

Bulletin n°37

Veille thermique

Période : mai 2026

Objectifs :

L'INRS est de plus en plus sollicité sur des questions concernant les activités en entreprise par forte chaleur : les activités en extérieur, l'été en période de canicule, mais aussi les activités en intérieur, dans des lieux aux conditions thermiques extrêmes. L'objectif de cette veille est de se tenir informé sur ces thématiques, dans une période où la problématique thermique croît avec les changements climatiques.

La bibliographie extraite de la base de données INRS-Biblio, permet la consultation des ressources en version PDF.

Les liens mentionnés dans le bulletin donnent accès aux documents sous réserve d'un abonnement à la ressource.

La validation des informations fournies (exactitude, fiabilité, pertinence par rapport aux principes de prévention, etc.) est du ressort des auteurs des articles signalés dans la veille. Les informations ne sont pas le reflet de la position de l'INRS.

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INRS-Biblio

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Travail par forte chaleur : anticiper pour mieux prévenir.

INRS. IC Audiovisuel - Paroles d'experts. 2026. p. 00:2:46.

<https://www.inrs.fr/media.html?refINRS=Anim-518>

Travailler en période de forte chaleur expose à des risques pour la santé (déshydratation, crampes voire coup de chaleur) ainsi qu'à des risques d'accidents. Il est important de ne pas attendre que la chaleur s'installe pour évaluer les risques dans son entreprise et prévoir des mesures de prévention. L'anticipation est la clé d'une démarche de prévention efficace.

EPI, matériaux protecteurs/réchauffants

Y. C. Bi, L. F. Zhu, M. T. Xu, Q. Sun, J. H. Jiang, L. Hong, W. F. Lu and H. L. Tu.

Personalized thermal injury prediction exposed to radiant thermal source: A numerical study focusing on skin burns.

CASE STUDIES IN THERMAL ENGINEERING. 2026;81.

<https://doi.org/10.1016/j.csite.2026.107965>

This study aims to develop a numerical model for predicting thermal injury and temperature due to radiation heat, specifically considering individual physiological variations. The model integrates a multi-layer thermal protective fabric (TPF) system with an enhanced Pennes bioheat transfer model, incorporating age-, gender- and segment-specific skin parameters (thickness, perfusion and metabolism). The results reveal significant individual variations in thermal response. Advancing age significantly elevates burn risk, with second degree burn times in the 60-70 age group being 27.1 % shorter than that in the 20-30 age group. Gender disparities are pronounced, as females experience second degree burns 20 s earlier than males, and uniquely suffer third degree burns under medium/long exposures when males remain unharmed. Extremities are more vulnerable than the trunk, with arms and legs reaching burn thresholds 37.4 % and 34.6 % faster than the trunk, reflecting regional differences in blood flow and tissue composition. These findings provide a scientific basis for quantifying individual burn risk and formulating more effective safety regulations.

N. K. Memis, S. Kaplan and N. K. Kinaytürk.

Structural Optimization of Radiative Cooling Nanocomposite Films for Clothing Applications.

POLYMERS FOR ADVANCED TECHNOLOGIES. 2026;37(5).

<https://doi.org/10.1002/pat.70619>

Passive radiative cooling structures that combine enhanced solar reflectivity and higher emissivity have recently drawn attention. However, achieving efficient cooling performance critically depends on the structural optimization of both material composition and fabrication parameters. Herein, randomly distributed micro-nano porous polyvinylidene fluoride (PVDF) nanocomposite films (PVDF-ZnO) including zinc oxide (ZnO) nanoparticles were fabricated through non-solvent induced phase separation (NIPS) method. A comprehensive optimization was carried out about film thickness, particle diameter, and concentration to obtain the necessary heterogeneous porous nanocomposite structure enabling enhanced mid-infrared emissivity and solar reflectivity for passive cooling performance. Besides standard morphological and chemical analyses, emissivity and reflectivity characteristics were measured by FT-IR and UV-VIS-NIR spectrophotometers with integrating spheres, respectively. Direct passive cooling performances were measured, and cooling power calculations were conducted under both simulated and real-life conditions by a hotplate system including lamp and outdoor measurements in turn. Results demonstrate that ZnO incorporation within the porous film enhanced both emissivity (up to 94%) and reflectivity (up to 94%) for all production parameters. Accordingly, the maximum passive cooling performance was obtained for the nanocomposite film having 30 nm, 20% ZnO and 600 μ m thickness according to hotplate test results compared to their nonporous form (7.73 degrees C), bare skin (9.2 degrees C), and cotton fabric (9.62 degrees C). For the real-life conditions, PVDF-90ZnO20_400 had the maximum cooling performance; namely 17.1 degrees C and 16.1 degrees C under cloudy and sunny weather, respectively. The optimized nanocomposite structures gave promising

results from a scalable production approach, making them ideal candidates for various clothing applications.

Maladies liées à la chaleur

G. Maistrello, K. Sykes, L. Xu, A. Adams and C. Et.

Foresight study on the occupational safety and health implications of future climate change-related developments and crises.

<https://osha.europa.eu/en/publications/foresight-study-climate-change-implications-osh>

Report. Bilbao (Espagne): European Agency for Safety and Health at Work (EU-OSHA); 2026. p. ill., bibliogr., 72.

Cette étude prospective, commandée par l'EU-OSHA, examine les effets indirects et en cascade du changement climatique sur la santé et sécurité au travail (SST) ainsi que sur l'avenir du travail en Europe au cours des 10 à 25 prochaines années. S'appuyant sur une méthodologie fondée sur des scénarios, cette étude combine une analyse documentaire préliminaire, une enquête auprès des parties prenantes et des ateliers d'experts. Quatre scénarios d'avenir plausibles sont élaborés afin de mettre en lumière les mécanismes complexes par lesquels le changement climatique pourrait remodeler les marchés du travail, les fonctions professionnelles et les risques sur le lieu de travail. Les conclusions soulignent que l'action climatique, bien qu'essentielle pour lutter contre le changement climatique, introduit de nouveaux défis et opportunités pour la SST, et qu'une main-d'œuvre en bonne santé et résiliente est essentielle pour parvenir à une transition verte juste. Le rapport examine des thèmes transversaux, définit les principaux objectifs pour 2050 et analyse les compromis et les implications pertinents pour les décideurs politiques, les employeurs et les représentants des travailleurs, les organisations intermédiaires, les travailleurs et les chercheurs. Il souligne l'importance de stratégies coordonnées, inclusives et adaptatives pour protéger la santé, la sécurité et le bien-être des travailleurs en Europe.

J. Wälde, G. Amesberger, S. Würth, M. Reichert and T. Finkenzerler.

Heat stress impacts affective processes and risk-taking behaviour.

Scientific Reports. 2026;16(1):16721.

<https://doi.org/10.1038/s41598-026-47250-x>

The understanding of heat stress on human behaviour is critical due to increasing frequency of extreme heat events. Heat stress has been shown to detrimentally alter affective states and cognition, effects that are particularly critical for individuals exposed to heat conditions such as firefighters, medical personnel, and athletes. Therefore, this study examined how heat stress, exercise, and wearing firefighter protective gear interact to influence affect and decision-making. A sample of 36 healthy young males was assigned to either a passive, combined or heat-stress-free group. Subjective perceptions of vitality, fatigue, thermal comfort and sensation were assessed, controlling for body core-, skin temperature, relative humidity in the jacket, and heart rate. Additionally, participants performed the Balloon Analogue Risk Task and the Beads Task. Linear mixed models revealed that passive heat stress increased fatigue, whereas vitality was not directly sensitive to heat stress. Fatigue and vitality bidirectionally influenced each other independent of heat stress, while thermal perception altered both affective states. Increased risk-taking behaviour was observed under prolonged combined heat stress. No effects on reflection impulsivity were found. Findings highlight differential impacts of heat stress on affective processes that can bias risk-taking behaviour. Particularly under combined heat stress, individuals may be prone to potentially riskier behaviour, insights that should be tested towards ecological validity in future proposals.

A. D. Castellano, R. Puentes, E. Ruiz, I. Y. Rodriguez, V. S. Hertzberg, L. A. McCauley and R. C. Chicas.

Heat-related illness symptoms and mental health in Florida farmworkers.

FRONTIERS IN PUBLIC HEALTH. 2026;14.

<https://doi.org/10.3389/fpubh.2026.1797619>

Background: Farmworkers face disproportionate occupational heat exposure and high rates of heat-related illness (HRI), and emerging evidence suggests associations between heat exposure and adverse mental health outcomes. Objective: This exploratory pilot study aimed to (1) characterize the burden of depression, anxiety, and climate change psychological distress among Florida farmworkers relative to national benchmarks, (2) explore cross-sectional associations between HRI symptoms and mental health outcomes, and (3) examine cross-sectional associations between perceived impacts of Florida Senate Bill 1718 (S.B. 1718) and mental health outcomes. Methods: In July 2024, 53 adult farmworkers (58% female, 42% male) were recruited through the Farmworker Association of Florida (FWAF) in Apopka and Pierson, Florida. Community health workers verbally administered the PHQ-9, GAD-7, CCPD scale, an eight-symptom HRI checklist, and two investigator-developed items on S.B. 1718. Workday heat index was derived from the Florida Automated Weather Network. Analyses included descriptive statistics, Fisher's exact tests, and linear and logistic regression adjusted for age, sex, and agricultural tenure. Results: Moderate-to-severe anxiety, depression, and climate change psychological distress were observed in 21, 25, and 34% of participants, respectively, exceeding U.S. adult and Hispanic-adult benchmarks. Cross-sectional associations were observed between the number of same-day HRI symptoms and each mental health outcome (all $p < 0.05$ unadjusted). Participants reporting feeling discouraged from seeking hospital care due to S.B. 1718 had higher mean PHQ-9 scores than those who did not (6.59 vs. 3.00; $p = 0.008$). Confidence intervals around regression estimates were wide, reflecting sparse-data instability rather than precise effect sizes. Significance: This study addresses an empirical gap at the intersection of occupational heat exposure, immigration policy, and mental health among farmworkers in the southeastern United States. The findings identify mental health as an under recognized dimension of farmworker occupational health and point to the need for integrated approaches that link heat-safety protections, routine mental health screening in community-based settings, and attention to the policy environments that shape healthcare access. Larger, longitudinal studies are needed to confirm these associations and to guide the scale and design of such integrated responses.

C. Yodawara, Y. Iio, H. Ejiri, S. Yamamoto, H. Kozai, M. Tanaka, M. Seguchi and M. Ito.

Heatstroke Awareness and Preventive Behaviors Among Automotive Maintenance Workers in Outdoor Environments: A Cross-Sectional Study in Japan.

HEALTHCARE. 2026;14(10).

<https://doi.org/10.3390/healthcare14101293>

Background/Objectives: Global climate change has increased occupational heat exposure, posing significant risks to outdoor workers. Automotive maintenance workers face high temperatures, radiant heat from machinery, and physically demanding tasks; however, their awareness and preventive behaviors regarding heat-related illness remain insufficiently understood. This study examined heatstroke awareness and preventive behaviors among automotive maintenance workers in Japan. Methods: A cross-sectional web-based survey was conducted among 371 automotive maintenance workers. Self-reported heat-related illness experience was assessed based on subjective judgment without formal medical diagnosis. Associations between heat-related illness experience and behavioral, physical, and health-related factors were analyzed using chi-square tests with Bonferroni

correction and multivariable logistic regression. Results: Approximately 39.6% of participants reported experiencing heat-related illness during summer work. In multivariable analysis, headache (OR: 2.66, 95% CI: 1.25-5.64), dizziness (OR: 2.06, 95% CI: 1.12-3.80), obesity (OR: 1.86, 95% CI: 1.06-3.27), and lower self-perceived health (OR: 2.19, 95% CI: 1.36-3.55) were independently associated with heat-related illness experience. Some preventive behaviors, including wearing cooling garments and frequent hydration, showed associations in the multivariable analysis; however, these findings should be interpreted with caution due to possible reverse causation, small cell sizes, and residual confounding. Conclusions: Behavioral and individual health-related factors, particularly symptom recognition and self-perceived health, are associated with heat-related illness experience among automotive maintenance workers. Interventions focusing on early symptom awareness, risk perception, and self-monitoring may be important components of workplace-based heat illness prevention. Future studies incorporating objective environmental and physiological measurements are needed to clarify causal relationships.

B. Hossain, M. K. Sifullah, N. Ali, I. Hossain, A. A. Nisha and S. Muntaha.

Heatwaves and health vulnerabilities of older informal workers in Dhaka, Bangladesh: A qualitative study.

HEALTH & PLACE. 2026;99.

<https://doi.org/10.1016/j.healthplace.2026.103677>

Climate change has intensified the frequency and severity of heatwaves, posing significant health and economic risks, especially for informal laborers in urban areas of low- and middle-income countries. This study examines the health impacts of heatwaves on older laborers in Dhaka city, Bangladesh, evaluates their adaptation strategies, and proposes context-specific measures to enhance resilience. Employing a reflexive thematic analysis, the research analyzed data from 21 in-depth interviews, 4 key informant interviews, and 2 focus group discussions. Five core themes were identified. Heatwaves have profound physical and psychological effects on older laborers, including dehydration, heat exhaustion, exacerbation of chronic illnesses, anxiety, and fatigue. These health impacts translated into reduced labor productivity, economic instability, and financial stress. While laborers employ a range of informal and culturally embedded coping mechanisms, such as altered work schedules and traditional cooling practices, these strategies are largely insufficient due to pervasive socioeconomic constraints, poor housing conditions, and a lack of institutional support. The study identifies a critical gap in labor policies and public health interventions addressing heat-specific occupational risks, underscoring the urgent need for comprehensive, context-sensitive policy interventions that integrate climate adaptation with occupational health and social protection frameworks.

F. M. Wang, Y. Xu, H. J. Wang, L. Han, X. Shen, Y. C. Zhai, X. Zhang, Z. Liang, B. Hong, P. Ma and Z. Zhao.

Human heat tolerance limits under prolonged exposure to extreme heat.

ENVIRONMENT INTERNATIONAL. 2026;211.

<https://doi.org/10.1016/j.envint.2026.110272>

Extreme heat poses an escalating threat to human health, yet current estimates of human heat tolerance across environmental conditions rely largely on shortcut or predictive approaches rather than direct evidence from prolonged experimental exposure. Here, we exposed 36 unacclimatized healthy young adults to four humid wetbulb temperature (T_w) conditions (32 degrees C, 33 degrees C, 34

degrees C and 35 degrees C) for up to 8 h while performing seated light office work under unrestricted hydration. Core temperature (T_{core}) responses were consistent across different dry-bulb temperature-humidity combinations at the same T_w , confirming the wet-bulb temperature as an effective integrated heat stress index in shaded extreme heat conditions without appreciable radiative sources. Conditions at $T_w = 32-33$ degrees C were compensable, whereas $T_w = 34-35$ degrees C were uncompensable, as evidenced by a clear progressive rise in T_{core} over time. At $T_w = 35$ degrees C, the widely cited upper survival limit, projected tolerance times to life-threatening hyperthermia were 7.1-7.7 h in males and 8.3-8.6 h in females, with females consistently exhibiting slower rates of T_{core} increase. Collectively, these findings provide the first prolonged, stable-exposure experimental characterization of human heat tolerance across $T_w = 32-35$ degrees C and enable psychrometric mapping of time-resolved, sex-specific tolerance limits. These empirical benchmarks constitute a critical empirical resource for refining climate-health projections of extreme humid heat and for validating biophysical models, while also complementing operational heat action plans and early-warning systems that focus on lower, subextreme heat exposures where the majority of heat-related morbidity occurs.

S. De Serres and A. Marchand.

Les répercussions des changements climatiques sur la SST : état des lieux et pistes d'action.

Montréal (Canada): Institut de recherche Robert-Sauvé en santé et en sécurité du travail (IRSST); 2026. p. ill., bibliogr., 76.

<https://pharesst.irsst.qc.ca/expertises-revues/175/>

Ce rapport de l'IRSST dresse un constat alarmant sur les répercussions multidimensionnelles des changements climatiques (CC) sur la santé et la sécurité du travail (SST). Avec une hausse thermique de +1,2 °C, les conditions professionnelles se dégradent, transformant des dangers connus en risques critiques. Le stress thermique est au cœur des préoccupations : il provoque des pathologies graves, de l'épuisement au coup de chaleur mortel, tout en altérant la vigilance, ce qui accroît la fréquence des accidents traumatiques. Sur le plan psychologique, l'intensification des événements météorologiques (inondations, feux de forêt) engendre une détresse émotionnelle et une écoanxiété croissante, particulièrement chez les intervenants de première ligne. Parallèlement, le réchauffement modifie les écosystèmes, favorisant l'expansion de maladies vectorielles comme Lyme ou le virus du Nil occidental, tandis que la dégradation de la qualité de l'air et l'exposition accrue aux UV multiplient les risques de cancers et de troubles cardiopulmonaires. Les secteurs de l'agriculture, de la construction et de la foresterie sont identifiés comme les plus vulnérables en raison de l'effort physique en extérieur. Cette fragilité est exacerbée par des facteurs individuels (âge, santé) ou contextuels, tels que la précarité de l'emploi ou l'usage d'équipements de protection qui entravent la thermorégulation. Le rapport souligne également des interactions toxiques complexes : la chaleur augmente l'absorption cutanée et respiratoire des agents chimiques, aggravant leur nocivité. Face à ces enjeux, l'IRSST appelle à une rupture avec la simple gestion de crise pour instaurer une prévention structurelle intégrée aux politiques publiques. Cela nécessite une approche hiérarchisée privilégiant l'organisation du travail (horaires adaptés, zones ombragées) et l'ingénierie. Enfin, le rapport insiste sur l'urgence de renforcer la recherche multidisciplinaire et la surveillance épidémiologique afin d'ajuster les interventions aux réalités locales et de protéger efficacement les travailleurs les plus exposés dans ce contexte climatique instable.

Outils et capteurs de mesure

Hashimoto, K. Noto, S. Tada and Y. Nishida.

Development of Wearable Multimodal Sensor Probe for Measurement of Core Body Temperature, Heart Rate, and Sweat Rate.

ELECTRICAL ENGINEERING IN JAPAN. 2026;219(2):82-90.

<https://doi.org/10.1002/eej.70031>

Global warming and frequent heatwaves make the prevention of heat-related illness an urgent issue. To avoid dangerous heat stress, monitoring core body temperature, heart rate, and sweat loss is essential. Conventional methods rely on several separate sensors, which reduce practicality in daily life or field use. This study introduces a compact, wearable multimodal sensor probe that can simultaneously measure core body temperature, electrocardiogram (ECG), heart rate, and sweat rate. The device uses a heat flux-based unit to track both core body temperature and cardiac signals, while a computational model estimates sweat loss. Validation experiments were conducted with ten healthy men during cycling exercise in a controlled environment. The prototype achieved a root mean square error of 0.087 degrees C for core temperature and 131 g for total sweat loss, surpassing previous approaches. During exercise and recovery, values were slightly overestimated, likely due to increased sweating and skin blood flow affecting heat transfer. Despite these limits, the device provides a practical way to monitor multiple physiological signals in real time under heat stress. It shows promise for use in occupational, athletic, and everyday settings to help prevent heat illness.

T. T. Xie, Y. Xu, M. Zhen, H. Zhu, Z. Tian, Y. Cheng and F. F. Wang.

Performance of a wearable CORE sensor for nocturnal core temperature monitoring during sleep.

JOURNAL OF THERMAL BIOLOGY. 2026;139.

<https://doi.org/10.1016/j.jtherbio.2026.104477>

Wearable sensors are increasingly used to estimate core body temperature (CBT) during sleep, and their validity is commonly assessed using classical Bland-Altman analysis. However, this approach assumes independence between observations and may be inappropriate for continuous, temporally autocorrelated physiological data. Whether reliance on pointwise Bland-Altman analysis leads to inflated agreement estimates during nocturnal sleep has not been systematically examined. We evaluated the validity and reliability of a wearable CORE sensor against rectal thermistor measurements during a controlled 9-h sleep protocol (22:00-07:00) in 26 healthy young adults (16 males & 10 females). Agreement was assessed using a modified Bland-Altman approach based on time-aggregated nocturnal CBT values to account for temporal autocorrelation. Circadian rhythmicity was characterized using cosinor analysis, and test-retest reliability was examined in a subset of 10 males. Classical pointwise Bland-Altman analysis suggested acceptable agreement (>95% of observations within limits of agreement). In contrast, the modified analysis revealed substantial disagreement, with 49.49% of male and 65.67% of female observations falling outside limits of agreement. Females exhibited significantly earlier circadian phase ($p = 0.012$) and greater amplitude ($p = 0.021$) compared with males. Test-retest reliability of the wearable sensor was good (ICC = 0.810). These findings demonstrate that classical Bland-Altman analysis overestimates agreement when applied to continuous nocturnal temperature data. Although the wearable sensor showed acceptable reliability and captured circadian trends, it did not accurately measure absolute nocturnal CBT in either sex.

Y. Z. Zhao and J. H. M. Bergmann.

A physics-guided hybrid model for core body temperature estimation: Thermoregulation model with residual learning.

EXPERT SYSTEMS WITH APPLICATIONS. 2026;329.

<https://doi.org/10.1016/j.eswa.2026.133001>

Accurate, non invasive estimation of core body temperature (T-c) is vital for real time physiological monitoring and heat illness prevention, yet gold standard measurements are invasive and impractical for wearables. We propose a physics guided hybrid framework that embeds a two node thermoregulation model within a neural residual learning pipeline. The physical layer uses heart rate (HR) to estimate metabolic heat production and directly incorporates wearable head skin temperature, while the residual learner (1D-CNN/LSTM/GRU) corrects systematic model discrepancies. Evaluated on a controlled dataset with strict participant-level splits, the Hybrid-CNN (full input) achieved the best overall accuracy (RMSE = 0.265 degrees C, MAE = 0.202 degrees C, R-2 = 0.638), outperforming CNN/LSTM/GRU-only networks, an Extended Kalman Filter (RMSE = 0.365 degrees C), and a physics-only baseline (RMSE = 0.604 degrees C, negative R-2). A simplified Hybrid-CNN that omits ambient sensors performed similarly (RMSE = 0.268 degrees C, R-2 = 0.632), indicating deployability with just HR and skin temperature. Noise robustness tests, conducted by injecting Gaussian noise into HR (sigma = 5-50 bpm), showed Hybrid-CNN leading for sigma <= 20 bpm, whereas Hybrid-LSTM was most resilient under extreme noise (sigma = 50 bpm; RMSE = 0.353 degrees C). The residual learners are lightweight (120-140 KB; 250k-700k FLOPs/step), supporting real-time, on-device inference. Overall, coupling interpretable thermophysiology with targeted residual learning yields accurate, robust, and computationally efficient T-c monitoring for wearable health systems.

J. Janowicz and G. Wiczynski.

A Wearable System for Remote Wrist Skin Temperature Monitoring to Assess Skin Thermal Response to Extreme Cold: A Case Study.

SENSORS. 2026;26(10).

<https://doi.org/10.3390/s26103235>

Skin temperature measurement is a complex issue. Skin tissue is one of the main thermoregulatory organs and takes major responsibility for heat exchange in the organism. Accurate skin temperature measurement may contribute to better estimation of deep core temperature, which is why enhancing possibilities of skin temperature measurement is considered substantial. However, the real value of the skin temperature can be influenced by many biological and non-biological factors. Some of the external factors such as extensive wind or extreme ambient temperature may significantly influence the raw value of the skin temperature regardless of the choice of the measuring point. Despite that, abnormal thermoregulatory behaviour can occur due to internal body stresses and reactions. Whilst internal influence is even more difficult to track than external factors, it is crucial to monitor and identify the thermal stresses in a correct way. The paper proposes a wrist temperature measurement system. The system consists of a sensory part placed in a housing adapted to the shape of the wrist. The sensory component enables contact measurement of wrist skin temperature under the assumed experimental conditions. The housing is designed to provide stable positioning of the sensory component relative to the wrist while simultaneously isolating it from external conditions. The paper presents the results of a case study concerning human thermoregulation, quantifying the thermal response of the hand under low-temperature exposure in temperature chamber and during the subsequent rewarming phase after removal. During the experiment, temperature measurements of both hands were recorded. One of the

co-authors participated in this case experiment. The temperature measurement results were compared between the hand subjected to thermal stress and the hand not exposed to low temperatures. Differences in the participant response to repeated thermal stress are demonstrated. The results highlight the complexity of the human body's thermoregulation process in extremely cold environments.

Travail dans une ambiance thermique extrême

B. Z. Luo, J. S. Zhang, Y. J. Wu, H. F. Jia and J. X. Huang.

Optimised WBGT assessment and heat mitigation: a case study of the Gaoligongshan Tunnel.

ENVIRONMENTAL GEOTECHNICS. 2026.

<https://doi.org/10.1680/jenge.25.00108>

The Gaoligongshan Tunnel in Yunnan Province, China, serves as a representative example of a high ground-temperature and high-altitude tunnel. The tunnel's construction through four heat-water conduction zones presented significant safety risks, which formed the primary motivation for this research. Correlation and regression analyses between on-site measured wet-bulb globe temperature (WBGT) values and environmental parameters, including air temperature, atmospheric pressure, wind speed, and relative humidity, reveal that air temperature, atmospheric pressure, and relative humidity exhibit significant correlations with. Based on Pearson correlation coefficients, the degree of correlation ranks in descending order as follows: air temperature > relative humidity > atmospheric pressure. A method utilising a Sparrow search algorithm (SSA)-BP neural network is proposed for the rapid and accurate prediction of values from conventional tunnel environmental parameters. This approach facilitates thermal environment assessment based on WBGT, supporting the development of a three-dimensional '3-D' tunnel cooling system. Compared with predictions from a standardised regression equation, the SSA-BP neural network improves the R² value between predicted and measured by 7.7%. Technical measures such as ventilation, cryocoolers, and ice cooling are demonstrated to reduce to approximate to 26 degrees C, thereby effectively improving the tunnel thermal environment.

Travail par fortes chaleurs et périodes de canicule

R. S. Wagoner, N. I. López-Gálvez, R. A. Canales, P. I. Beamer, L. V. Farland, F. A. von Hippel, J. G. de Zapien, C. B. Rosales and M. A. Furlong.

Associations of Heat Exposure with Acute Kidney Injury and Kidney Function in Mexican Agricultural Workers.

JOURNAL OF AGROMEDICINE. 2026.

<https://doi.org/10.1080/1059924X.2026.2679282>

Objective: Agricultural workers endure physically demanding, high heat work daily, increasing the risk of kidney injury and reduced kidney function. However, few studies have examined individual measures of heat exposure and risk of kidney injury and impaired function. We assessed the association between measures of heat exposure with acute kidney injury and kidney functioning among agricultural workers, compared to a group of office workers in the same region. Methods: We recruited 77 adult males working in agriculture and 21 adult males in office jobs in Sonora, Mexico in 2019. We administered a demographic questionnaire to participants. A proxy physiological strain index (PSI), based on point measurements of heart rate and tympanic temperature, was used to estimate individual heat exposure. Kidney function was measured using the estimated glomerular filtration rate (eGFR). Kidney injury was assessed via urinary neutrophil gelatinase-associated lipocalin (uNGAL). We compared uNGAL and eGFR over time in the two study groups. We assessed proxy PSI associations with uNGAL and eGFR using linear mixed-effects models, adjusting for age, body mass index, and urinary specific gravity factor. Results: We observed statistically significant differences between agricultural and office workers for eGFR (GM: 121.85 vs. 115.66 mL/min/1.73 m²), $p = .04$). Among agricultural workers, creatinine-adjusted uNGAL levels rose in summer compared to spring (GM: 4.47 vs. 1.98 mg/g creatinine, $p < .01$), and eGFR declined during the same period GM:(108.41 vs. 122.38 mL/min/1.73 m²), $p < .01$). In mixed models, proxy PSI was inversely associated with eGFR (beta-coefficient:-2.87, 95% CI: -4.02, -1.72). Conclusion: Season and proxy PSI predicted kidney functioning in agricultural workers in this study. As climate warming continues, high-risk occupational groups such as agricultural workers will face increasing heat-related health risks.

M. Y. Cheng and Q. T. Vu.

Bidirectional Revolving Gate Fourier Transform: a newly spectrum deep machine learning for enhancing construction worker safety classification.

ENGINEERING CONSTRUCTION AND ARCHITECTURAL MANAGEMENT. 2026.

<https://doi.org/10.1108/ECAM-01-2026-0089>

Purpose Falls from heights (FFH) remain the leading cause of fatalities in the construction industry worldwide. Mental fatigue associated with heat stress and psychological stressors is a critical yet overlooked contributor to FFH risk. Current risk-mitigation approaches emphasize physical protective measures but fail to address cognitive impairment caused by environmental and psychological stressors. Moreover, existing deep-learning (DL) models struggle to capture the oscillatory patterns and long-term dependencies inherent in time-series physiological data. This study develops a novel prediction model evaluated on two case studies: (1) FFH risk associated with heat stress and hazardous areas and (2) mental fatigue classification in construction workers. Design/methodology/approach This study proposes the Bidirectional Revolving Gate Fourier Transform (BiRGFT), a novel DL architecture that integrates bidirectional gated recurrent units with dual bidirectional fast Fourier transform and

cross-attention mechanisms. The model leverages data from wearable sensors, environmental monitoring systems and historical fall incident records at active construction sites. Findings BiRGFT achieved average precision, recall and F1-score of approximately 0.98 for case study 1 and 0.95 for case study 2, outperforming eight baseline DL and hybrid DL models. The minimal gap between training and testing results indicates strong generalization. The results support the capability of this real-time risk classification system to enable continuous monitoring and generate timely alerts for safety managers. Originality/value This research advances DL applications in construction safety by bridging time-frequency domain representations through BiRGFT. This framework enables the integrated monitoring of environmental risks and worker mental states, supporting proactive safety management across diverse construction environments.

A. J. Abdulsalam, F. A. Rathore and L. Özçakar.

Climate Change and Musculoskeletal Health: Implications for Rehabilitation Medicine.

JOURNAL OF THE PAKISTAN MEDICAL ASSOCIATION. 2026;76(5):797-9.

<https://doi.org/10.47391/JPMA.26-41>

The relationship between climate change and human health has become increasingly clear as global temperatures rises. The cardiovascular and pulmonary consequences of extreme weather events have been well researched and documented in the literature. However, the effects of climate change on MSK health are not well understood. This mini-review explores the complex relationship between MSK health and climate change particularly global warming. It highlights the emerging challenges for rehabilitation medicine due to the climate change and suggests adaptive approaches to clinical practice. The mechanisms linking environmental factors and MSK health are multifactorial and intricate. Temperature extremes can disrupt tissue physiology, while severe weather events may result in trauma and limit access to healthcare services. In addition, exposure to poor air quality has been associated with the exacerbation of inflammatory MSK conditions. Vulnerable populations including elderly adults, outdoor workers, and those with pre-existing MSK disorders face increased risks from climate changes. Climate-resilient rehabilitation services using telemedicine, mobile units, and environmental monitoring can be important considerations. Further research is suggested to establish evidence-based guidelines for climate-adaptive rehabilitation protocols.

Y. J. Zhu and H. B. Zhang.

Increased Risk of Work Safety Accidents During Extremely High Temperatures.

RISK ANALYSIS. 2026;46(5).

<https://doi.org/10.1111/risa.70251>

Global climate change and the urban heat island effect are increasingly exposing workplaces to extreme high temperatures, but the extent to which this elevates the risk of work safety accidents remains uncertain. In this study, we introduced an environmental epidemiology approach to quantify the relationship between extreme heat and work safety accidents in Chinese cities. We found that exposure to extremely high temperature was associated with an 18.7% increase in the risk of work safety accidents, compared to the reference temperature. Notably, low-severity, road transport, and vehicle accidents, as well as regions located in temperate monsoon and tropical/subtropical monsoon zones, were susceptible to extreme heat. We also estimated that 1% of work safety accidents in our dataset could be attributed to extremely high temperatures. These findings enhance our understanding

of extreme weather risks in work safety and emphasize the urgent need for effective adaptation strategies and preventive measures in city management.

A. Nath, D. Chakraborty and S. Sahu.

Physiological Responses to Occupational Heat Exposure Among Male Agricultural and Brick-Field Workers in Eastern India: A Biochemical Perspective.

AMERICAN JOURNAL OF HUMAN BIOLOGY. 2026;38(6).

<https://doi.org/10.1002/ajhb.70285>

Occupational heat exposure is considered a major health concern for workers performing strenuous work during hot environmental conditions. This cross-sectional study aimed to assess the biochemical and physiological responses to occupational heat exposure among agricultural and brick-field workers working in hot environmental conditions in eastern India. A sub-sample of 20 agricultural workers and 20 brick-field workers was selected from the larger sample of 200 workers each to assess the physiological and biochemical responses to hot environmental conditions during the summer and winter seasons. Environmental heat exposure was measured using the time-weighted average Wet Bulb Globe Temperature (TWA-WBGT in degrees C). Venous blood samples were collected to measure the levels of sodium, potassium, and aldosterone. Active sweat gland responses were measured using the modified starch-iodine technique. Multivariate general linear models of repeated measures were used to measure the effect of the following factors: season, exposure day, and occupation. The multivariate analysis showed significant seasonal effects on serum potassium, sodium, and aldosterone levels, and that exposure day influenced only potassium, not occupation. The monitoring sessions showed normal physiological levels of electrolytes in both occupational groups. Sweat gland activation was also significantly higher during the summer season. TWA-WBGT values above 23 degrees C-25 degrees C are associated with a higher probability of hyponatremia, as revealed by the receiver operating characteristic (ROC) analysis. These findings highlight the physiological adjustments associated with occupational heat exposure and emphasize the importance of hydration and heat mitigation strategies for outdoor workers.

S. Basu, T. Patel, P. Goswami and B. Ningthoujam.

Predictive Modeling of Work-Rest Schedule for Agricultural Workers Using Heat Stress and Physiological Data.

IISE TRANSACTIONS ON OCCUPATIONAL ERGONOMICS & HUMAN FACTORS. 2026.

<https://doi.org/10.1080/24725838.2026.2665231>

Background: Agricultural tillage involves prolonged physical exertion under heat stress, increasing fatigue and injury risk. Existing work-rest guidance for industrial settings does not directly translate to small-scale agricultural work in hot climates. Purpose: To develop and validate predictive models that estimate (a) the working time to reach targeted heart-rate thresholds and (b) the resting time required to recover under field heat-stress conditions, using physiological, environmental, and behavioral inputs. Methods: Field measurements were collected from 48 male agricultural workers during manual and power-tiller tillage (WBGT, continuous heart rate). Factor analysis identified body-composition factors; stepwise multiple regression models were developed to predict working time (WT) and resting time (RT). Models were validated against independent observations using mean absolute percentage error (MAPE), Theil's U, and normalized root mean square error (NRMSE). Results: Significant predictors for WT included age, WBGT, resting heart rate, alcohol and smoking habits, and mechanization status; for

RT, predictors included age, actual working time, resting heart rate (RHR), recovery heart rate (ReHR), lifestyle habits, and mechanization. Model performance was strong: WT ($R^2 = 0.858$, MAPE = 3.87%, Theil's U = 0.0216, NRMSE = 0.1102) and RT ($R^2 = 0.879$, MAPE = 4.76%, Theil's U = 0.0256, NRMSE = 0.1124). Mechanization increased WT, while lifestyle factors and higher WBGT reduced WT and increased RT. Conclusions: Regression models accurately predict work and rest durations for agricultural tillage under heat stress and can inform evidence-based, field-applicable work-rest schedules to improve worker safety and productivity.

C. Gariazzo, L. Taiano, M. Bonafede and A. Marinaccio.

Projection of heat-related occupational injuries under climate change and demographic scenarios in Italian cities.

ENVIRONMENTAL RESEARCH. 2026;302.

<https://doi.org/10.1016/j.envres.2026.124644>

Introduction: High temperatures have been associated with occupational injuries (OIs). However, studies projecting future OIs under climate change scenarios are scarce, particularly in Europe. To fill this gap, we estimated projected heat-related OIs in 87 Italian cities under climate and demographic scenarios. Materials and methods: OIs occurring from 2014 to 2019 were collected from the Italian national archive. Daily counts of OIs in each city were merged with ERA5-land Copernicus mean temperatures. City-specific exposure-response functions were estimated using a time-series analysis with distributed lag non-linear model (dlnm) and then meta-analysed to obtain a national estimate. This estimate was applied to project heat-attributable OIs from 2015 to 2100 using downscaled daily temperatures from 19 general circulation models, under three European Shared Socioeconomic Pathways (SSP) scenarios (SSP1-2.6; SSP2-4.5; SSP3-7.0), including demographic projections. Adaptation scenarios were also considered by applying risk attenuation. Results: Under the lowest mitigation scenario (SSP3-7.0), an increase in the attributable number of OIs is foreseen, with 537 (95% CI 365-709) additional cases in 2070-2079 compared with the baseline decade 2010-2019, corresponding to an attributable relative fraction of 0.38% (95% CI 0.26-0.5). Under the intermediate scenario (SSP2-4.5), 464 (95%CI 312-616) additional cases are projected compared with baseline. Agriculture showed high vulnerability with attributable fraction of 1.20% (95% CI 0.99-1.41) under SSP3-7.0 scenario in 2070-2079. Conclusions: Heat-related OIs are predicted to increase under future climatic conditions. Workplace mitigation measures and public health actions are recommended to reduce heat-attributable OIs.

L. Clemans-Cope, L. Dubay, V. Pancini and A. Pugazhendhi.

Unequal Exposure: Examining Outdoor Work And Climate Exposure In The US.

HEALTH AFFAIRS. 2026;45(5):535-44.

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Outdoor workers face growing exposure to poor air quality, wildfire smoke, and extreme heat, yet protections remain uneven across states and incomplete federally, and little is known about outdoor workers. We combined data from national labor-force surveys with occupation-based exposure data and county-level environmental indicators on air quality, wildfire, and heat waves to describe and compare outdoor and indoor workers. Outdoor workers accounted for 21.9 percent of the workforce in 2023. About 16.9 percent of outdoor workers lived in counties with the highest frequency of unhealthy air quality days, and nearly one-third lived in counties with the highest wildfire (32.4 percent) and heat

wave (31.4 percent) risks. Compared with indoor workers, outdoor workers had higher rates of uninsurance, more self-employment, lower access to paid sick leave, and higher rates of work injuries. Results identified outdoor workforces with elevated climate-related risks and differences in coverage and job arrangements, informing federal, state, and local prevention, standards, and enforcement.

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