WORKER PROTECTION

Peer-Reviewed

HEAT STRAIN TECHNOLOGIES

A Practical Model for Implementation & Use

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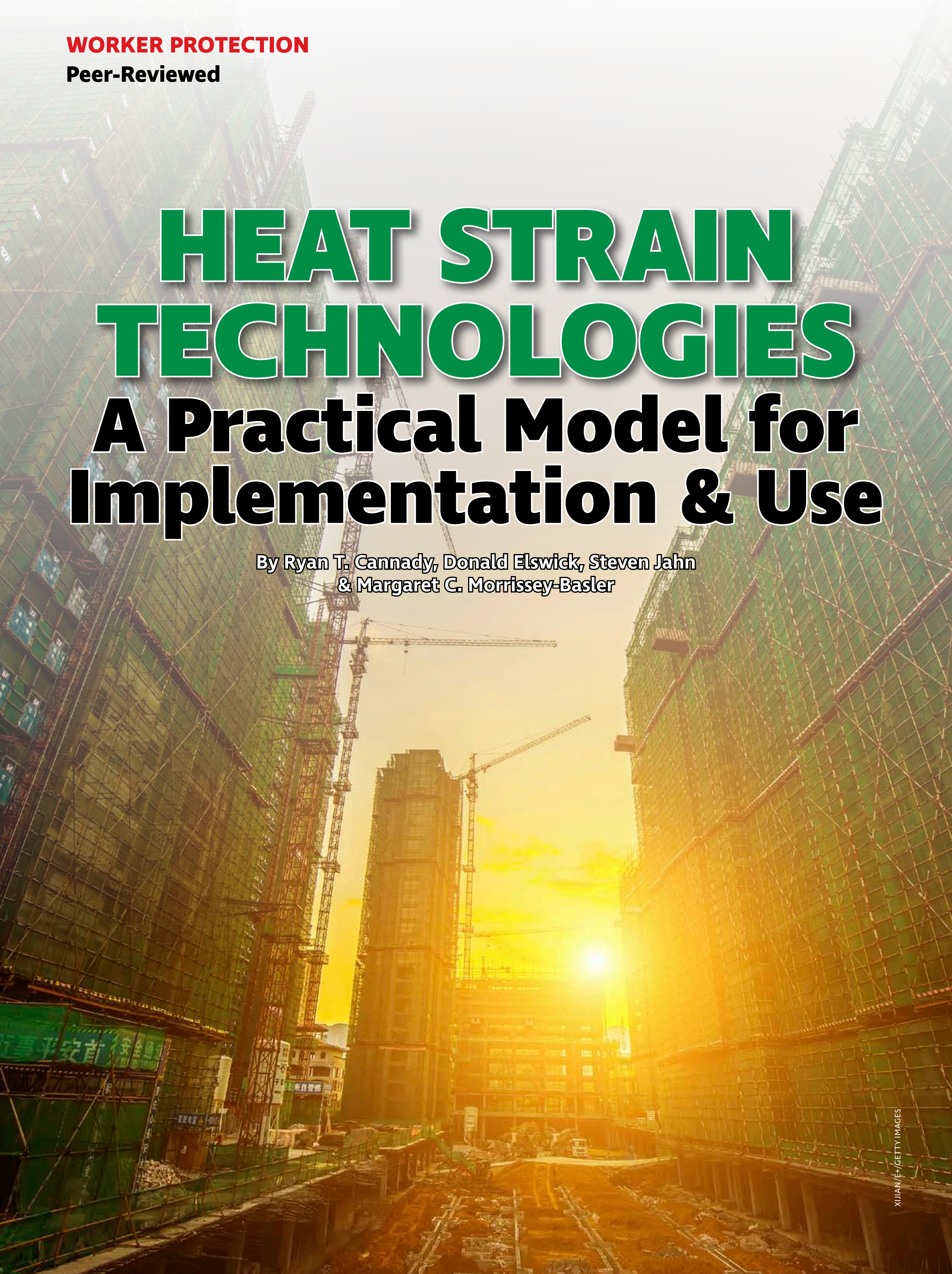

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OCCUPATIONAL HEAT remains a persistent hazard across indoor and outdoor work activities, occurring under various work conditions (OSHA, n.d.). Nearly all industrial sectors in the United States see an increase in work injury risk when the heat index reaches 85 °F, and the odds rise rapidly above 90 °F (Alahmad et al., 2025). If the risks are not mitigated, occupational heat may negatively impact worker productivity (Yi & Chan, 2017) and cognitive performance (Mazlomi et al., 2017), result in traumatic injuries (Spector et al., 2019), and induce chronic health effects such as kidney disease (Chapman et al., 2021). A common approach to mitigating the risk of heat-related work injuries and illnesses is to implement activity modifications through stay times and work-rest allocations (Notley et al., 2025) based on environmental variables (e.g., wet-bulb globe temperature, heat index; Budd, 2008), clothing ensembles and work intensity (Jacklitsch et al., 2016). The combination of these factors determines the recommended work-to-rest allocation to minimize the risk of heat-related injury and illness (ACGIH, 2025). Despite the effectiveness and common use of environmental-based controls in occupational heat risk assessments, several challenges arise when applying them to a worksite (Cannady, 2024). Activity modification strategies that rely solely on environmental monitoring often overlook the variability in physiological responses (e.g., heat strain) to identical heat conditions among workers. Additionally, some high-risk work situations such as working in confined spaces or tasks requiring substantial PPE can impose increased heat load through the combined effects of environmental conditions and exertion. Physiological monitoring of heat strain using heat strain technologies has emerged as a risk-mitigation control in thermal-stress work environments.

Physiological monitoring, primarily focused on collecting vital signs such as heart rate or estimated core body temperature, is gaining traction as a solution for managing occupational heat strain (Notley et al., 2025). As such, physiological monitoring technology is being widely adopted by EHS professionals (NSC, 2024). The use of these monitors provides a means to directly quantify how inter- and intraindividual factors influence heat strain in real time (Notley et al., 2019). Other heat strain technologies that are designed to evaluate hydration status (Rodin et al., 2022; Sreeharsha et al., 2024; Stewart et al., 2023), cognitive impairment (Zhang et al., 2024; Zhu et al., 2025) and biomarker measurements (Notley et al., 2018) have also been explored for managing heat risks. Given the need to mitigate heat-related injuries and illnesses, heat strain technologies have progressed beyond a theoretical solution and now require a deliberate long-term implementation strategy. To the authors' knowledge, guidance for EHS professionals on integrating heat strain technologies into existing heat stress management programs (HSMPs) is limited and understudied.

The purpose of this article is to propose practical, key strategies and a model that EHS professionals can follow when incorporating heat strain technologies into their HSMPs. In this article, "heat strain technologies" is defined as integrated monitoring devices and systems that provide real-time measurements of physiological and cognitive parameters of human performance during heat exposure. This article consolidates the existing research on programmatic implementation and applies these principles to the implementation of heat strain technologies. To address gaps in the literature, the authors propose a logic model for implementing heat strain technologies into HSMPs.

KEY TAKEAWAYS

- **Occupational heat can have negative effects on workers, from decreased productivity and lower cognitive function to injuries and chronic illness.**
- **While environmental monitoring provides employers with an overall sense of heat risks, technologies designed to measure heat strain indicators such as heart rate, core body temperature or hydration status can be used to mitigate the effects of occupational heat on an individual level.**
- **Heat hazards vary by industry and workplace. Technology selection should take into account not just envrionmental conditions but the clothing and PPE used, operational workflows and worker exertion.**
- **This article presents a logic model that outlines the key elements employers should consider when planning to implement a heat-strain technology program, including organizational readiness, technology selection, engaging cybersecurity and information technology departments, communicating the change, and training users.**

Logic Model of Technology Implementation

Organizations funding EHS initiatives expect a clearly defined problem that the initiative will address, a concise description of the approach and a detailed outline of performance indicators (W.K. Kellogg Foundation, 2004). When implementing heat strain technologies, the first step is to select the appropriate device fit for purpose for organizational needs and available resources (AIHA, 2023). Recent research has identified several commercially available devices that are used to assess heat strain (Cannady et al., 2024; Friedrich et al., 2025; Notley et al., 2025). This article outlines a strategic plan for considering heat-strain technology in organizational HSMPs.

As a starting point, the authors developed a logic model (Figure 1, p. 22) that outlines the key elements to consider when planning to incorporate heat-strain technology into HSMPs. Logic models provide a systematic visual representation of the program resources, the planned activities or interventions, and the changes or results (W.K. Kellogg Foundation, 2004). Logic models can also illustrate the relationship between program inputs and outputs, and they often include the program outcomes (Zyromski & Mariani, 2019).

The problem statements in this model focus on how environmental conditions increase the risks of heat-related injury and illnesses and the challenges of implementing physiological monitoring and other heat strain technologies in HSMPs. As a result, EHS professionals need a comprehensive guideline to address these challenges and ensure long-term programmatic sustainability and regulatory compliance. The goal for this guideline is to reduce heat strain, minimize heat-related injury and illnesses, enhance operational efficiency and increase workforce awareness of heat-related risks.

Once the technology is selected, the suggested next step is to engage organizational cybersecurity and information technology departments to ensure secure integration, which is discussed later in this article. Continuing through the logic model, many commercially available devices offer pilot testing or trials, which is suggested as an initial activity to gain user acceptance and feedback. A methodological framework has been developed for conducting qualitative focus groups to gather key considerations and perceptions on heat-related technology (Cannady et al., 2025). Following these activities, effectiveness reviews that evaluate the pilot study, worker feedback and the current program are critical for refining implementation.

These activities provide the foundation for establishing internal operating procedures and workforce training materials. The final activity before complete implementation is worker training and communication. Before authorizing full implementation, organizations should communicate guidelines, internal operating procedures, and training to ensure understanding and alignment with expectations. Together, these activities build a comprehensive implementation strategy that supports sustainable use of heat strain technologies.

Organizational Readiness, Programmatic Development & Implementation

Within the proposed logic model, programmatic development supports the organization in the practical implementation of heat strain technologies. Successfully incorporating heat strain technologies into an organizational structure requires more than device procurement. It also depends on organizational readiness, management and stakeholder coordination, operational workflows, and continuous evaluation. These elements must be outlined as core components of EHS management systems and are foundational to effective heat stress management programs (ACGIH, 2025; Glaser et al., 2022). Given the frequent learning curve among stakeholders and barriers to success, a deliberate implementation process must be fully understood before effectiveness can be demonstrated (Glaser et al., 2022).

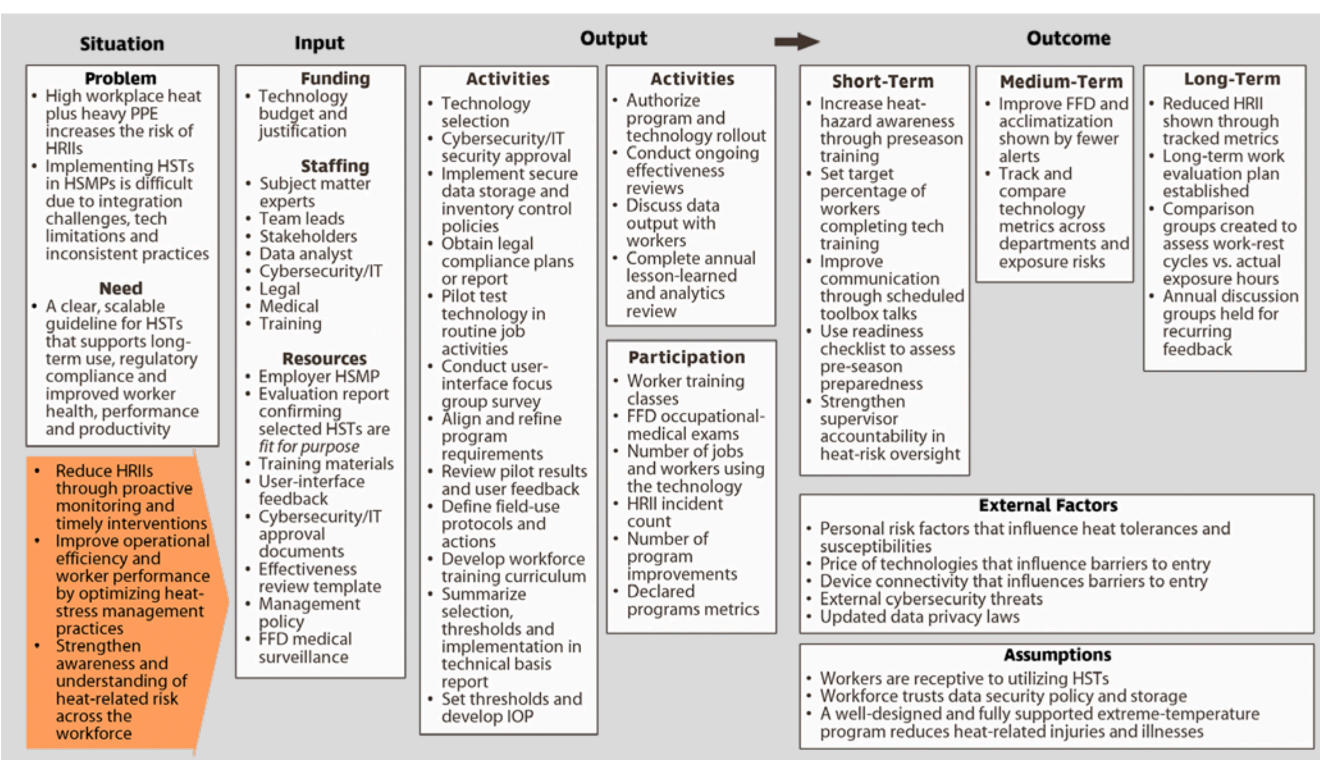
Management, Organizational Readiness & Communication Strategy

Management establishes the strategic, cultural and communication conditions necessary for organizational preparedness when adopting heat strain technologies. Senior leaders must formally recognize occupational heat as a material risk and allocate sufficient financial, technical and personnel resources to support technology acquisition, pilot testing, training, continued use and long-term maintenance. Communication strategies should also include routine reporting of program metrics related to conformance and accountability for responding to technology prompts (e.g., alerts, vibrations). Regular communication reinforces program intent, supports transparency and trust, addresses misinformation, and prompts uniform implementation across workgroups and shifts. Without visible executive endorsement and clear communication, wearable and physiological monitoring programs risk being perceived as optional or punitive rather than preventive.

Hazard Evaluation & Training

Heat strain technologies should augment, not replace, traditional hazard identification and assessment methods

FIGURE 1
HEAT STRAIN TECHNOLOGY IMPLEMENTATION LOGIC MODEL



Abbreviations: HRII = heat-related injury and illness; HST = heat strain technology; HSMP = heat stress management program; IT = information technology; FFD = fitness for duty; IOP = internal operating procedure

used in heat stress environments. Existing controls including occupational heat evaluations, environmental monitoring, engineering controls and work-rest schedules should remain in place, while heat strain technologies are used as supplemental controls when traditional approaches are impractical or infeasible. Examples of heat stress environments include construction, emergency response operations, radiological environments and nuclear operations, and foundry operations, where the nature of the work inherently requires use of supplemental PPE for non-heat hazards. These environments require a worker-centric approach. Organizations must clearly define how heat strain technologies integrate with environmental monitoring, job hazard analyses, work intensity classifications and clothing adjustments to ensure that they function as a decision-support tool rather than a standalone exposure determinant that replaces existing controls (ACGIH, 2025; Notley et al., 2019).

Specific training that formally qualifies personnel may be needed to configure the technology to meet the company's objectives for monitoring worker heat strain. Depending on the organization, these trainings may look different for users, supervisors, management and support personnel. Training programs must address both technical and operational competencies of these technologies. Workers need to understand the existing heat stress controls while being educated on the purpose of heat stress technology, limitations, alert meanings and expected responses. Support and oversight personnel must understand the software use, data interpretation, connectivity troubleshooting, response escalation and documentation requirements. Training should emphasize that devices are preventive tools designed to protect health, not performance management tools. The training should also explain that these preventive tools are an option alongside other traditional heat stress controls. Refresher training and competency verification are recommended as technologies and protocols evolve.

Stakeholder Participation & Continuous Improvement

Stakeholder participation is essential for acceptance, effectiveness and ethical implementation. Workers should be engaged early through pilot testing, focus groups and feedback mechanisms that allow concerns regarding comfort, usability, privacy and perceived fairness to be addressed. Participation reinforces trust, sustains implementation and usage, improves adherence to response protocols, and supports continuous improvement by refining thresholds, training materials and response actions (Cannady et al., 2025; Schall et al., 2018). Involving all stakeholders at the beginning—including those wearing the monitor, supervisors overseeing those wearing the monitor, support personnel overseeing the data in real time, and medical personnel reviewing the data—enables feedback for continuous improvement cycles. This engagement is necessary at the start of heat stress technologies implementation in HSMPs.

Selecting Heat Strain Technologies

Many conventional hierarchies of control cannot feasibly be applied to heat stress conditions because of logistical, cultural and financial barriers, or because they offer limited effectiveness (Notley et al., 2025). Heat strain technologies used as heat-related controls have been shown to balance worker health and productivity (Cannady, 2024). Wearable monitoring devices are used to provide timely, continuous, individualized monitoring in risk assessments and decision-making (AIHA, 2024). The individual physiological responses offer an opportunity to assess the level of heat strain present in the workforce, control exposures and assess the effectiveness of implemented controls (ACGIH, 2025). However, adopting physiological monitoring systems and other devices to assess heat strain comes with several considerations, challenges, limitations and weaknesses (AIHA, 2024; Notley et al., 2025).

When selecting these devices, a safety professional should consider cost, user acceptance and performance measurements such as data reliability, validity, sensitivity and specificity before procurement and implementation (AIHA, 2024). Heat strain technologies commonly measure physiological variables such as estimated core body temperature, heart rate, hydration status and sweat concentration to assess heat strain (AIHA, 2024). By continuously monitoring physiological indicators, the technology allows for personalized heat-related prevention strategies and individual feedback on the risk of heat-related illness (Friedrich et al., 2025). Other heat strain technologies can also indicate physiological and cognitive strain. Hydration technologies have proven to be a strong contender to reduce the likelihood of a worker experiencing an injury from heat stress (Stewart et al., 2023). Wearable electrochemical or optical sensors have the potential for real-time perspiration monitoring (Rodin et al., 2022). Additional heat strain indicators may be monitored through sensor-based safety helmets (Sharma et al., 2022), photoplethysmograms (PPGs) evaluating the volume of blood circulation (Kimball et al., 2022; Notley et al., 2025), and devices that detect cellular changes in the interstitial fluids and saliva (Notley et al., 2025).

Selecting an appropriate technology for heat strain, whether focused on physiological monitoring, hydration, cognitive monitoring or other biomarkers, should begin by deliberately identifying the organizational needs and systemic problems that require solutions. If proposed solutions surpass the rest as fit-for-purpose, then procurement and preliminary testing can commence. For instance, if an EHS professional observes several cases of heat exhaustion during hotter months, physiological monitoring may be the most appropriate tool for prevention purposes. If further analysis reveals that dehydration specifically is a recurring issue among workers, organizations may also incorporate a device that can indicate dehydration risks. Selecting a device that aligns with organizational needs and available resources is essential for long-term operational sustainability. The use of real-time detection systems requires well-documented, thoughtful decisions that confirm the surveillance objectives and clearly identify organizational needs, ensuring appropriate deliberation when selecting devices.

Implementation Barriers & Sustainability

Cyber & Information Security

Previous analyses have shown mixed results regarding worker concerns over data ownership and privacy related to wearable technologies (Cannady et al., 2025; Schall et al., 2018; Spook et al., 2019). Despite potential concerns, limited research exists on technological infrastructure considerations for heat strain technologies. AIHA (2024) recommends consulting allied professions' resources on the legal aspects of data management, privacy and security protocols. However, much of this literature concludes a lack of scientific consensus and indicates risks associated with how technologies are managed (Dunmire, 2024; Scheid et al., 2023). Even with an unclear path, organizations should establish a robust technological infrastructure to maintain data protection, privacy and security. Many risks can be mitigated through developing best management practices, internal policies and consensus protocols guided by the best available evidence, combined with adherence to the established requirements (Dunmire, 2024). These considerations enable a secure data management process by following the best available resources.

Data management is a critical component of heat strain technologies (AIHA, 2024). Integrated heat strain technologies can generate substantial data, and the data flow often relies on cloud-centric frameworks. Cloud services have transformed risk from a localized operational concern into a global governance imperative (Faruq, 2024). As such, a key best practice when selecting a technology involves evaluating whether the technology complies with cloud assurance standards and frameworks such as ISO/IEC 27001, SOC 2 Type 1 security certification, FedRAMP and C5-Cloud Computing Compliance Controls Catalog (Di Giulio et al., 2017; Hegde et al., 2024). These assurance standards and frameworks provide a strategy for cloud security assessments and data protection.

In summary, heat strain technologies rely on digital infrastructure that introduces cybersecurity, data protection and governance considerations extending beyond traditional occupational health programs. The integration of wearable devices, mobile applications and cloud-based analytics necessitates collaboration between safety, information technology, legal and cybersecurity functions.

Ethical & Legal Considerations

Beyond technical feasibility, the ethical and legal implications of heat strain technologies must be explicitly addressed to ensure lawful, equitable and ethical deployment. There is little in the way of a summation of the ethical and legal considerations that must be studied in a disciplined, organized manner. Since the hierarchy of controls for occupational hazards often relies on organizational feasibility and trade-offs, ethical considerations must balance practical implications in risk tolerance and remain flexible in managing occupational heat (Swanepoel, 2025).

Industrial Hygiene Exposure Records, Monitoring Data & Medical Records

A critical distinction exists between industrial hygiene exposure records, industrial hygiene monitoring and medical records data. How technology is intended to be used establishes whether a wearable sensor is a defined medical device or contributes to a medical system (Ravizza et al., 2019). The regulatory threshold considers a product a medical device if it is intended to diagnose, cure, mitigate, treat or prevent a disease (FDA, 2022). Heat strain technology serves as a risk indicator and safety monitoring device; it does not diagnose a heat-related illness or injury (Pizzani, 2024). Within this intended use, these technologies align with the U.S. Food and Drug Administration's (FDA, 2019) general wellness product declaration, establishing that such technology helps reduce the risk or impact of certain diseases or conditions. Considering the nuanced legal jargon, EHS professionals must clearly delineate this boundary to avoid unintentionally creating regulated medical surveillance obligations or violating health privacy expectations. Within this context, heat strain technologies remain focused on physiological indicators that may or may not result in the risk of heat-related disease (Pizzani, 2024) and rely on the manufacturers of the technology to provide clear messaging regarding how to interpret the data (Scheid et al., 2023). Therefore, programmatic documentation should emphasize heat strain prevention rather than determining individual health status. Additionally, such documents should bear a signature from senior management with properly invested authorities.

Fitness-for-Duty Considerations, Legal Risks & Antidiscrimination Guardrails

In general, occupational medical monitoring programs consist of three categories: worker wellness programs, medical monitoring for illness prevention and fitness-for-duty determinations (Dunmire, 2024). As noted, physiological indicators generated by heat strain technologies may inform decisions but must be used cautiously for fitness for duty. When using informative physiological indicators, employers must consider the antidiscrimination protections governing the use of age, gender and health status when setting job restrictions. Reliance on FDA legal documents and manufacturer use terms places an unrealistic burden on EHS professionals to stay informed about the legal nuances regarding wearable technology (Schumann & Doherty, 2024). Organizations should avoid establishing rigid exclusion criteria based solely on physiological thresholds without clinical evaluation or contextual assessment. Within occupational programs, explicit safeguards can prevent discrimination based on age, health status or physiological variability. Physiological monitoring data should trigger preventive interventions (e.g., rest, hydration, task modification) rather than disciplinary actions. These thresholds and response actions should be uniformly applied, job-related and consistent with legitimate safety objectives.

Legal and ethical risks emerge when workers are discriminated against based on genetic factors or exposome (Pizzani, 2023). When using heat-strain technologies, particularly those that utilize PPG sensors, several sources of bias can exist related to genetic factors (e.g., sex, skin tone, body height) and exposome (e.g., body mass index, scars, tattoos, cardiovascular disease, medications; Mühlen et al., 2021). Policies and guidelines should be implemented cautiously in these circumstances. Such considerations should manage heat-strain susceptibility as a dynamic of risk rather than prevent certain workers from performing their job functions (Pizzani, 2023).

Daily individual variability plays a considerable role when using heat strain technologies. For instance, several biases and limitations may arise when using PPG sensors on dehydrated individuals (Porto et al., 2023), individuals with varying skin tones (Colvonen et al., 2020), workers taking medications (e.g., beta blockers) that affect perfusion and autonomic tone (Bent et al., 2020), workers with hormonal fluctuations (Sides et al., 2023), those who smoke cigarettes (NHLBI, 2022), and those who drink alcohol (Piano, 2017). Such variability introduces confounding factors that may limit the ability of some workers to use these devices effectively. Consequently, heat-strain technologies may not be suitable for all workers, making it necessary to provide an alternative pathway for those who cannot rely on this approach. In cases where a worker may require work accommodation, organizations should follow established processes rather than attempt ad hoc interpretations of physiological data.

Field Data Interpretation

Heat-strain risk assessment frameworks that use technology potentially enhance HSMPs in specific areas related to heat strain safety management, prevention practices, safety training and safety planning (Ojha, 2022). Heat strain technology is intended to warn personnel when they approach dangerous levels of heat exposure (MIT Lincoln Laboratory, 2024). Such monitoring technologies facilitate a proactive approach to safety, which also differentiates from traditional methods of periodic

TABLE 1

EXAMPLE WORKFLOW FOR PHYSIOLOGICAL MONITORING DATA

<table>
<tr><th>Worker symptoms</th><th colspan="3">Heat strain indication metric</th><th>Response action(s)</th></tr>
<tr><td>Heat strain indicator from measured prework HR</td><td colspan="3">Prework HR should be at or below 100 BPM.</td><td>If prework HR is greater than 100 BPM:
• Have worker rest for 5 min.
• Recheck HR.
If still greater than 100 BPM:
• Avoid or postpone work.
• Worker informs supervisor.
• Supervisor considers whether medical evaluation is needed.</td></tr>
<tr><td rowspan="3">Heat strain indicator from measured sustained HR based on the selected guideline</td><td>Sustained working threshold</td><td>180 – age</td><td>75% HR max</td><td rowspan="3">If sustained working HR exceeds recommended threshold:
• Reduce physical exertion (lower intensity or shorten duration).
• Monitor for recovery.
• Remove from heat exposure.
If HR does not recover:
• Move worker to shade or cool area.
• Provide hydration.
• Monitor for heat-related illness.
• Worker informs supervisor; medical consultation may be needed.</td></tr>
<tr><td>Peak working threshold</td><td>95% HR max</td><td>95% of 208 – (0.7 • age)</td></tr>
<tr><td colspan="3">Sustained heart rate (5 min) is measured as the instantaneous heart rate and should not exceed the selected quantitative metric of BPM for the given individual.

HR max is defined as 220 – age and used as a peak value.</td></tr>
<tr><td>Heat strain indicator from measured recovery HR</td><td colspan="3">The recovery heart rate at 1 min after cessation of peak work effort should be at or below 120 BPM.</td><td>If recovery heart rate at 1 min is greater than 120 BPM:
• Rest for 1 min.
• Recheck.
If still greater than 120 BPM:
• Remove from heat exposure.
• Move worker to shaded, cool area.
• Provide hydration.
• Monitor for heat-related illness.</td></tr>
<tr><td>Heat strain indicator from measured prework eCBT</td><td colspan="3">Prework estimated body temperature should be at or below 100.4 °F. This temperature is an indirect indication of body core temperature before initiating the scope associated with heat stress hazards.</td><td>If prework eCBT is greater than 100.4 °F:
• Have worker rest 5 min.
• Recheck temperature.
If still greater than 100.4 °F:
• Notify supervision.
• Rest in cool or shaded space.
• Provide hydration.</td></tr>
<tr><td>Heat strain indicator from measured eCBT</td><td colspan="3">eCBT should be at or below 101.3 °F. This temperature is an indication of indirect body core temperature associated with metabolic load from work exertion.</td><td>If working eCBT is greater than 101.3 °F:
• Immediately stop heat exposure.
• Move to shaded, cool environment.
• Provide hydration.
• Monitor for heat-related illness.</td></tr>
</table>

Abbreviations: HR = heart rate; BPM = beats per minute; eCBT = estimated core body temperature

health assessments or reactive interventions (Handayani et al., 2025). When proactively using real-time heat strain technologies, organizations need a structured operational workflow to mitigate heat-related risks.

An operational workflow enables a decision logic to frame how data is collected, monitored, interpreted, communicated and acted upon. Integrating a decision logic into an HSMP can facilitate actionable steps that lead to timely intervention controls. Organizational policies and procedures can outline a framework that incorporates a decision logic, working thresholds, alerts, indicators, response actions and escalation triggers.

Table 1 (p. 25) outlines a suggested operational workflow for implementing physiological monitoring and response actions for the device thresholds for healthy, hydrated, acclimated workers with increased ability to tolerate heat stress. This includes a protocol for evaluating a worker's fitness for duty (prework metrics), sustained physiological metrics (heart rate and estimated core body temperature), and normal physiological responses dedicated to dissipating excess heat (recovery heart rate). Current guidelines for physiological monitoring of heat strain focus on signs and symptoms related to sustained heart rate and measured or estimated core body temperature (ACGIH, 2025) for healthy individuals with normal cardiac responses. Many commercially available technologies monitor these signs and symptoms (Cannady et al., 2024; Friedrich et al., 2025; Notley et al., 2025).

The protocol focuses on heat strain technology that monitors heart rate or estimated core body temperature. Although no published works have clearly defined "sustained" in terms of physiological measurements, the protocol in this article incorporates a 5-min threshold. This threshold integrates professional judgment and ongoing field evaluation rather than acting on a transient peak in physiological exertion. The protocol uses relevant literature on exercise science (Tagliati et al., 2021; Tanaka et al., 2001) and the ACGIH threshold limit values (ACGIH, 2025).

Healthy individuals rely on a constant exchange of heat between the body and the environment (Jacklitsch et al., 2016). Without this normal rate of exchange, excessive heat strain may result (ACGIH, 2025). The proposed protocol illustrates controls for maintaining individual thermal equilibrium through an alert-to-action operational workflow for healthy, hydrated workers.

It is essential to select a heat strain indicator that best suits the organizational job activities and workers. Although a commonly used threshold is a heart rate that measures 180 beats per minute minus the individual's age in years for healthy individuals with a normal cardiac response (ACGIH, 2025), other performance-based metrics (Marx et al., 2018; Tanaka et al., 2001) may better suit the organization's job tasks. In the proposed protocol, 75% of maximum heart rate was selected as a threshold because it falls within the moderate-intensity zone and corresponds to aerobic-level effort (Marx et al., 2018). Further, this protocol incorporates 95% of the maximum heart rate as an upper threshold to account for a decision-making margin. Table 2 illustrates how these alternative sustained heart rate thresholds can be applied for a 40-year-old worker.

Data Review

An effective implementation of heat strain technologies requires that the data be transformed into actionable and useful information for decision-making (AIHA, 2024). As such, employers should conduct ongoing analysis, at least annually, to evaluate program effectiveness, identify opportunities for improvement and track whether the program achieved its goals (OSHA, 2016). The reviews can draw on various analytical measures that reflect proactive and retrospective indications of prevention and reduction performance (Wurzelbacher & Jin, 2011).

Heat-related policy development and application are still novel topical areas that need further guidelines (Khorshid & Song, 2025). As policies are implemented, deliberate strategies that promote learning from program experience, including reflective practices and course correction, can positively influence sustainability and continuous improvement (Fleiszer et al., 2015). Such strategies incorporate real-time and retrospective analytics that identify trends, assist with incident evaluations,

TABLE 2
USING SUSTAINED & PEAK THRESHOLDS AS HEAT STRAIN INDICATORS

<table>
<tr><td>Sustained working threshold</td><td>180 – age</td><td>75% HR max</td></tr>
<tr><td>Peak working threshold</td><td>95% HR max</td><td>95% of 208 – (0.7 • age)</td></tr>
<tr><td colspan="3">Sustained HR (5 min) is measured as the instantaneous HR and should not exceed the selected quantitative metric of BPM for the given individual.

HR max is defined as 220 – age and used as a peak value.</td></tr>
<tr><td>Sustained HR threshold for a 40-year-old in BPM</td><td>180 – age
180 – 40 = 140</td><td>75% of 220 – age
0.75 • (220 – 40) = 135</td></tr>
<tr><td>Peak HR threshold for a 40-year-old in BPM</td><td>220 – age
0.95 • (220 – 40) = 171</td><td>208 – (0.7 • 40) = 180
0.95 • (180) = 171</td></tr>
</table>

Abbreviations: HR = heart rate; BPM = beats per minute

assess high-risk activities or organizational groups, and initiate potential interventions to mitigate heat-related risks. Annual data analyses and opportunities for improvement should be documented within formal reporting structures to illustrate how observed trends relate to program objectives.

Context in Practice

As noted, heat strain technologies are intended to complement, not replace, traditional heat stress controls. Although general implementation considerations are important across industries, the operational role, frequency of use and decision-making applications of these technologies may vary depending on work activities, environmental conditions and organizational objectives. Some industries may routinely rely on technologies, while others may implement them only during elevated heat conditions, high-exertion tasks or PPE-intensive operations. The following examples illustrate how organizations may operationalize the proposed logic model across different work environments and operational scenarios.

Construction

Construction activities such as roofing, paving, utility or concrete work involve intense environmental conditions resulting from radiant heat exposure, metabolic demands and varying worker acclimatization challenges. These dynamic environments may present challenges outside of controls driven by environmental monitoring assessments (e.g., work-rest regimen). Heat strain technologies can provide personal indicators to complement existing controls and support supervisory decisions regarding allowance for continued work, recovery periods, hydration and task rotation. Successful implementation relies on a clear communication strategy regarding the technology's purpose, trigger thresholds for use, and worker training on alert recognition and response.

Emergency Response Operations

Emergency response, HazMat, firefighting and storm response operations routinely involve fully encapsulating PPE, increased exertion rates, prolonged work durations, remote environments and rapidly changing environmental conditions that limit the ability to use traditional heat stress controls. In such settings, worker-centric heat strain technologies support operational decision-making regarding recovery practices, worker rotation, hydration interventions, cooling mechanisms or worker removal from operations. Implementation considerations should specifically focus on predefined escalation protocols, such as those outlined in Tables 1 and 2; stakeholder education and training; and operational workflows that support immediate field usage and accessibility.

High Radiological or Nuclear Operations

High radiological and nuclear operations often involve layered protective clothing without clearly defined clothing adjustment factors. For example, radiological work activities may require permeable and encapsulating clothing ensembles combined with glove layers and respiratory protection. These work activities may also restrict access to hydration and cooling stations due to competing workplace hazards and operational constraints intended to minimize time spent in controlled areas. Heat strain technologies can assist in identifying early physiological strain while supporting other hazard exposure controls. Organizations should establish clear governance regarding cybersecurity, data interpretation, supervisory response actions, and continuous review strategies to refine implementation protocols over time.

Foundry Operations

The foundry industry routinely works in conditions of intense radiant heat exposure, excessive ambient temperature and high-exertional activities near process equipment. While facilities may incorporate engineering controls, such as climate-controlled pulpits or control rooms, workers may still experience prolonged heat exposure during tasks within the melting shop, casting facilities and cold or hot mill molding operations. Organizations should focus on establishing protocols for when to implement heat strain technologies to complement existing controls. Worker training and periodic evaluations should be conducted to educate the workplace about the hazards and ensure continuous improvement when operations evolve or change.

Conclusion

Heat strain technologies are emerging as a widely adopted administrative control for mitigating heat-related injuries and illnesses. This article presents a relevant logic model for EHS professionals to follow when implementing heat strain technology. This model considers the various considerations of implementing and using heat-strain technologies for healthy, hydrated and acclimated workers. The article further develops a protocol that EHS professionals can incorporate when using the technologies and appropriate response actions. These considerations stitch together the barriers and key strategies that emerge when deploying such technologies. This novel model and outline provide a technical foundation that supports EHS professionals implementing heat strain control measures. **PSJ**

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