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Assessing the Validity of Aural Thermometry for Measuring Internal Temperature in Patients With Exertional Heat Stroke

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Context: The use of aural thermometry as a method for accurately measuring internal temperature has been questioned. No researchers have examined whether aural thermometry can accurately measure internal body temperature in patients with exertional heat stroke (EHS).

Objective: To examine the effectiveness of aural thermometry as an alternative to the criterion standard of rectal thermometry in patients with and those without EHS.

Design: Cross-sectional study.

Setting: An 11.3-km road race.

Patients or Other Participants: A total of 49 patients with EHS (15 men [age = 38 ± 17 years], 11 women [age = 28 ± 10 years]) and 23 individuals without EHS (10 men [age = 62 ± 17 years], 13 women [age = 45 ± 14 years]) who were triaged to the finish-line medical tent for suspected EHS.

Main Outcome Measure(s): Rectal and aural temperatures were obtained on arrival at the medical tent for patients with and those without EHS and at 8.3 ± 5.2 minutes into EHS treatment (cold-water immersion) for patients with EHS.

Results: The mean difference between temperatures measured using rectal and aural thermometers in patients with EHS at medical tent admission was 2.4°C ± 0.96°C (4.3°F ± 1.7°F; mean rectal temperature = 41.1°C ± 0.8°C [106.1°F ± 1.4°F]; mean aural temperature = 38.8°C ± 1.1°C [101.8°F ± 2.0°F]). Rectal and aural temperatures during cold-water immersion in patients with EHS were 40.4°C ± 1.0°C (104.6°F ± 1.8°F) and 38.0°C ± 1.2°C (100.3°F ± 2.2°F), respectively. Rectal and aural temperatures for patients without EHS at medical tent admission were 38.8°C ± 0.87°C (101.9°F ± 1.6°F) and 37.2°C ± 1.0°C (99.1°F ± 1.8°F), respectively.

Conclusions: Aural thermometry is not an accurate method of diagnosing EHS and should not be used as an alternative to rectal thermometry. Using aural thermometry to diagnosis EHS can result in catastrophic outcomes, such as long-term sequelae or fatality.

Key Words: exertional heat illness, body temperature, hyperthermia, exercise, heat

Key Points

- Aural thermometry is not an accurate method for diagnosing exertional heat stroke (EHS) and should not be used as an alternative to rectal thermometry.
- Using aural thermometry to diagnosis EHS can result in catastrophic outcomes.
- Corrective factors to account for differences in rectal and aural temperature should not be used in an attempt to diagnose EHS via an alternative method.
- Health care professionals responsible for the care of patients with suspected EHS must be educated on the importance and accuracy of rectal thermometry as the criterion standard for assessing internal temperature.

Exertional heat stroke (EHS) is a life-threatening condition characterized by an internal temperature ≥40°C (104°F) accompanied by central nervous system dysfunction.[1–3] In athletic, occupational, and military settings, EHS most often occurs in warm environmental conditions during intense physical activity, in which the body's thermoregulatory system is unable to dissipate the metabolic heat that is generated, which has been termed *uncompensable heat stress*.[4,5] Researchers[1,6] have estimated that approximately 9000 high school athletes are treated annually for exertional heat illnesses in the United States; therefore, health care professionals must be aware of the importance of accurate and rapid recognition, assessment, and treatment of patients with EHS.

When a patient collapses, the clinician's differential diagnoses may include several conditions, including traumatic head injury, hyponatremia, diabetic emergency, hemorrhage, or EHS.[7] To accurately treat the patient, an accurate diagnosis of the condition is imperative.[1,7,8] Fortunately, EHS is the only condition that is characterized by an internal body temperature of ≥40°C.[1] Therefore, an accurate and valid method for measuring temperature is critical to ensure proper diagnosis and subsequent treatment.[1,7,8] If an inaccurate or invalid temperature is obtained, clinicians will not know if they are treating the correct injury or illness. In the case of EHS, if the actual temperature is >40°C and, thus, rapid cooling is indicated, but the invalid internal temperature measurement is <40°C, the patient may not receive the aggressive cooling needed. The reverse is also possible. If the patient's temperature is measured at >40°C, cooling may be started; however, the patient may not have EHS, and cooling may not be the appropriate treatment for the correct diagnosis. Death due to EHS is 100% preventable with proper recognition and care.[1] As such, if clinicians do not obtain accurate and valid internal temperatures to aid in the differential diagnosis, catastrophic outcomes are likely.

When a patient is suspected of having EHS, rectal thermometry is the criterion standard method for assessing internal temperature.[1,8–12] Rectal thermometry is a quick and valid measurement that accurately indicates whether the patient has EHS. Despite the method's validity and reliability,[9] many health care clinicians do not perform rectal thermometry in patients with suspected EHS because of its invasiveness and stigma.[13,14] In a cross-sectional survey examining EHS management strategies implemented by high school athletic trainers (ATs), Kerr et al[13] found that of 225 ATs who treated patients with EHS, only 0.9% (n = 2) used rectal thermometry to assess hyperthermia. Approximately 50% (n = 113) used other thermometry methods.[13] Although researchers continue to suggest increased compliance over time with the use of rectal thermometry,[13,14] athletes continue to die of EHS.[15]

Claims that other temperature assessments, such as aural (ear canal, infrared tympanic) thermometry, are appropriate alternatives to rectal thermometry are not supported by empirical evidence. In fact, investigators[9–11] have shown that aural thermometry is an invalid measure of internal temperature when individuals exercise in the heat. Although temperature measured in the ear using commercially available devices is commonly referred to as *tympanic* or *infrared tympanic temperature*, the device does not actually touch the tympanic membrane. It represents the temperature within the ear canal or uses an infrared system to estimate tympanic temperature. In this study, we refer to temperature obtained from the ear as *aural temperature*. In 2 recent studies,[16,17] authors suggested that aural thermometry could be used as an alternative to rectal thermometry. Although Otani et al[16] proposed that aural temperature was acceptable for monitoring core temperature during exercise in the heat when solar radiation was ≤500 W/m^2, their research was performed in a laboratory-controlled environment with simulated radiation, and the average internal temperature of participants appeared to be <39°C. Therefore, health care professionals should not interpret this conclusion to support the use of an aural thermometer in clinical settings (when attempting to diagnose possible EHS), as these specific conditions are unlikely to be present. Additionally, in 2017, Fogt et al[17] concluded that tympanic (aural) and temporal devices could be used as alternatives to internal temperature devices (eg, gastrointestinal temperature devices) for individuals exercising in a hot, humid environment. First, the average gastrointestinal temperature of participants at the end of the exercise was 38.3°C ± 1.0°C, which is considered a low internal temperature for an examination of exercise-induced hyperthermia. Second, the authors indicated that a mean difference of 1.9°C between gastrointestinal temperature and tympanic (aural) temperature was acceptable. However, a valid device is characterized as one that provides an internal temperature reading within ±0.27°C (±0.5°F) of rectal thermometry or other valid devices, such as gastrointestinal or esophageal thermometry.[11] Furthermore, a difference of 1.9°C (3.42°F) could be the difference between accurately and inaccurately diagnosing EHS in a patient. For example, if a patient's temperature reads 38°C via an aural thermometer when the internal temperature is actually 40°C, the clinician will misdiagnose EHS based on the invalid temperature assessment.

To determine whether aural temperature can be used as an alternative to rectal temperature in patients with suspected EHS, we must examine the relationship between aural and rectal temperatures in patients with EHS. Therefore, the primary purpose of our investigation was to determine the effectiveness of aural thermometry as an alternative to the criterion standard of rectal thermometry in patients with EHS. To measure this, we examined whether (1) aural thermometry accurately measured internal temperature for correctly diagnosing EHS at medical tent admission and (2) aural thermometry accurately measured internal temperature during treatment (ie, cooling) in patients with EHS. As a secondary objective, we characterized the relationship between aural and rectal temperatures in patients who were suspected of having EHS at medical tent admission but did not meet the rectal temperature criterion specified for the Falmouth Road Race. These patients had hyperthermia (37°C–39.99°C). We hypothesized that aural thermometry measurements would result in misdiagnosis via underestimation of internal temperature and would not be associated with rectal thermometry measurements.

METHODS

Study Design

We assessed patients with and those without EHS at the Falmouth Road Race (11.3-km race) in Falmouth, Massachusetts, on August 18, 2019. All patients in this investigation had been triaged to the finish-line medical tent. Permission to use the patients' medical record data for research purposes was granted by the University of Connecticut-Storrs Institutional Review Board, which concluded that informed consent was not required. The environmental conditions during the race were temperature of 27.0°C ± 2.8°C and relative humidity of 75.5% ± 12% (wet bulb globe temperature = 27.5°C ± 1.8°C), which was obtained from an environmental monitoring device (model Kestrel 5400; Nielsen-Kellerman Co, Boothwyn, PA) located at the finish-line medical tent.

Diagnosis and Treatment of EHS

Runners who presented to the medical tent with signs and symptoms of EHS (eg, altered mental status, collapse, altered gait) were transported to the triage area. Medical volunteers obtained an initial rectal temperature using a digital thermometer (model 690; Welch Allyn, Skaneateles Falls, NY) that was inserted approximately 7 to 10 cm past the anal sphincter. As the thermometer was inserted, aural temperature was also obtained. Aural temperature was collected using a thermometer (model Pro 6400; Braun, Kronberg, Germany) according to the manufacturer's

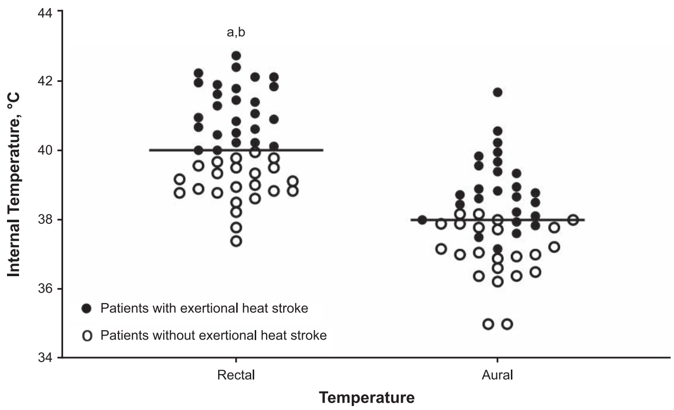

Figure 1. Rectal and aural temperatures at medical tent admission. [a] Indicates a difference from aural temperature in patients with exertional heat stroke (*P* < .001). [b] Indicates a difference from aural temperature in patients without exertional heat stroke (*P* < .001).

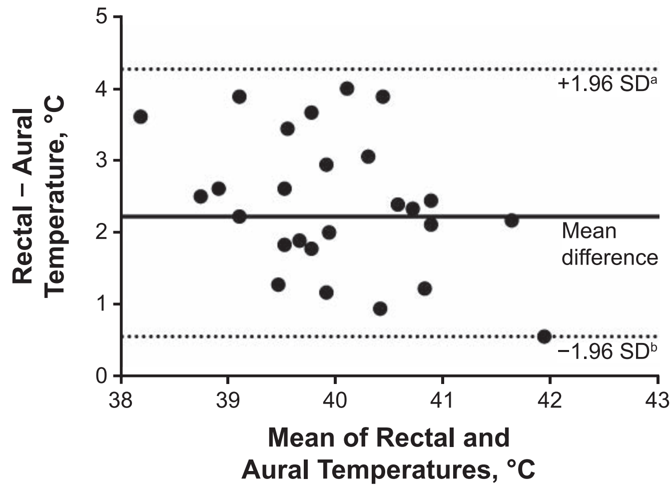

Figure 2. EHS Patients at Recognition. Bland-Altman plot indicating limits of agreement (dashed lines) and mean bias (bold line) in rectal and aural temperatures at medical tent admission in patients with exertional heat stroke. Rectal thermometry was set as the referent. [a] Calculated as mean difference + (1.96 × SD). [b] Calculated as mean difference − (1.96 × SD).

instructions. The Braun Pro 6400 thermometer is designed to read the infrared energy emitted by the tympanic membrane and surrounding tissues to determine the person's temperature. Patients with rectal temperatures <40°C (non-EHS group) were sent to the recovery area and provided with cold towels for less aggressive cooling. If EHS was confirmed (≥40°C and central nervous system dysfunction; EHS group), a rectal thermistor (model DataTherm II; Geratherm Medical AG, Geschwenda, Germany) was inserted 15 cm past the anal sphincter for continuous monitoring during EHS treatment. The thermometer was replaced with the thermistor for EHS treatment because the thermometer is inflexible and cannot continuously monitor rectal temperature or be submerged in ice water. Immediately after thermistor insertion, patients were transported to and immersed in a 50-gallon (190-L) cold-water immersion tub. Ice was continuously added to the tub to maintain a water temperature of approximately 50°F (10°C). Rectal temperature was continuously monitored during EHS treatment, and patients were removed from the ice bath when rectal temperature decreased to 38.88°C. Aural temperature was assessed at 1 time point within 15 minutes of starting EHS treatment (8.3 ± 5.2 minutes). Exertional heat illness was diagnosed in 49 patients (EHS group = 26, non-EHS group = 23) at the finish-line medical tent.

Statistical Analyses

We analyzed the data collected at medical tent admission (initial temperature) and during EHS treatment (cooling). Dependent *t* tests were performed to identify differences between rectal and aural temperatures, with the α level set at .05. The limits of agreement (mean difference ± 1.96 × standard deviation) and mean bias between the measurement devices were assessed using Bland-Altman plots. Rectal thermometry was set as the referent. Rectal and aural temperatures within ±0.27°C (±0.5°F) were deemed clinically acceptable and valid.[11] Statistical analyses were conducted using SPSS (version 26; IBM Corp, Armonk, NY).

RESULTS

Internal Temperature at Medical Tent Admission

Exertional Heat-Stroke Group. Exertional heat stroke was diagnosed in 15 men (age = 38 ± 17 years) and 11 women (age = 28 ± 10 years). Their average rectal and aural temperatures at medical tent admission were 41.1°C ± 0.8°C (106.1°F ± 1.4°F) and 38.8°C ± 1.1°C (101.8°F ± 2.0°F), respectively (Figure 1). Rectal temperature was greater than aural temperature ($t_{25} = 12.47$, $P < .001$). The Bland-Altman plot showed that the limits of agreement were 0.52°C and 4.28°C and the mean bias between devices was 2.4°C ± 0.96°C (Figure 2).

Non-EHS Group. Ten men (age = 62 ± 17 years) and 13 women (age = 45 ± 14 years) were characterized as patients without EHS. The rectal and aural temperatures for these patients at medical tent admission were 38.8°C ± 0.87°C (101.9°F ± 1.6°F) and 37.2°C ± 1.0°C (99.1°F ± 1.8°F), respectively ($t_{22} = 13.21$, $P < .001$; Figure 1). The Bland-Altman plot showed that the limits of agreement were 0.29°C and 2.91°C and the mean bias between devices was 1.6°C ± 0.67°C (Figure 3).

Internal Temperature During EHS Treatment

Rectal and aural temperatures during EHS treatment (cold-water immersion) in the EHS group (n = 22) were 40.4°C ± 1.0°C (104.6°F ± 1.8°F) and 38.0°C ± 1.2°C (100.3°F ± 2.2°F), respectively (Figure 4). Rectal temperature was higher than aural temperature during EHS treatment ($t_{22} = 11.24$, $P < .001$). Treatment data were not collected for 4 patients with EHS due to logistical constraints. The Bland-Altman plot showed that the limits of agreement were 0.44°C and 4.36°C and the mean bias between devices was 2.4°C ± 1.0°C (Figure 5).

DISCUSSION

We are the first to examine whether aural thermometry can be used to appropriately diagnose EHS in patients with

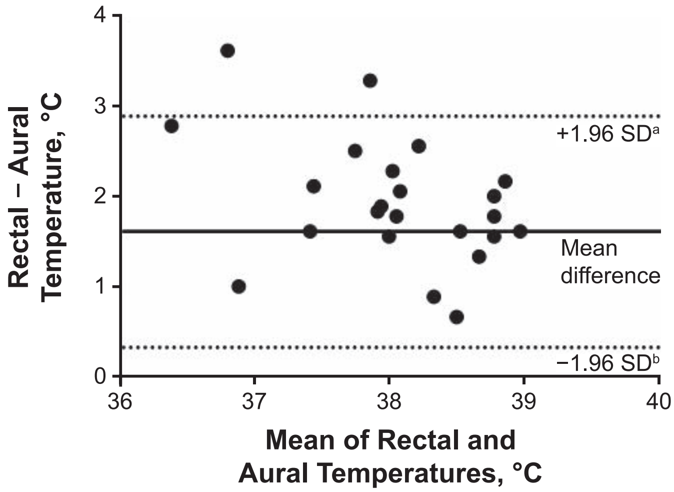

Figure 3. NonEHS Patients and Recognition. Bland-Altman plot indicating limits of agreement (dashed lines) and mean bias (bold line) in rectal and aural temperatures at medical tent admission in patients without exertional heat stroke. Rectal thermometry was set as the referent. [a] Calculated as mean difference + (1.96 × SD). [b] Calculated as mean difference − (1.96 × SD).

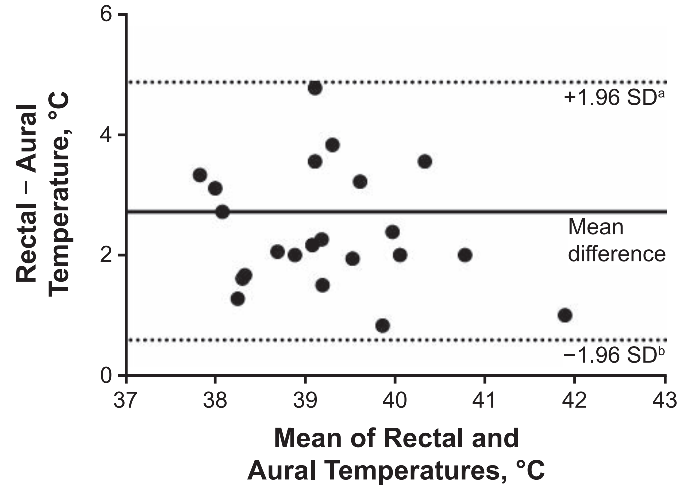

Figure 5. EHS Patients During Treatment. Bland-Altman plot indicating limits of agreement (dashed lines) and mean bias (bold line) in rectal and aural temperatures in patients with exertional heat stroke during treatment (cold-water immersion). Rectal thermometry was set as the referent. [a] Calculated as mean difference + (1.96 × SD). [b] Calculated as mean difference − (1.96 × SD).

suspected cases. Whereas authors of previous studies have identified the lack of validity in aural temperature as it relates to rectal temperature in patients with hyperthermia, to our knowledge, we are the first to evaluate the validity of aural temperature in patients with EHS. Aural temperature was approximately 2.4°C (4.3°F) lower than the criterion standard assessment of rectal temperature in patients with EHS at medical tent admission. A corrective factor (ie, adding a certain value to aural temperature to "estimate" internal temperature) is strongly discouraged because of the level of disagreement between the measures. Of note, only 3 of the 26 patients in the EHS group had aural temperatures >40°C (Figure 1). Similarly, compared with rectal temperature, aural temperature was consistently lower in the EHS group during cooling (mean difference = 2.4°C [4.3°F]) and in the non-EHS group (mean difference = 1.6°C [2.8°F]). Therefore, our results provide strong evidence to suggest that aural thermometry is not a viable method for diagnosing EHS or monitoring internal temperature during EHS treatment. Health care professionals should not use aural thermometry as an alternative to rectal thermometry.

Our findings are similar to those of other investigators[9,10] who examined the validity of aural temperature in exercising individuals with hyperthermia. In a meta-analysis, Huggins et al[10] evaluated 9 articles that compared mean differences in internal temperature via aural and rectal thermometry in exercising individuals with hyperthermia. The pooled weighted mean difference between aural and rectal temperatures during exercise was 0.97°C (1.72°F), whereas we identified a mean difference of 2.4°C (4.3°F). The variances between the meta-analysis[10] and our study should continue to raise concern about the validity and variability between aural and rectal temperatures. Huggins et al also noted that the discrepancy between temperature devices increased as the internal temperature obtained through rectal thermometry increased.[10] The greatest difference between assessments occurred when rectal temperature was >39°C, with a mean difference of 1.7°C (3.06°F) between devices.[10] Similarly, we observed that the mean difference between devices in the non-EHS group was 1.6°C (2.8°F), which was 0.8°C lower than in the EHS group. Additionally, we saw no change in the mean difference between devices at medical tent admission and during treatment in the EHS group (2.4°C). This finding is not surprising, given that rectal temperature was similar at both time points (41.1°C and 40.4°C, respectively). It is also not surprising that Otani et al[16] and Fogt et al[17] demonstrated correlations between rectal and aural thermometry, given that all of their participants had average internal temperatures <39°C. It is critically important to obtain a valid measure of internal temperature as rectal

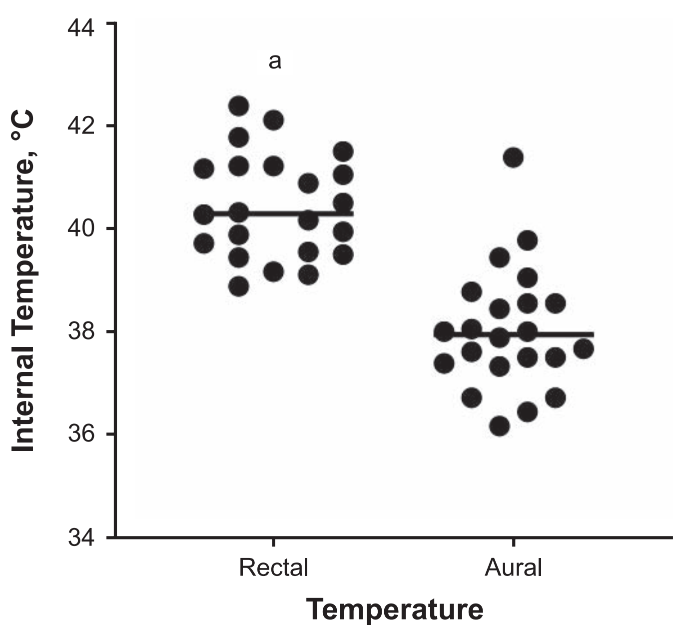

Figure 4. Rectal and aural temperatures in patients with exertional heat stroke during treatment (cold-water immersion). [a] Indicates a difference from aural temperature ($P < .001$).

temperature exceeds 40°C (104°F) to prevent the misdiagnosis of EHS, which could have fatal results. Therefore, in our study, a mean difference of 2.4°C between devices in the EHS group was an extremely large discrepancy and indicated that aural thermometry was not an appropriate alternative to rectal thermometry.

Health care professionals must recognize that corrective factors cannot be used to account for differences in internal temperature between rectal and aural thermometry. In other words, health care professionals cannot assess internal temperature via aural temperature and add a corrective factor of 2.4°C (4.3°F). Not only is it necessary to obtain valid temperature assessments at initial EHS diagnosis, but internal temperature must be continuously monitored during EHS treatment.[1] In our study, a discrepancy persisted between rectal and aural temperatures during treatment (2.4°C). The National Athletic Trainers' Association position statement[1] on exertional heat illnesses recommended keeping patients with EHS in the cold-water immersion tub until their internal temperature decreases to 38.88°C (102°F).[18] Without an accurate temperature assessment, patients with EHS are at risk for hypothermia (if cooled too long) or "rebound hyperthermia" after exiting the tub (if not cooled long enough).[19] Exertional heat stroke is 100% survivable with appropriate care, and it is imperative to quickly distinguish EHS from other emergent conditions.[1] Having a valid and accurate assessment of internal temperature, which excludes an estimation of internal temperature using a corrective factor, will prevent EHS fatalities and keep athletes, laborers, and warfighters safe.

Health care professionals responsible for the care of patients with heat-related emergencies must be properly educated on the use of rectal thermometry. Rectal thermometers must be available onsite to avoid EHS fatalities and quickly diagnose and treat patients with EHS. Our results build on evidence that rectal thermometry is the only method for quickly and accurately measuring internal temperature. Other devices, such as aural thermometry, should not be used as surrogates.[8,9,11,12] In athletics, a discrepancy persists between best-practice recommendations and the behaviors of ATs in diagnosing EHS and using rectal thermometers.[1,13,14] Mazerolle et al[14] found that, despite knowing the best practices for EHS recognition, many ATs did not use rectal thermometry and cited invasiveness and lack of appropriate training or equipment as barriers. Although these barriers are perceived to be implacable, educational initiatives must be created to provide strategies for overcoming them. For example, educational initiatives designed to address current health behaviors and common barriers to performing rectal thermometry may facilitate change. Additional approaches include increasing the awareness of physicians, emergency medical services, parents, athletes, and coaches about the importance of rectal thermometry. By increasing awareness across the socioecological framework, we can enhance the overall perception and understanding of exertional heat illnesses, which may lead to increased adoption of best practices for the management of patients with these conditions.[20]

LIMITATIONS

Despite the clinical relevance and numerous strengths of this investigation, certain limitations must be addressed. We decided to obtain medical records from the medical tent in order to examine the differences between the methods used for temperature assessment in a field setting (11.3-km road race). Therefore, the results allow for more applicability to typical on-field or onsite recognition and management of patients with EHS, which differs from laboratory studies that may not be as real-world applicable. However, multiple health care professionals obtained rectal and aural temperatures from patients with suspected EHS, so we were unable to calculate interrater and intrarater reliability. Furthermore, the devices were used in a medical setting, and were unaware if the thermometry devices were calibrated before being used for patients. Despite this, the clinical applicability of our findings cannot be understated. Future researchers should investigate other temperature-monitoring locations, such as oral, axillary, and temporal sites, in patients with EHS to identify if similar trends occur.

CONCLUSIONS

Aural thermometry is not accurate for diagnosing EHS and should not be used as an alternative to rectal thermometry. Using aural thermometry to diagnose EHS can result in catastrophic outcomes, such as long-term sequelae or fatalities. Also, corrective factors to account for differences in rectal and aural temperatures should not be used in an attempt to diagnose EHS via an alternative method. Lastly, health care professionals responsible for the care of patients with suspected EHS must be educated on the importance and accuracy of rectal thermometry as the criterion standard for assessing internal temperature.

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