker on each day the wearable device was worn. For those who did not return the wearable technology device, we capped the work time at 18 h since that is the maximum hours reported by workers in those who returned the device. The unit of analysis in this report is not the worker, but the number of days the wearable device was used by the 15 workers. Devices were not worn every day by every worker because there were not enough devices to fit the entire feedyard workforce. In addition, no personal demographic data was available for these workers. There was no biometric data available due to the measurements that the MākuSafe device collects. The study protocol was deemed Exempt by the University of Nebraska Medical Center Institutional Review Board (IRB Protocol: 599–17-EP).

Maximum daily temperatures were obtained for the feedyard location from the US Weather Service for each day of the study period. Humidity data was not obtained from the US Weather Service; however, the devices collect humidity to determine heat warning thresholds. Feedyard work roles were coded as cowboy, mill, or shop workers. Heat warnings were reported in four categories (no warning, high temperature, heat index danger, and heat index extreme danger) based on the temperature and heat index measured by the device. Warnings were recoded as binary (present or absent) for the regression analysis.

Statistical analysis

Descriptive statistics were calculated for work role, hours worked, and the types of heat warnings recorded. The Pseudo Score Test was used to assess for a changepoint in the logistic regression model with temperature predicting a heat warning. The Davies Test was used to estimate the changepoint.

A segmented logistic regression model was used to model the nonlinear relationship and identify the changepoint with its 95% confidence interval (CI). Potential confounders include work role (cowboy or mill/shop) and number of hours worked. The analysis was conducted with the Segmented package in R.

Results

Ten of the fifteen workers were cowboys, four were mill workers and one worked in the shop. The mean hours worked in a day was 10.4 (SD = 2.11). Cowboys worked significantly more hours than mill and shop workers on the days they wore a device. There was a total of 490 wearable tech events in the sample with 243 (49.6%) feedlot workers working a shift without a heat warning and 247 having one or more heat warnings (Table 1). Most of the observations were from those working as cowboys (78.8%) (Table 1).

The number of warnings per shift varied for each worker and multiple warnings occurred in the same shift for an individual worker. The maximum high temperatures ranged from 64°F to 103°F. The Pseudo Score Test identified a single statistically significant changepoint ($p < .0001$). The Davies test confirmed the result and estimated the change at 78°F. The segmented regression model showed a significant and nonlinear slope up to 81°F (CI 79.1,82.9). The probability of a heat warning is exponentially increasing until it reaches 81°F, after which a linear increase in the probability of a heat warning is observed (Figure 2). The covariates worker role or hours worked that day were not significantly associated with the probability of a heat warning.

Table 1. Summary of work roles of cattle feedyard workers and type of heat warnings reported, June through September, 2023.

Variable	n (%)
Work role represented wearable technology days	
Cowboy	386 (78.8)
Mill	94 (19.2)
Shop	10 (2.0)
Wearable technology warning	
No warning during shift	243 (49.6)
High temperature warning	42 (8.57)
Heat index danger warning	160 (32.7)
Heat index extreme danger warning	45 (9.18)

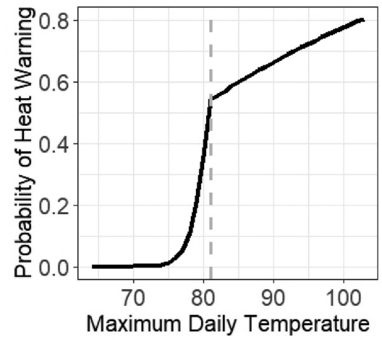

Figure 2. Segmented regression showing a nonlinear relationship between the maximum daily temperature (^{0}F) and the probability of a heat warning as measured by wearable technology in 15 cattle feedyard workers, June through September, 2023.

Discussion

The findings reveal that there is greater than a 50% probability of a heat warning at a relatively low temperature, which can help safety managers make better decisions regarding the precautions and preparedness for heat-related illness. A dangerous heat index warning can be triggered at a heat index at 105°F. Midwest cowboys who are riding pens in the direct sun, may be at risk of heat stress at a relatively low temperature. This is also true of those who are working indoors in shops and mills without the benefit of air conditioning. Indoor spaces can trap heat and humidity, leaving these worker roles just as vulnerable as those outdoors.

A concerning observation is the number of repeated warnings in some workers on the same day. The warning from the MakuSafe device goes directly to management, but management may not be monitoring these warnings. Managers may need to have procedures and policies in place to protect workers by moving them to a shady place and having cold water readily available. Education about hydration is a critical aspect of worker safety, considering that 70% of workers across five different industries have been shown to arrive to work already dehydrated based on their measured urine specific gravity values.[8] Interestingly, the few available devices for monitoring hydration status have limited published studies assessing their validity.[9]

Despite some limitations, wearable technology devices can provide valuable information on more than heat-related illness risk. They can provide data on injury near-misses, movements that put a worker at risk of a musculoskeletal disorder and warn of other health conditions. This has the potential to increase not only worker safety but also productivity, providing economic benefits.[10] Biometric wearable technology is a valuable addition to environmental wearable technology, because together they can provide powerful and individualized data for each worker. In the future, we plan to add biometric monitoring devices to feedyard workers. The amount of data they provide can be difficult to interpret, posing challenges to safety managers. Other considerations include who has access to the data, validity of the device, and measuring what is intended to be measured. Presently at this feedyard, only safety management receives notifications on employee alerts from the MākuSafe devices via the MākuSmart dashboard. Another recommendation based on this project is to develop or modify dashboards to assist the safety managers with decision-making on alerts. An overabundance of alerts can overwhelm a safety manager. Developing protocols on how to respond appropriately to alerts will be an essential step to effectively adopting this technology. This remains a challenge with lack of large-scale field validation in occupational settings.[11] Great strides have been made at the intersection of wearable technology and worker health. More research is needed on how to best utilize these devices to optimize not only worker safety but risk mitigation. Protecting the wellness of workers ultimately benefits the organization.

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Author contributions

ST procured the data and assisted with the drafting and review of the manuscript; AMY designed the study, worked with the feedlot to collect the data, and reviewed the manuscript; JO worked with AMY to conduct the study on the feedlot; CLB analysed the data, and drafted and reviewed the manuscript.

Institutional and ethics approval and informed consent

This project was deemed Exempt by the University of Nebraska Medical Center Institutional Review Board.

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References

1. Ramos AK, Adhikari S, Yoder AM, Rautiainen RH. Occupational injuries among Latino/a immigrant cattle feedyard workers in the Central States region of the United States. *Int J Environ Res Public Health*. 2021;18(16):8821. doi: 10.3390/ijerph18168821.
2. U.S. Bureau of Labor Statistics. Table 1. Incidence rates of nonfatal occupational injuries and illnesses by industry and case types, 2020 [internet]. Injuries, Illnesses, and Fatalities IIF Program Links. https://www.bls.gov/web/osh/summ1_00.htm. November 3, 2021. Accessed June 9, 2024.
3. El Khayat M, Halwani DA, Hneiny L, Alameddine I, Haidar MA, Habib RR. Impacts of climate change and heat stress on farmworkers' health: a scoping review. *Front Public Health*. 2022;10:782811. doi: 10.3389/fpubh.2022.782811.
4. Gubernot DM, Anderson GB, Hunting KL. Characterizing occupational heat-related mortality in the United States, 2000–2010: an analysis using the Census of Fatal Occupational Injuries database. *Am J Ind Med*. 2015;58(2):203–211. doi: 10.1002/ajim.22381.
5. U.S. Department of Labor. The Department of Labor takes critical steps in heat safety rulemaking, continues heightened enforcement efforts, focuses on dangers to agricultural workers. [Internet]. https://www.dol.gov/newsroom/releases/osha/osha20240508-0. May 8, 2024. Accessed June 9, 2024.
6. Nath ND, Akhavian R, Behzadan AH. Ergonomic analysis of construction worker's body postures using wearable mobile sensors. *Appl Ergon*. 2017;6:107–117. doi: 10.1016/j.apergo.2017.02.007.
7. Valero E, Sivanathan A, Bosché F, Abdel-Wahab M. Musculoskeletal disorders in construction: a review and a novel system for activity tracking with body

area network. *Appl Ergon*. 2016;54:120–130. doi: 10.1016/j.apergo.2015.11.020.

8. Piil JF, Lundbye-Jensen J, Christiansen L, et al. High prevalence of hypohydration in occupations with heat stress—perspectives for performance in combined cognitive and motor tasks. *PLOS ONE*. 2018;13(10): e0205321. doi: 10.1371/journal.pone.0205321.
9. Sandys V, Bhat L, O'Hare E, et al. Pilot study of a wearable hydration monitor in haemodialysis patients: haemodialysis outcomes & patient empowerment study 02.digit biomark. *Digit Biomarker*. 2023;7(1):18–27. doi: 10.1159/000529899.
10. Häikiö J, Kallio J, Mäkelä S-M, Keränen J. IoT-based safety monitoring from the perspective of construction site workers. *IJOOES*. 2020;4(1):1–14. doi: 10.24840/2184-0954_004.001_0001.
11. Cannady R, Warner C, Yoder A, et al. The implications of real-time and wearable technology use for occupational heat stress: a scoping review. *Safsci*. 2024;117:106600. doi: 10.1016/j.ssci.2024.106600.