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Short Communication

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Heat strain in road construction workers during the summer in New Mexico: a preliminary study

Jonathan W. Specht[1,*], Serena Garcia[1], David H. Wegman[2,3], Jason Glaser[2], Zachary J. Schlader[2,4], Fabiano T. Amorim[1,2]

[1]Department of Health, Exercise, and Sports Sciences, University of New Mexico, Cornell Dr, Albuquerque, NM 87131, United States
[2]La Isla Network, California St NW, Washington, DC 20005, United States
[3]Department of Public Health, University of Massachusetts Lowell, University Avenue, Lowell, MA 01854, United States
[4]Department of Kinesiology, Indiana University School of Public Health – Bloomington, 7th St, Bloomington IN 47405, United States

[*]Corresponding author: Email: jspecht1@unm.edu

Abstract

In the summer season, road construction workers perform physically demanding tasks outdoors, placing them at greater risk for exertional heat illness conditions. Assessing core temperature (Tcore) is critical as it serves as a key indicator of heat strain and helps to estimate the risk of heat-related illness. Despite the increased risk of hyperthermia, previous research has not assessed Tcore in road construction workers in the United States during summer work.

Purpose: To report heat strain and environmental heat stress in a pilot study of road construction workers during work in the summer.

Methods: Seven male road construction workers in New Mexico were observed performing physically demanding work during a summer work shift. Environmental heat stress (heat index [HI], dry/wet bulb temperature, and relative humidity), Tcore, and skin temperature (Tskin) were measured continuously at a single job site throughout the workday. Hydration was assessed pre- and post-shift via measurements of urine specific gravity (USG) and changes in body weight.

Results: The peak HI recorded throughout the workday was 34.1 °C, corresponding to a "warning" heat risk level according to the Occupational Safety and Health Administration Heat Safety Tool App. Two of seven (29%) workers reached a peak Tcore of greater than 38.0 °C, and 4 (57%) began the work shift dehydrated, indicated by a USG >1.020.

Conclusions: Findings from this pilot study suggest that road construction workers may begin their shifts dehydrated and some experience moderate hyperthermia while performing physically demanding work in hot environmental conditions.

Key words: climate change; heat illness; hydration; worker safety.

What's Important About This Paper?

This is the first study to assess heat strain via core temperature in road construction workers during summer work. These workers can experience heat strain during work, even in moderately hot conditions, likely due to a combination of physically demanding tasks and hot environmental conditions. Dehydration is a risk factor for heat-related illness, and approximately half of the participants were found to be dehydrated before and after work.

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Introduction

Road construction workers perform physically demanding tasks including laying concrete, paving roads, and operating machinery (Burstyn et al. 2000), resulting in substantial cardiovascular, musculoskeletal, and metabolic demands (Meerding et al. 2005; Roja et al. 2006). Excessive metabolic heat production from physically demanding tasks can lead to severe hyperthermia (Lucas et al. 2014). Additionally, these workers are exposed to environmental heat stress during warmer periods of the year (Calvache Ruales et al. 2022), which include high radiation exposure, air temperature, and/or humidity (Gao et al. 2018). Furthermore, they need to wear protective clothing (Baral and Koirala 2022), impairing heat dissipation (Glitz et al. 2015), and often work with materials at high temperatures (i.e. hot mix asphalt). These combined factors increase heat strain (physiological responses to heat stress) and the risk of heat-related illness (Ioannou et al. 2021).

Although construction workers are thirteen times more likely to die from heat-related illnesses compared with workers in other occupations (Gubernot et al. 2015), heat strain in these workers is not well understood. To reduce the risk of heat-related illness in workers, the American Conference of Governmental Industrial Hygienists (ACGIH) has established threshold limits, recommending that workers maintain a core temperature (Tcore) within 1.0 °C of baseline, or below 38.0 °C (ACGIH 2017). If heat acclimatized, workers are recommended to stay below 38.5 °C. No previous research has assessed heat strain experienced by road construction workers in the summer. This pilot study aimed to measure heat stress and strain in a sample of road construction workers repairing a bridge roadway during the summer.

Methods

Recruitment

The protocol was approved by the University of New Mexico institutional review board (protocol #2208012352). The day prior to data collection, workers were consented and screened for health risks, physical limitations, and medications that could impair thermoregulatory responses.

Data collection

Seven workers were studied during a single workday at a jobsite in New Mexico in July 2023. Pre-shift urine was collected to assess hydration status via urine specific gravity (USG) using a test strip and urine analyzer (Model 120, Medline Industries, Northfield, IL). Body weight was measured with clothing due to limited private space. A skin temperature (Tskin) sensor (model DS1921H, Embedded Data Systems, KY) was applied to the chest, and a Tcore pill (BodyCap, e-Celsius, Caen, France) was ingested by participants. Workers then performed their usual work routines for ~8.5 h. Environmental conditions (heat index [HI], wet and dry bulb temperature, and relative humidity [RH]) were continuously recorded (Kestrel 4400 Heat Stress Tracker, Nielsen-Kellerman, Boothwyn, PA) in the primary work area. Due to a device malfunction, solar radiation was not collected and wet bulb globe temperature was not calculated. Post-shift urine was collected to remeasure USG, and body weight was measured to determine percent change, a marker of changes in body water (American College of Sports Medicine et al. 2007).

Data analyses

Environmental conditions and Tcore were recorded every minute and subsequently averaged over 5-min periods. Tskin was recorded and analyzed for every minute. Peak values were reported as the highest value. Data for HI were categorized using the Occupational Safety and Health Administration (OSHA) Heat Safety Tool App, using classifications of "Warning" (26.7 to 34.9 °C HI) and "Danger" (≥35.0 °C HI) (OSHA 2022), indicating risk of heat-related illness. A heat gradient for HI was created using data averaged over 30-min intervals. Data cleaning for the variables above was completed via graphing and visual inspection. The first hour of Tcore data, and any point that changed ≥0.5 °C from the previous time point were removed due to the Tcore pill being located in the stomach where beverage ingestion affected accurate Tcore. Observation by researchers categorized effort in accordance with ACGIH criteria (rest, light, moderate, heavy, and very heavy work) (ACGIH 2017). Data are presented throughout as mean ± SD.

Results

Seven males completed this observational study (Table 1). The specific job was renewing a bridge on an interstate highway and involved building forms, pouring/forming concrete, cleaning the worksite, and operating machinery. Researchers observed primarily "heavy" work (laying rebar, pouring concrete) before lunch, with "moderate" work (cleaning and organizing) during the afternoon (ACGIH 2017). During lunch (~30 min long, 4 h into the shift), some workers went to cars and shaded areas to rest. Short breaks of ~10 min were noted around hours 2 and 6, where workers prioritized hydrating with freely available water. All workers were engaged in outdoor activities with limited shade access. Peak HI reached 34.1 °C, with an average of 28.1 ± 3.7°, both within the "warning" risk category. Based on averages shown in Fig. 1A, 6.0 of the 8.5 working hours (~71%) were in the "warning" risk category. Peak dry bulb temperature was 36.5 °C (average: 30.0 ± 4.1 °C) while peak wet bulb temperature was 22.2 °C (average: 15.3 ± 1.1 °C).

Table 1. Road construction participant characteristics (n = 7).

Variables	Mean ± SD	Range (min to max)
Age (y)	39 ± 14	23 to 57
Height (cm)	169 ± 6	161 to 179
Weight (kg)	86.1 ± 25.4	65.3 to 140.6
BMI (kg/m²)	30 ± 9	22 to 49
Systolic BP (mm Hg)	130 ± 8	120 to 138
Diastolic BP (mm Hg)	83 ± 3	80 to 90

Note: BMI, body mass index; BP, blood pressure; max, maximum; min, minimum.

RH peaked at 50.4% during the first hour, but decreased throughout the day (average: 24.4 ± 8.3%).

Two workers (29%) reached a Tcore >38.0 °C (Fig. 1B), while none surpassed 38.5 °C. Heat gradients for Tcore and Tskin throughout the workday are shown in Fig. 1C and E. Average Tcore was highest prior to lunch (Fig. 1D), when workers were finishing pouring concrete. Tskin increased continuously throughout the day (Fig. 1F), and peak values were 36.71 ± 0.62 °C. Hydration measured via USG slightly increased from pre- (1.020 ± 0.01) to post-shift (1.024 ± 0.01). Notably, 4 workers (57%) began work in a dehydrated state (USG >1.020) (Cheuvront et al. 2010). Four workers were also dehydrated post-shift, 3 of which were the same individuals as pre-shift. Both workers who surpassed a Tcore of 38.0 °C were adequately hydrated pre-shift and one was dehydrated post-shift. There was a percent body weight loss of 0.9 ± 1.0%, but no workers lost >2.0% (American College of Sports Medicine et al. 2007).

Discussion

To our knowledge, this is the first study to document Tcore during hot summer conditions in road construction workers. This study offers novel insight into heat strain, finding that nearly 1/3 of workers reached a peak Tcore exceeding the 38.0 °C threshold recommended for non-heat acclimatized workers, (ACGIH 2017) while none surpassed the threshold for acclimatized workers (38.5 °C). Although we did not assess acclimatization status, we assume workers were heat acclimatized based on their history of daily outdoor work throughout the summer. Thus, even workers who surpassed 38.0 °C were likely not at high risk for heat-related illness. The sensation of heat and initiation of thermoregulatory responses are induced by changes in Tskin, (Romanovsky 2014) which we observed to increase linearly throughout the workday.

Due to a combination of hot environmental conditions and high workload, the construction industry has the second highest risk of heat-related death, with a yearly fatality rate of 1.1 per 1 000 000 workers (Gubernot et al. 2015). In this study, ~71% of the workday was in the "warning" risk category for risk of heat-related illness (OSHA 2022). The worksite was in the southwest United States, an area with high solar radiation and low humidity. Reaching a dry bulb temperature of 36.5 °C, the heat stress in this study was lower than other Southwest locations, such as Phoenix which is regularly greater than 43 °C during summer (Chow et al. 2012). Lack of radiation measurement likely underestimated heat stress, as direct sunlight increases heat stress and reduces work capacity (Foster et al. 2022; OSHA n.d.). Tcore closely mirrored work intensity, plateauing during the latter half of the day despite increasingly hot environmental conditions. Similar findings have been shown by McKenna et al. (2023) who demonstrated that Brazilian sugarcane cutters experienced an abrupt rise in Tcore at the beginning of work, followed by a plateau. High work intensity is a risk factor for hyperthermia and heat-related illness (Park et al. 2017). Work-to-rest schedules are often implemented to decrease metabolic heat production and mitigate the risk of heat-related illness (Jacklitsch et al. 2016). It was unclear if rest periods were intentionally planned every 2 h, or whether physically demanding tasks were purposefully distributed during the cooler parts of the day.

Dehydration increases the risk of heat-related illness by altering thermoregulation and increasing cardiovascular strain (Périard et al. 2021). Our findings suggest that road construction workers may report for work somewhat dehydrated, without dehydrating much further during the workday. It seems that the access to water and ad libitum drinking were sufficient to maintain hydration, suggesting that water should be easily accessible, and workers should be encouraged to hydrate adequately before starting work.

As a pilot study, a limitation was the small sample size. Additionally, body weight measurements being conducted with clothing on may have underestimated change in body weight due to the absorption of sweat by clothing. Behavior patterns by workers may have also changed knowing they were monitored,

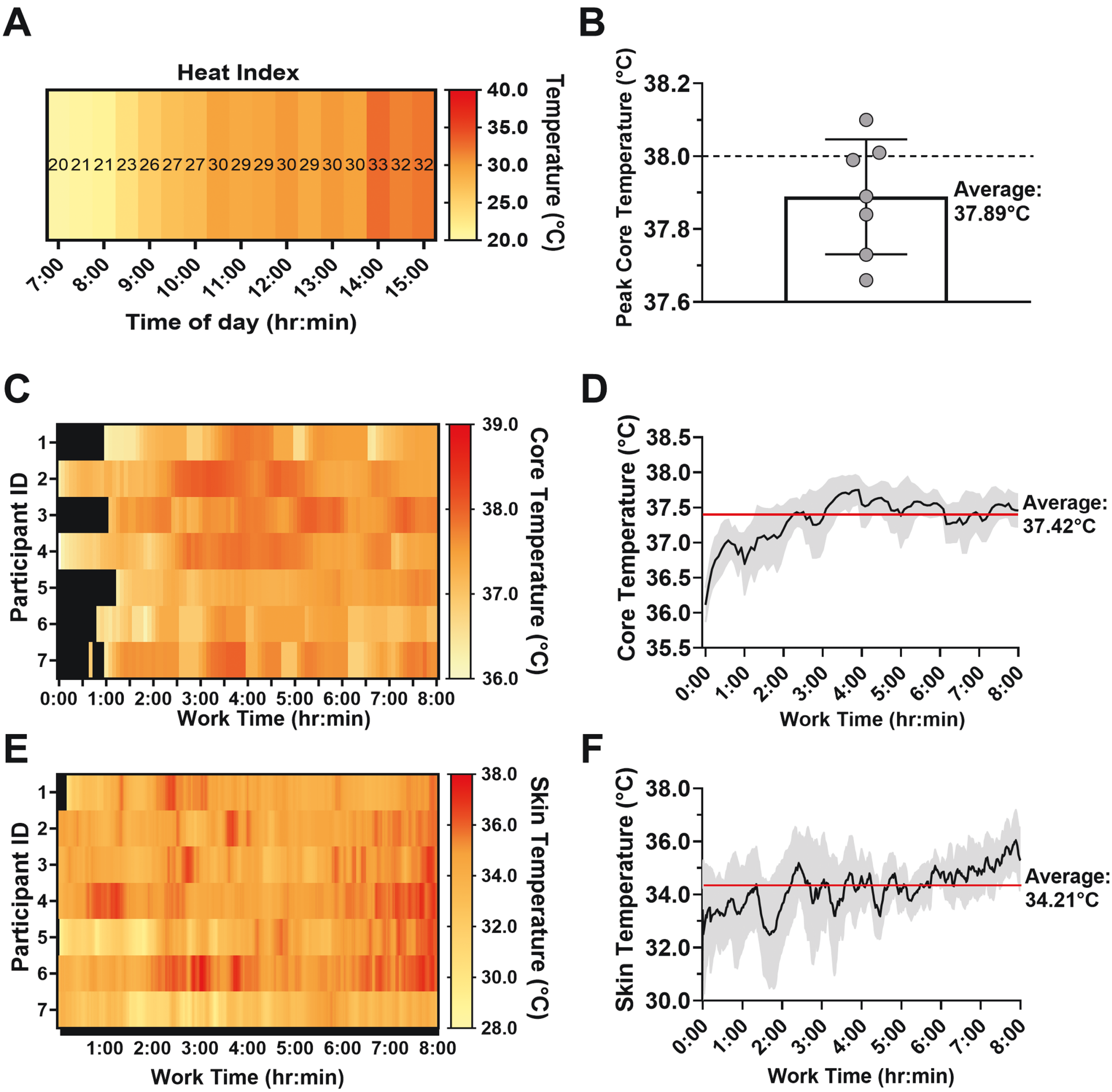

Fig. 1. (A) Heat gradient of HI reported as the 30-min average for each variable. (B) Individual peak core temperature is reported as individual data and mean ± SD, with a dashed line at the recommended threshold for non-heat acclimatized workers. (C) Heat gradient of core temperature, throughout the work shift for all participants, and (D) average core temperature (black line) ± SD (gray shaded area) throughout a work shift. (E) Heat gradient of skin temperature, throughout the work shift for all participants, and (F) average skin temperature (black line) ± SD (gray shaded area) throughout a work shift (N = 7). Figure was created using GraphPad Prism 9.4 (GraphPad Software Inc., La Jolla, CA, USA).

potentially impacting findings. Future research on a larger scale and a wider variety of workers is warranted to further quantify work-related heat strain, explore cooling strategies, and evaluate risk factors for heat-related illness such as age, metabolic rate, and heat acclimatization.

Conclusions

Our preliminary results demonstrate that some road construction workers experience moderate heat strain during summer work in a hot environment. Additionally, we found that around half of the workers began their workday in a dehydrated state, indicating that hydration advice may be necessary to improve worker safety in the heat.

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Conflict of interest statement.

ZJS has received consultant fees from Otsuka Holdings Co., Ltd.

Data availability

The data that support the findings of this study are available from the corresponding author, JWS, upon reasonable request.

References

ACGIH. 2017. Heat stress, TLVs and BEIs: threshold limit values for chemical substances and physical agents & biological exposure indices. Cincinnati, OH, USA: ACGIH.

American College of Sports Medicine, Sawka MN, Burke LM, Eichner ER, Maughan RJ, Montain SJ, Stachenfeld NS. 2007. American College of Sports Medicine position stand. Exercise and fluid replacement. Med Sci Sports Exerc. 39:377–390. https://doi.org/10.1249/mss.0b013e31802ca597

Baral P, Koirala MP. 2022. Assessment of safety and health practices in road construction. OJSST. 12:85–95. https://doi.org/10.4236/ojsst.2022.124008

Burstyn I, Kromhout H, Boffetta P. 2000. Literature review of levels and determinants of exposure to potential carcinogens and other agents in the road construction industry. AIHAJ. 61:715–726. https://doi.org/10.1080/15298660008984582

Calvache Ruales MF, Westerhausen S, Zapata Gallo HA, Strehl B, Naza Guzman SD, Versteeg H, Stöppelmann W, Wittlich M. 2022. UVR exposure and prevention of street construction workers in Colombia and Germany. Int J Environ Res Public Health. 19:7259. https://doi.org/10.3390/ijerph19127259

Cheuvront SN, Ely BR, Kenefick RW, Sawka MN. 2010. Biological variation and diagnostic accuracy of dehydration assessment markers. Am J Clin Nutr. 92:565–573. https://doi.org/10.3945/ajcn.2010.29490

Chow WTL, Chuang W-C, Gober P. 2012. Vulnerability to extreme heat in metropolitan phoenix: spatial, temporal, and demographic dimensions. Prof Geogr. 64:286–302. https://doi.org/10.1080/00330124.2011.600225

Foster J, Smallcombe JW, Hodder S, Jay O, Flouris AD, Nybo L, Havenith G. 2022. Quantifying the impact of heat on human physical work capacity; part III: the impact of solar radiation varies with air temperature, humidity, and clothing coverage. Int J Biometeorol. 66:175–188. https://doi.org/10.1007/s00484-021-02205-x

Gao C, Kuklane K, Östergren P-O, Kjellstrom T. 2018. Occupational heat stress assessment and protective strategies in the context of climate change. Int J Biometeorol. 62:359–371. https://doi.org/10.1007/s00484-017-1352-y

Glitz KJ, Seibel U, Rohde U, Gorges W, Witzki A, Piekarski C, Leyk D. 2015. Reducing heat stress under thermal insulation in protective clothing: microclimate cooling by a 'physiological' method. Ergonomics. 58:1461–1469. https://doi.org/10.1080/00140139.2015.1013574

Gubernot DM, Anderson GB, Hunting KL. 2015. 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. 58:203–211. https://doi.org/10.1002/ajim.22381

Ioannou LG, Gkikas G, Mantzios K, Tsoutsoubi L, Flouris AD. 2021. Risk assessment for heat stress during work and leisure. Toxicological risk assessment and multi-system health impacts from exposure. Amsterdam, Netherlands: Elsevier. p. 373–385. ISBN 978-0-323-85215-9.

Jacklitsch B, Williams J, Musolin K, Coca A, Kim J-H, Turner N. 2016. Criteria for a recommended standard: occupational exposure to heat and hot environments. Cincinnati, OH, USA: NIOSH.

Lucas RAI, Epstein Y, Kjellstrom T. 2014. Excessive occupational heat exposure: a significant ergonomic challenge and health risk for current and future workers. Extrem Physiol Med. 3:14. https://doi.org/10.1186/2046-7648-3-14

McKenna ZJ, Nava RC, Magalhães C, Magalhães de Castro F, Machado Moreira C, Shibuya E, da Cunha I, Maia PA, Cauduro Roscani R, Rocha-Vieira E, et al. 2023. A comprehensive evaluation of heat stress and heat strain in a sample of sugarcane cutters in Brazil. J Appl Physiol (1985). 135:1431–1439. https://doi.org/10.1152/japplphysiol.00555.2023

Meerding WJ, IJzelenberg W, Koopmanschap MA, Severens JL, Burdorf A. 2005. Health problems lead to considerable productivity loss at work among workers with high physical load jobs. J Clin Epidemiol. 58:517–523. https://doi.org/10.1016/j.jclinepi.2004.06.016

OSHA. 2022. Temporary worker initiative: Exposure to outdoor and indoor heat-related hazards. https://www.osha.gov/sites/default/files/publications/OSHA4185.pdf. Accessed February 14, 2024.

OSHA. n.d. Heat—heat hazard recognition. https://www.osha.gov/heat-exposure/hazards. Accessed February 14, 2024.

Park J, Kim Y, Oh I. 2017. Factors affecting heat-related diseases in outdoor workers exposed to extreme heat. Annal Occup Environ Med. 29:30. https://doi.org/10.1186/s40557-017-0183-y

Périard JD, Eijsvogels TMH, Daanen HAM. 2021. Exercise under heat stress: thermoregulation, hydration, performance implications, and mitigation strategies. Physiol Rev. 101:1873–1979. https://doi.org/10.1152/physrev.00038.2020

Roja Z, Kalkis V, Vain A, Kalkis H, Eglite M. 2006. Assessment of skeletal muscle fatigue of road maintenance workers based on heart rate monitoring and myotonometry. J Occup Med Toxicol. 1:20. https://doi.org/10.1186/1745-6673-1-20

Romanovsky AA. 2014. Skin temperature: its role in thermoregulation. Acta Physiol (Oxf). 210:498–507. https://doi.org/10.1111/apha.12231