

Bulletin n°15

Veille thermique

Période : février 2024

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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EPI, matériaux protecteurs/refroidissants

J. Li, X. W. Cui, Q. Q. Huang and J. Li.

Determining Safe Working Hours of Wearing Medical Disposable Protective Clothing From Physiological Thermal Limits: A Pilot Study.

AATCC JOURNAL OF RESEARCH. 2024.

<https://doi.org/10.1177/24723444231222564>

Despite the mandatory use of medical disposable protective clothing to protect against infectious hazards, how to determine optimal safe working hours induced by physical fatigue while wearing medical disposable protective clothing remains unknown. Driven by these questions, here we quantify the extent of physical fatigue experienced by medical staff wearing medical disposable protective clothings in isolation wards to identify a safe work duration. Eight healthy males were subjected to light (2.1 km/h) and moderate (4.3 km/h) treadmill exercises while wearing two different ensembles. Four physiological (tympanic temperature T_{core} , mean skin temperature T_{sk} , heart rate, and sweat loss) and two subjective indicators (thermal sensation and humidity sensation) were measured. We then introduced a discrete gray model(1,1) to determine safe working hours. The study indicated that even at lower temperatures, prolonged wearing of medical disposable protective clothing could significantly affect physiological indicators such as T_{core} and T_{sk} ($p < 0.001$), with T_{core} being the predominant factor limiting safe working hours. Regarding medical disposable protective clothing-1-light, medical disposable protective clothing-1-moderate, medical disposable protective clothing-2-light, and medical disposable protective clothing-2-moderate intensity activities, the safe working hours were 6.33, 2.83, 2.83, and 2.25 h. This article presented a new approach to determining safe working hours for wearing medical disposable protective clothing from physiological thermal limits with small sample data. However, this is a preliminary study, and further validation of the prediction model through additional experiments is necessary.

Maladies liées à la chaleur

Hansson, K. Jakobsson, J. Glaser, C. Wesseling, D. Chavarria, R. A. Lucas, H. Prince and D. H. Wegman.

Impact of heat and a rest-shade-hydration intervention program on productivity of piece-paid industrial agricultural workers at risk of chronic kidney disease of nontraditional origin.

ANNALS OF WORK EXPOSURES AND HEALTH. 2024.

<https://doi.org/10.1093/annweh/wxae007>

Objectives : Assess the impact of environmental heat and a rest-shade-hydration (RSH) intervention against heat stress on productivity of piece-paid Mesoamerican sugarcane cutters. These workers are at a high risk of chronic kidney disease of non-traditional origin (CKDnt), from the severe heat stress they experience due to heavy work under hot conditions. RSH interventions in these populations improve kidney health outcomes, but their impact on productivity has yet to be examined. Methods: We accessed routine productivity data from seed (SC, N = 749) and burned (BCC, N = 535) sugarcane cutters observed over five harvest seasons with increasing RSH intervention at a large Nicaraguan sugarcane mill. Hourly field-site wet-bulb globe temperature (WBGT) was recorded by mill staff and summarized as a daily mean. Mixed linear regression was used to model daily productivity, adjusting for age (18-29, 30-44, and >45 years), sex, WBGT (<28, 28-29, 29-30, 30-31, and >31(degrees)C) on the same and preceding day, harvest season (2017-18 to 2021-22), month, and acclimatization status (<1, 1-2, and >2 weeks). Results: There was an inverse dose-response relationship between SC productivity and WBGT on the same and preceding days, decreasing by approximately 3%/C-degrees WBGT. Productivity increased during the study period, i.e. coinciding with RSH scale-up, by approximately 19% in SC and 9% in BCC. Conclusion: Agricultural worker productivity was expected lower on hotter days, strengthening the interest in all stakeholders to mitigate increasing global temperatures and their impact. Despite decreasing the total time allocated for work each day, an RSH intervention appears to result in increased productivity and no apparent loss in productivity.

J. R. Buzan.

Implementation and Evaluation of Wet Bulb Globe Temperature Within Non-Urban Environments in the Community Land Model Version 5.

JOURNAL OF ADVANCES IN MODELING EARTH SYSTEMS. 2024;16(2).

<https://doi.org/10.1029/2023MS003704>

Global heat stress is a phenomenon that impacts the livelihood of humans worldwide. Due to climate change, heatwaves are already increasing negatively impact outdoor laborers and activities. However, calculating heat stress on a global scale is disparaged due to the interplay and treatment of temperature, humidity, and radiation. To help resolve this issue, the Wet Bulb Globe Temperature (WBGT), a standardized heat stress metric, is implemented into the Community Land Model (CLM5), the land surface component of the Community Earth System Model (CESM2). This resolves a long lasting, complex issue within global heat stress: the treatment of solar and thermal radiation. A default configuration of CLM5 is executed and shows the advantages of simulating the WBGT within multiple environments. Additionally, two commonly used WBGT approximations are implemented for solar exposed (sWBGT) and shaded (FiWBGT) conditions. The 1995 Chicago Heatwave is examined as a case study, focusing on the rural regions impacted by the heatwave. Derivative functions of labor capacity show that assumptions about calculating a non-linear algorithm generate non-negligible biases that

can grossly over or underestimate the impact of heat stress on future climate change projections. For example, a difference of 0.5 degree celsius from WBGT can result in >10% change in labor capacity. Using a conservative difference of +/- 0.3 degree celsius, 100% of land surface extreme sWBGT values and >77% extreme shaded conditions (FiWBGT) differ from WBGT. Therefore, to accurately assess the direct exposure, risk, and damage from climate change on people, it is critical to implement diagnostics directly into Earth system models.

G. W. McGarr, R. D. Meade, S. R. Notley, A. P. Akerman, B. J. Richards, E. R. McCourt, K. E. King, J. J. McCormick, P. Boulay, R. J. Sigal and G. P. Kenny.

Physiological responses to 9 hours of heat exposure in young and older adults. Part III: Association with self-reported symptoms and mood state.

JOURNAL OF APPLIED PHYSIOLOGY. 2024;136(2):408-20.

<https://doi.org/10.1152/jappphysiol.00740.2023>

Older adults are at greater risk of heat-related morbidity and mortality during heat waves, which is commonly linked to impaired thermoregulation. However, little is known about the influence of increasing age on the relation between thermal strain and perceptual responses during daylong heat exposure. We evaluated thermal and perceptual responses in 20 young (19-31 yr) and 39 older adults (20 with hypertension and/or type 2 diabetes; 61-78 yr) resting in the heat for 9 h (heat index: 37 degrees C). Body core and mean skin temperature areas under the curve (AUC, hours 0-9) were assessed as indicators of cumulative thermal strain. Self-reported symptoms (68-item environmental symptoms questionnaire) and mood disturbance (40-item profile of mood states questionnaire) were assessed at end-heating (adjusted for prescores). Body core temperature AUC was 2.4 degrees C [1.0, 3.7] higher in older relative to young adults ($P < 0.001$), whereas mean skin temperature AUC was not different (-0.5 degrees C [-4.1, 3.2] $P = 0.799$). At end-heating, self-reported symptoms were not different between age groups (0.99-fold [0.80, 1.23], $P = 0.923$), with or without adjustment for body core or mean skin temperature AUC (both $P \geq 0.824$). Mood disturbance was 0.93-fold [0.88, 0.99] lower in older, relative to young adults ($P = 0.031$). Older adults with and without chronic health conditions experienced similar thermal strain, yet those with these conditions reported lower symptom scores and mood disturbance compared with young adults and their age-matched counterparts (all $P \leq 0.026$). Although older adults experienced heightened thermal strain during the 9-h heat exposure, they did not experience greater self-reported symptoms or mood disturbance relative to young adults.

Outils et capteurs de mesure

L. P. Liu, R. Pua, D. N. Rosario-Berrios, O. F. Sandvold, A. E. Perkins, D. P. Cormode, N. Shapira, M. C. Soulen and P. B. Noël.

Reproducible spectral CT thermometry with liver-mimicking phantoms for image-guided thermal ablation.

PHYSICS IN MEDICINE AND BIOLOGY. 2024;69(4).

<https://doi.org/10.1088/1361-6560/ad2124>

Objectives : Evaluate the reproducibility, temperature tolerance, and radiation dose requirements of spectral CT thermometry in tissue-mimicking phantoms to establish its utility for non-invasive temperature monitoring of thermal ablations. *Methods.* Three liver mimicking phantoms embedded with temperature sensors were individually scanned with a dual-layer spectral CT at different radiation dose levels during heating (35 degrees C-80 degrees C). Physical density maps were reconstructed from spectral results using varying reconstruction parameters. Thermal volumetric expansion was then measured at each temperature sensor every 5 degrees C in order to establish a correlation between physical density and temperature. Linear regressions were applied based on thermal volumetric expansion for each phantom, and coefficient of variation for fit parameters was calculated to characterize reproducibility of spectral CT thermometry. Additionally, temperature tolerance was determined to evaluate effects of acquisition and reconstruction parameters. The resulting minimum radiation dose to meet the clinical temperature accuracy requirement was determined for each slice thickness with and without additional denoising. *Results.* Thermal volumetric expansion was robustly replicated in all three phantoms, with a correlation coefficient variation of only 0.43%. Similarly, the coefficient of variation for the slope and intercept were 9.6% and 0.08%, respectively, indicating reproducibility of the spectral CT thermometry. Temperature tolerance ranged from 2 degrees C to 23 degrees C, decreasing with increased radiation dose, slice thickness, and iterative reconstruction level. To meet the clinical requirement for temperature tolerance, the minimum required radiation dose ranged from 20, 30, and 57 mGy for slice thickness of 2, 3, and 5 mm, respectively, but was reduced to 2 mGy with additional denoising. *Conclusions.* Spectral CT thermometry demonstrated reproducibility across three liver-mimicking phantoms and illustrated the clinical requirement for temperature tolerance can be met for different slice thicknesses. The reproducibility and temperature accuracy of spectral CT thermometry enable its clinical application for non-invasive temperature monitoring of thermal ablation.

A. Kaltsatou, M. Anifanti, A. D. Flouris, G. Xiromerisiou and E. Kouidi.

Validity of the CALERA Research Sensor to Assess Body Core Temperature during Maximum Exercise in Patients with Heart Failure.

SENSORS. 2024;24(3).

<https://doi.org/10.3390/s24030807>

Background: It is important to monitor the body core temperature (T_c) of individuals with chronic heart failure (CHF) during rest or exercise, as they are susceptible to complications. Gastrointestinal capsules are a robust indicator of the T_c at rest and during exercise. A practical and non-invasive sensor called CALERA Research was recently introduced, promising accuracy, sensitivity, continuous real-time analysis, repeatability, and reproducibility. This study aimed to assess the validity of the CALERA Research sensor when monitoring patients with CHF during periods of rest, throughout brief

cardiopulmonary exercise testing, and during their subsequent recovery. Methods: Twelve male CHF patients volunteered to participate in a 70-min protocol in a laboratory at 28 degrees C and 39% relative humidity. After remaining calm for 20 min, they underwent a symptom-limited stress test combined with ergospirometry on a treadmill, followed by 40 min of seated recovery. The Tc was continuously monitored by both Tc devices. Results: The Tc values from the CALERA Research sensor and the gastrointestinal sensor showed no associations at rest ($r = 0.056$, $p = 0.154$) and during exercise ($r = -0.015$, $p = 0.829$) and a weak association during recovery ($r = 0.292$, $p < 0.001$). The Cohen's effect size of the differences between the two Tc assessment methods for rest, exercise, and recovery was 1.04 (large), 0.18 (none), and 0.45 (small), respectively. The 95% limit of agreement for the CALERA Research sensor was -0.057 ± 1.03 degrees C. (4) Conclusions: The CALERA sensor is a practical and, potentially, promising device, but it does not provide an accurate Tc estimation in CHF patients at rest, during brief exercise testing, and during recovery.

Travail dans une ambiance thermique extrême

M. Ijaz, S. R. Ahmad, M. Akram and W. S. Carter.

Workplace induced heat-related-illness and kidney disorders among coal cutters of underground mines.

INDOOR AND BUILT ENVIRONMENT. 2024.

<https://doi.org/10.1177/1420326X241229431>

Workers in hot underground coal mines could develop heat-related illnesses, (especially skin, digestion and kidney problems), as compared to workers in non-hot mines. This study found severity of this situation by comparing heat illness symptoms, core body and skin temperature and kidney malfunctioning amongst workers of both types of mines. Ingestible thermometric pills (sending readings to Sensor Electronic Module every 15 s), skin temperature probes (connected to various body parts and sending readings to loggers) and laboratory analysis of pre- and post-shift samples of blood and urine, US-NIOSH-HETA-2012 sheet to survey symptoms, were used to collect data from 50 workers (25 from five hot mines (G1) and 25 from five non-hot mines (G2)). Two mine groups showed significant differences (p -value $< .001$) regarding wet-bulb globe temperature, dry-bulb temperature and relative humidity. The highest core body temperature was 38.8 degrees C in G1 and 37.9 degrees C in G2. In intra-group comparison for kidney functioning, post-shift samples showed haematocrit (%) was reduced to 43.6 \pm 2.1 from 45.4 \pm 1.4 in G1 and to 44.0 \pm 2.9 from 45.0 \pm 0.75 in G2, and estimated glomerular filtration rate was reduced from 100 \pm 19 to 94 \pm 0 mL/min/1.72 m² in G1 and to 113 \pm 15 from 115 \pm 19(a) in G2 workers. The comparison showed hot mines could induce heat-related illnesses which would necessitate intervention to reduce exposure.

Travail par fortes chaleurs et périodes de canicule

A. De Vita, A. Belmusto, F. Di Perna, S. Tremamunno, G. De Matteis, F. Franceschi, M. Covino and C. Grp.

The Impact of Climate Change and Extreme Weather Conditions on Cardiovascular Health and Acute Cardiovascular Diseases.

JOURNAL OF CLINICAL MEDICINE. 2024;13(3).

<https://doi.org/10.3390/jcm13030759>

Climate change is widely recognized as one of the most significant challenges facing our planet and human civilization. Human activities such as the burning of fossil fuels, deforestation, and industrial processes release greenhouse gases into the atmosphere, leading to a warming of the Earth's climate. The relationship between climate change and cardiovascular (CV) health, mediated by air pollution and increased ambient temperatures, is complex and very heterogeneous. The main mechanisms underlying the pathogenesis of CV disease at extreme temperatures involve several regulatory pathways, including temperature-sympathetic reactivity, the cold-activated renin-angiotensin system, dehydration, extreme temperature-induced electrolyte imbalances, and heat stroke-induced systemic inflammatory responses. The interplay of these mechanisms may vary based on individual factors, environmental conditions, and an overall health background. The net outcome is a significant increase in CV mortality and a higher incidence of hypertension, type II diabetes mellitus, acute myocardial infarction (AMI), heart failure, and cardiac arrhythmias. Patients with pre-existing CV disorders may be more vulnerable to the effects of global warming and extreme temperatures. There is an urgent need for a comprehensive intervention that spans from the individual level to a systemic or global approach to effectively address this existential problem. Future programs aimed at reducing CV and environmental burdens should require cross-disciplinary collaboration involving physicians, researchers, public health workers, political scientists, legislators, and national leaders to mitigate the effects of climate change.

Actualités février 2024

- **Travail par fortes chaleurs et périodes de canicule**

Simulation fortes chaleurs : il faut plus de secouristes. Le Parisien (Presse), p.34, 1^{er} février 2024

[Changement climatique : on ne pourra plus dire qu'on ne savait pas !](#) sciencesetavenir.fr, 4 février 2024

[France: plus de 5.000 décès liés à la chaleur pendant l'été 2023.](#) sciencesetavenir.fr, 8 février 2024

[Réchauffement climatique: l'année 2024 débute par de nouveaux records.](#) challenges.fr, 8 février 2024

[Réchauffement climatique : 2 milliards d'aides pour les entreprises.](#) lacuisinepro.fr, 19 février 2024

[La Cameroun sous l'effet d'une vague de chaleur.](#) africa.la-croix.com, 21 février 2024

[Attorney General James Takes Action to Protect Workers from Occupational Heat Exposure.](#) ag.ny.gov, 9 février 2024

[We can't air-condition our way out of global heating problem: UN heat officer.](#) hindustantimes.com, 26 février 2024

- **Outils et capteurs de mesure**

[Digitally-defined ultrathin transparent wireless sensor network for roomscale imperceptible ambient intelligence.](#) nature.com, 6 février 2024

[Ingestible Thermo Sensor Performs Core Body-Temperature Monitoring.](#) mwrf.com, 22 février 2024

- **Maladies liées à la chaleur**

[Hygrothermal stress increases malignant arrhythmias susceptibility by inhibiting the LKB1-AMPK-Cx43 pathway.](#) nature.com, 29 février 2024

- **EPI, matériaux protecteurs/refroidissants**

[Climate Adaptive Health Leads 2024 Global Wellness Trends: Higher Demand For Heat Stress And Heat Related Illness \(HRI\) Solutions.](#) prnewswire.com, 21 février 2024

Une gamme antichaleur et antifleuves. Le Moniteur des Artisans (Presse), p. 52, 24 février 2024