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Heat:

An Interdisciplinary Annotated Bibliography

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2023

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CPWR is the research and training arm of NABTU. Production of this document was supported by cooperative agreement OH 009762 from the National Institute for Occupational Safety and Health (NIOSH). The contents are solely the responsibility of the authors and do not necessarily represent the official views of NIOSH.

Heat: An Interdisciplinary Annotated Bibliography

North American Research

Acharya, P., et al. (2018). "Assessing Heat Stress and Health among Construction Workers in a Changing Climate: A Review." Int J Environ Res Public Health 15(2).

Construction workers are at an elevated risk of heat stress, due to the strenuous nature of the work, high temperature work condition, and a changing climate. An increasing number of workers are at risk, as the industry's growth has been fueled by high demand and vast numbers of immigrant workers entering into the U.S., the Middle East and Asia to meet the demand. The risk of heat-related illnesses is increased by the fact that little to no regulations are present and/or enforced to protect these workers. This review recognizes the issues by summarizing epidemiological studies both in the U.S. and internationally. These studies have assessed the severity with which construction workers are affected by heat stress, risk factors and co-morbidities associated with heat-related illnesses in the construction industry, vulnerable populations, and efforts in implementing preventive measures.

Bonauto, D., et al. (2007). "Occupational heat illness in Washington State, 1995-2005." Am J Ind Med 50(12): 940-950.

BACKGROUND: Little information exists describing the incidence of heat-related illness (HRI) among non-military working populations. An analysis of HRI cases utilizing workers' compensation data has not been previously reported. METHODS: We used both ICD-9 and ANSI Z16.2 codes with subsequent medical record review to identify accepted Washington State Fund workers' compensation claims for HRI over the 11-year time period from 1995-2005. RESULTS: There were 480 Washington workers' compensation claims for HRI during the 11-year study period. NAICS industries with the highest workers' compensation HRI average annual claims incidence rate were Fire Protection 80.8/100,000 FTE, Roofing Construction 59.0/100,000 FTE, and Highway, Bridge and Street Construction 44.8/100,000 FTE. HRI claims were associated with high outdoor ambient temperatures. Medical risk factors for HRI were present in some cases. CONCLUSIONS: HRI cases occur in employed populations. HRI rates vary by industry and are comparable to those previously published for the mining industry.

Bourbonnais, R., et al. (2013). "Identification of workers exposed concomitantly to heat stress and chemicals." Ind Health 51(1): 25-33.

In the context of climate change, concomitant exposure to heat stress and chemicals takes on great importance. However, little information is available in this regard. The purpose of this research, therefore, was to develop an approach aimed at identifying worker groups that would be potentially most at risk. The approach comprises 5 consecutive steps: - Establishment of a list of occupations for all industry sectors - Determination of heat stress parameters - Identification of occupations at risk of heat stress - Determination of exposure to chemicals - Identification of occupations potentially most at risk. Overall, 1,010 occupations were selected due to their representativeness of employment sectors in Quebec. Using a rating matrix, the risk stemming from exposure to heat stress was judged "critical" or "significant" for 257 occupations. Among these, 136 occupations were identified as showing a high potential of simultaneous exposure to heat stress and chemicals. Lastly, a consultation with thirteen experts made it possible to establish a list of 22 priority occupations, that is, 20 occupations in the metal

manufacturing sector, as well as roofers and firefighters. These occupations would merit special attention for an investigation and evaluation of the potential effects on workers' health.

Calkins, M. M., et al. (2019). "A case-crossover study of heat exposure and injury risk among outdoor construction workers in Washington State." Scand J Work Environ Health 45(6): 588-599.

Objectives The primary objective of this study was to assess the relationship between heat exposure and occupational traumatic injuries among construction workers. Methods We assessed the relationship between humidex, a measure of apparent temperature, and Washington State Fund workers' compensation injuries among outdoor construction workers using a case-crossover design with time-stratified referent selection. Warm month (March-October) adult outdoor construction traumatic injury claims from 2000-2012 were spatiotemporally joined with high-resolution meteorological data. We used conditional logistic regression with linear splines to assess the association between maximum daily humidex and injuries. Results There were 63 720 occupational traumatic injury claims in construction that met our eligibility criteria during the study period. The traumatic injury odds ratio (OR) was 1.005 [95% confidence interval (CI) 1.003-1.007] per one degrees C change in humidex. In the spline analyses, we observed a nearly linear association of humidex with the risk of a traumatic injury. Effect estimates were higher among younger (18-24 years) and older (>54 years) workers, workers with lower extremity injuries, workers with less job experience, smaller employers, workers working in Western Washington, and time of injury before 12:30 hours, although CI of effect estimates overlapped in stratified analysis categories. Conclusions In this study of Washington outdoor construction workers, increasing maximum daily humidex was associated with increasing traumatic injury risk. Further work should explore mechanisms of the association between heat exposure and traumatic injuries. Injury prevention efforts targeted at construction should address heat-related risk factors. In addition, heat awareness campaigns should address outcomes beyond heat-related illness.

Chicas, R., et al. (2020). "Cooling intervention studies among outdoor occupational groups: A review of the literature." Am J Ind Med 63(11): 988-1007.

BACKGROUND: The purpose of this systematic review is to examine cooling intervention research in outdoor occupations, evaluate the effectiveness of such interventions, and offer recommendations for future studies. This review focuses on outdoor occupational studies conducted at worksites or simulated occupational tasks in climatic chambers. METHODS: This systematic review was performed in accordance with Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines. PubMed, Embase, and Web of Science were searched to identify original research on intervention studies published in peer-reviewed journals that aimed at reducing heat stress or heat-related illness from January 2000 to August 2020. RESULTS: A systematic search yielded a total of 1042 articles, of which 21 met the inclusion criteria. Occupations with cooling intervention studies included agriculture (n = 5), construction (n = 5), industrial workers (n = 4), and firefighters (n = 7). The studies focused on multiple types of cooling interventions cooling gear (vest, bandanas, cooling shirts, or head-cooling gel pack), enhanced heat dissipation clothing, forearm or lower body immersion in cold water, water dousing, ingestion of a crushed ice slush drink, electrolyte liquid hydration, and modified Occupational Safety and Health Administration recommendations of drinking water and resting in the shade. CONCLUSION: Current evidence indicates that using multiple cooling gears along with rest cycles may be the most effective

method to reduce heat-related illness. Occupational heat-related illnesses and death may be mitigated by targeted cooling intervention and workplace controls among workers of vulnerable occupational groups and industries.

Dong, X. S., et al. (2019). "Heat-related deaths among construction workers in the United States." Am J Ind Med 62(12): 1047-1057.

BACKGROUND: Heat is a severe hazard for construction workers and may be worsening with global warming. This study sought to explore heat-related deaths among U.S. construction workers and a possible association with climate change. METHODS: Heat-related deaths in the Census of Fatal Occupational Injuries from 1992 to 2016 were analyzed. Denominators estimated from the Current Population Survey were matched with demographic and occupational categories in rate calculations. Statistical tests were used to examine heat-related deaths in relation to time, geographic region, and temperature. RESULTS: Construction workers, comprising 6% of the total workforce, accounted for 36% (n = 285) of all occupational heat-related deaths from 1992 to 2016 in the U.S. Mean temperatures from June to August increased gradually over the study period. Increasing summer temperatures from 1997 to 2016 were associated with higher heat-related death rates (r = 0.649; 95% confidence interval: 0.290, 0.848). Compared to all construction workers (risk index = 1), statistically significant elevated risk of heat-related death was found among Hispanics (1.21), in particular workers born in Mexico (1.91). Occupations with a high risk index included cement masons (10.80), roofers (6.93), helpers (6.87), brick masons (3.33), construction laborers (1.93) and heating, air conditioning, and refrigeration mechanics (1.60). CONCLUSIONS: U.S. construction workers are at a high risk of heat-related death, and this risk has increased with climate change over time. Effective workplace interventions, enhanced surveillance, and improved regulations and enforcement should accompany broader efforts to combat global warming. The construction industry can help reduce global warming through increased implementation of green building principles.

Evoy, R., et al. (2022). "The impact of wildfire smoke and temperature on traumatic worker injury claims, Oregon 2009-2018." Health Sci Rep 5(5): e820.

BACKGROUND AND AIMS: As average temperatures rise and wildfire events increase in the United States, outdoor workers may be at an increased risk of injury. Recent research suggests that heat exposure increases outdoor workers' risk of traumatic injuries, but co-exposures of heat and wildfire smoke have not been evaluated. METHODS: Oregon workers' compensation data from 2009 to 2018 were linked to satellite data by the date of injury to determine if acute heat (maximum Heat Index) and wildfire smoke (presence/absence) were associated with a traumatic injury. North American Industry Classification System (NAICS) codes were utilized to identify accepted, disabling injury claims from construction (NAICS 23) and agriculture, forestry, fishing, and hunting (NAICS 11). Claims from April to October were analyzed using negative binomial models to calculate incident rate ratios (IRR) by heat and wildfire exposure for All workers and specifically for Agricultural (Ag)/Construction workers. RESULTS: During the study period, 91,895 accepted, traumatic injury claims were analyzed. All workers had an injury IRR of 1.04 (95% confidence interval [CI]: 1.02-1.06) while Ag/Construction workers had an IRR of 1.11 (95% CI: 1.06-1.16) when wildfire smoke was

present. When the maximum Heat Index was 75 degrees F or greater, the IRR significantly increased as temperatures increased. When the maximum Heat Index was above 80-84 degrees F, All workers had an IRR of 1.04 (95% CI: 1.01-1.06) while Ag/construction workers had an IRR of 1.14 (95% CI: 1.08-1.21) with risk increasing with increased temperatures. In joint models, heat remained associated with injury rates, but not wildfire smoke. No multiplicative interactions between exposures were observed. CONCLUSION: Increasing temperature was associated with increased rates of traumatic injury claims in Oregon that were more pronounced in Ag/Construction workers. Future work should focus on further understanding these associations and effective injury prevention strategies.

Fortune, M. K., et al. (2013). "Work-attributed illness arising from excess heat exposure in Ontario, 2004-2010." Can J Public Health 104(5): e420-426.

OBJECTIVE: To describe the incidence of occupational heat illness in Ontario. METHODS: Heat illness events were identified in two population-based data sources: work-related emergency department (ED) records and lost time claims for the period 2004-2010 in Ontario, Canada. Incidence rates were calculated using denominator estimates from national labour market surveys and estimates were adjusted for workers' compensation insurance coverage. Proportional morbidity ratios were estimated for industry, occupation and tenure of employment. RESULTS: There were 785 heat illness events identified in the ED encounter records (incidence rate 1.6 per 1,000,000 full-time equivalent (FTE) months) and 612 heat illness events identified in the lost time claim records (incidence rate 1.7 per 1,000,000 FTE months) in the seven-year observation period with peak incidence observed in the summer months. The risk of heat illness was elevated for men, young workers, manual workers and those with shorter employment tenure. A higher proportion of lost time claims attributed to heat illness were observed in the government services, agriculture and construction sectors relative to all lost time claims. CONCLUSIONS: Occupational heat illnesses are experienced in Ontario's population and are observed in ED records and lost time claims. The variation of heat illness incidence observed with worker and industry characteristics, and over time, can inform prevention efforts by occupational health services in Ontario.

Garzon-Villalba, X. P., et al. (2016). "Exertional heat illness and acute injury related to ambient wet bulb globe temperature." Am J Ind Med 59(12): 1169-1176.

BACKGROUND: The Deepwater Horizon disaster cleanup effort provided an opportunity to examine the effects of ambient thermal conditions on exertional heat illness (EHI) and acute injury (AI). METHODS: The outcomes were daily person-based frequencies of EHI and AI. Exposures were maximum estimated WBGT (WBGTmax) and severity. Previous day's cumulative effect was assessed by introducing previous day's WBGTmax into the model. RESULTS: EHI and AI were higher in workers exposed above a WBGTmax of 20 degrees C (RR 1.40 and RR 1.06/ degrees C, respectively). Exposures above 28 degrees C-WBGTmax on the day of the EHI and/or the day before were associated with higher risk of EHI due to an interaction between previous day's environmental conditions and the current day (RRs from 1.0-10.4). CONCLUSIONS: The risk for EHI and AI were higher with increasing WBGTmax. There was evidence of a cumulative effect from the prior day's WBGTmax for EHI. Am. J. Ind. Med. 59:1169-1176, 2016. (c) 2016 Wiley Periodicals, Inc.

Gubernot, D. M., et al. (2015). "Characterizing occupational heat-related mortality in the United States, 2000-2010: an analysis using the Census of Fatal Occupational Injuries database." Am J Ind Med 58(2): 203-211.

BACKGROUND: Occupational heat-related mortality is not well studied and risk factors remain largely unknown. This paper describes the epidemiological characteristics of heat-related deaths among workers in the US 2000-2010. METHODS: Fatality data were obtained at the Bureau of Labor Statistics from the confidential on-site Census of Fatal Occupational Injuries database. Fatality rates and risk ratios with 95% confidence intervals were calculated by year, sex, age group, ethnicity, race, state, and industry. RESULTS: Between 2000 and 2010, 359 occupational heat-related deaths were identified in the U.S., for a yearly average fatality rate of 0.22 per 1 million workers. Highest rates were found among Hispanics, men, the agriculture and construction industries, the state of Mississippi, and very small establishments. CONCLUSIONS: This study provides the first comprehensive national profile of heat-related deaths in the U.S. workplace. Prevention efforts should be directed at small businesses and at industries and individuals with the highest risk.

Hawkins, D. and M. Ibrahim (2023). "Characteristics of Occupational Environmental Heat Injuries/Illnesses: Survey of Occupational Injuries and Illnesses, 2011 to 2019." J Occup Environ Med 65(5): 401-406.

OBJECTIVE: This study describes the characteristics of workers experiencing occupational heat-related injuries/illnesses in the United States and explores the associations between states' average annual temperatures and heat-related injury/illness rates. METHODS: The number and rate of occupational environmental heat injuries/illnesses were calculated according to age group, gender, race/ethnicity, occupation group, and state from 2011 to 2019. RESULTS: Injury/illness rates were higher among Black and Hispanic workers. Workers in farming, fishing, and forestry; installation, maintenance, and repair; and construction/extraction occupations had the highest rates. There was a positive correlation between states' average annual temperatures and heat-related injury/illness rates. DISCUSSION: There are demographic and occupational disparities in occupational environmental heat-related injuries/illnesses in the United States and a correlation between these injuries/illnesses and state average annual temperatures. There is a need for policies and other interventions to protect workers from occupational environmental heat injuries/illnesses.

Jung, J., et al. (2021). "Heat illness data strengthens vulnerability maps." BMC Public Health 21(1): 1999.

BACKGROUND: Previous extreme heat and human health studies have investigated associations either over time (e.g. case-crossover or time series analysis) or across geographic areas (e.g. spatial models), which may limit the study scope and regional variation. Our study combines a case-crossover design and spatial analysis to identify: 1) the most vulnerable counties to extreme heat; and 2) demographic and socioeconomic variables that are most strongly and consistently related to heat-sensitive health outcomes (cardiovascular disease, dehydration, heat-related illness, acute renal disease, and respiratory disease) across 67 counties in the state of Florida, U. S over 2008-2012. METHODS: We first used a case-crossover design to examine the effects of air temperature on daily counts of health outcomes. We employed a time-stratified design with a 28-day comparison window. Referent periods were extracted from +/-7, +/-14, or +/- 21 days to address seasonality. The results are expressed as odds ratios, or the change in the likelihood of each health outcome for a unit change in heat exposure. We then

spatially examined the case-crossover extreme heat and health odds ratios and county level demographic and socioeconomic variables with multiple linear regression or spatial lag models. RESULTS: Results indicated that southwest Florida has the highest risks of cardiovascular disease, dehydration, acute renal disease, and respiratory disease. Results also suggested demographic and socioeconomic variables were significantly associated with the magnitude of heat-related health risk. The counties with larger populations working in farming, fishing, mining, forestry, construction, and extraction tended to have higher risks of dehydration and acute renal disease, whereas counties with larger populations working in installation, maintenance, and repair workers tended to have lower risks of cardiovascular, dehydration, acute renal disease, and respiratory disease. Finally, our results showed that high income counties consistently have lower health risks of dehydration, heat-related illness, acute renal disease, and respiratory disease. CONCLUSIONS: Our study identified different relationships with demographic/socioeconomic variables for each heat-sensitive health outcome. Results should be incorporated into vulnerability or risk indices for each health outcome.

Karthick, S., et al. (2023). "A review of construction workforce health challenges and strategies in extreme weather conditions." Int J Occup Saf Ergon 29(2): 773-784.

Construction sites continue to operate despite inclement weather, exposing workers to unpleasant working circumstances that can lead to various physical and mental health challenges. A thorough literature review yielded 21 challenges for hot weather conditions such as heat stroke, kidney disease, heat cramps, anxiety and depression, and 20 challenges for cold weather conditions like asthma, frostbite, musculoskeletal disorders and hallucination. Workers vulnerable to hot and cold weather based on demographic characteristics were identified. The study also provides 27 strategies to address the challenges experienced in hot and cold weather conditions. Some of these include ensuring that workers stay hydrated, scheduling sufficient rest periods and allowing workers to self-pace. The results of this study will help construction decision-makers and project managers understand the difficulties faced by a field workforce who labors in extreme working conditions on construction sites and will facilitate adoption of strategies that can prevent weather-related physical and mental health problems.

McCarthy, R. B., et al. (2019). "Outcomes of a Heat Stress Awareness Program on Heat-Related Illness in Municipal Outdoor Workers." J Occup Environ Med 61(9): 724-728.

INTRODUCTION: Heat stress is an occupational hazard. Exposed workers may suffer heat-related illness, disease exacerbation, increased injuries, and reduced productivity. Response strategies include mitigation policies and preparedness. METHODS: Frequency of heat-related illness and workers' compensation costs before and after implementation of a voluntary Heat Stress Awareness Program were evaluated retrospectively in outdoor workers from 2009 to 2017. The program consisted of training, acclimatization, and medical monitoring as outlined in NIOSH's Criteria for a Recommended Standard: Occupational Exposure to Heat and Hot Environments. RESULTS: Of the 604 workers assessed, those with two or more risk factors reported a heat-related illness at greater frequency, which decreased after program implementation. Median workers' compensation costs decreased by 50%. DISCUSSION: Heat-related illness prevention programs can be effective in reducing the frequency and severity of these occupational injuries as well as associated costs.

Morrissey, M. C., et al. (2021). "Heat Safety in the Workplace: Modified Delphi Consensus to Establish Strategies and Resources to Protect the US Workers." Geohealth 5(8): e2021GH000443.

The purpose of this consensus document was to develop feasible, evidence-based occupational heat safety recommendations to protect the US workers that experience heat stress. Heat safety recommendations were created to protect worker health and to avoid productivity losses associated with occupational heat stress. Recommendations were tailored to be utilized by safety managers, industrial hygienists, and the employers who bear responsibility for implementing heat safety plans. An interdisciplinary roundtable comprised of 51 experts was assembled to create a narrative review summarizing current data and gaps in knowledge within eight heat safety topics: (a) heat hygiene, (b) hydration, (c) heat acclimatization, (d) environmental monitoring, (e) physiological monitoring, (f) body cooling, (g) textiles and personal protective gear, and (h) emergency action plan implementation. The consensus-based recommendations for each topic were created using the Delphi method and evaluated based on scientific evidence, feasibility, and clarity. The current document presents 40 occupational heat safety recommendations across all eight topics. Establishing these recommendations will help organizations and employers create effective heat safety plans for their workplaces, address factors that limit the implementation of heat safety best-practices and protect worker health and productivity.

Rappaport, S. M., et al. (1999). "Application of mixed models to assess exposures monitored by construction workers during hot processes." Ann Occup Hyg 43(7): 457-469.

Particulate exposures were assessed among construction workers engaged in hot processes in four jobs (boilermakers, ironworkers, pipefitters and welder-fitters) at nine sites in the U.S. After being trained by occupational hygienists, the workers obtained shift-long personal samples at each site for total particulates (TP). Selected samples were also assayed for manganese (Mn), nickel (Ni), and chromium (Cr). Workers provided information about process- and task-related covariates that were present on the days of monitoring. Data were investigated with mixed-model regression analyses that designated the jobs and covariates as fixed effects and the worker and error terms as random effects. Results indicated that the within-worker variance components, but not the between-worker variance components, could be pooled among jobs. Mean air levels for a given agent varied by roughly six to 100 fold among the jobs, with boilermakers and ironworkers experiencing much higher levels of TP and Mn than pipefitters and welder-fitters. Limited data also suggested that welder-fitters were exposed to greater levels of Ni and Cr than pipefitters. Sufficient sample sizes were available to evaluate the effects of covariates upon exposures to TP and Mn. As expected, processes involving more than 50% hot work led to substantially higher levels of TP and Mn than those involving shorter durations of hot work. Local-exhaust or mechanical ventilation reduced exposure to TP (but not Mn) by as much as 44%, and shielded or manual arc welding increased exposure to Mn (but not TP) by about 80%. Parameters estimated with these mixed models were used to calculate probabilities that workers were exposed at levels above U.S. occupational exposure limits (OELs). Regarding TP and Mn, these calculations suggested that 26-95% of exposures to boilermakers and pipefitters and 2-13% of exposures to pipefitters and welder-fitters exceeded the current Threshold Limit Values. Among welder-fitters, limited data also pointed to probabilities of 2-50% for exceeding particular OELs for Ni and Cr. Using the significance of the estimated random-worker effects as a gauge for the uniformity of exposure within a job, administrative or engineering changes appear appropriate for reducing exposures to

boilermakers and ironworkers, while individual personal environments should be investigated for pipefitters and welder-fitters.

Riley, K., et al. (2018). "Mortality and Morbidity during Extreme Heat Events and Prevalence of Outdoor Work: An Analysis of Community-Level Data from Los Angeles County, California." Int J Environ Res Public Health 15(4).

Heat is a well-recognized hazard for workers in many outdoor settings, yet few investigations have compared the prevalence of outdoor work at the community level and rates of heat-related mortality and morbidity. This analysis examines whether heat-related health outcomes occur more frequently in communities with higher proportions of residents working in construction, agriculture, and other outdoor industries. Using 2005-2010 data from Los Angeles County, California, we analyze associations between community-level rates of deaths, emergency department (ED) visits, and hospitalizations during summer heat events and the prevalence of outdoor work. We find generally higher rates of heat-related ED visits and hospitalizations during summer heat events in communities with more residents working outdoors. Specifically, each percentage increase in residents working in construction resulted in an 8.1 percent increase in heat-related ED visits and a 7.9 percent increase in heat-related hospitalizations, while each percentage increase in residents working in agriculture and related sectors resulted in a 10.9 percent increase in heat-related ED visits. The findings suggest that outdoor work may significantly influence the overall burden of heat-related morbidity at the community level. Public health professionals and healthcare providers should recognize work and employment as significant heat risk factors when preparing for and responding to extreme heat events.

Roelofs, C. (2018). "Without Warning: Worker Deaths From Heat 2014-2016." New Solut 28(2): 344-357.

Worker deaths from heat exposure are unlike heat deaths in the general population; workers tend to be outside in variable temperatures and younger than sixty-five years. Climate change will increase the frequency, duration, and variability of hot temperatures. Public health warning systems, such as the Heat Index of the National Weather Service, do not generally account for workers' greater likelihood of exposure to direct sunlight or exertion. Only 28% of the 79 worker heat-related fatalities during 2014-2016 occurred on days when the National Weather Service warning would have included the possibility of fatal heat stroke. Common heat illness prevention advice ignores workers' lack of control over their ability to rest and seek cooler temperatures. Additionally, acclimatization, or phased-in work in the heat, may be less useful given temperature variability under climate change. Workers' vulnerability and context of heat exposure should inform public health surveillance and response to prevent heat illness and death.

Sabrin, S., et al. (2021). "Understanding occupational heat exposure in the United States and proposing a quantifying stress index." Int Arch Occup Environ Health 94(8): 1983-2000.

PURPOSE: Millions of workers exposed to the outdoor environment are extremely susceptible to extreme heat. Although several articles analyzed heat-related illnesses, injuries, fatalities at the country level, few investigated regional and state statistics especially for OSHA Region 4 and the state of Alabama, U.S, which we explored in this study. METHODS: We studied the number of heat-days over 90 degrees F (32.2 degrees C) heat-index within our study area, analyzed heat-related injury and illnesses to calculate their incidence rate during 2015 to

2019, observed the nature of such incidents, their monthly occurrence, and incidence trend over average air temperature. We conducted a comparative analysis of heat-related fatalities between construction and all industries. The existing heat regulations by OSHA and some state agencies have also been summarized. RESULTS: We observed the highest mean, maximum heat-days and injury-illness rate in the south and southeast part of Region 4; increase in incidence rate from 0.03 in 2017 to 0.28 per 10,000 employees in 2018 for the contiguous U.S; highest injury-illness rate (HIR) in OSHA Region 1, 4 and 6; highest HIR in Lee, Montgomery, Mobile and Madison counties of Alabama; 34.7% (construction) and 31.3% (all industries) of all cases experiencing nonclassifiable heat-light effects; high fatalities in construction industry with a trend of 1 death/5 years; increased mortality in all occupations with 1 death/2.4 years. We also proposed a Heat-Stress Index (HSI) as a routine heat-stress measure on jobsite. CONCLUSION: The findings from this research and the proposed index can help in understanding heat-related risk at a regional level and implementing workplace interventions.

Scott, J., et al. (2018). "Ensuring the Right to Rest: City Ordinances and Access to Rest Breaks for Workers in the Construction Industry." J Occup Environ Med 60(4): 331-336.

OBJECTIVE: The aim of this study was to evaluate the effectiveness of city Rest Break Ordinance (RBO) policies in expanding access to rest at work. METHODS: We use data from surveys of construction workers in Austin and Dallas, Texas, in 2009, 2012, and 2015 (n = 557) to calculate the odds of receiving a rest break in pre- versus post-RBO Austin and in post-RBO Austin versus pre-RBO Dallas, controlling for demographic and employment characteristics. RESULTS: Construction workers were 35% more likely to report receiving a rest break in Austin post-RBO and 16% less likely in Dallas without a RBO as compared to Austin with a RBO. CONCLUSION: The increased likelihood of receiving rest breaks at work in a RBO city suggests that, in the absence of enforceable national standards, city-level RBOs can be an important first step to effective prevention of heat-related illnesses (HRIs) and heat-related fatalities at work.

Shi, D. S., et al. (2022). "Hospitalised heat-related acute kidney injury in indoor and outdoor workers in the USA." Occup Environ Med 79(3): 184-191.

OBJECTIVES: To characterise heat-related acute kidney injury (HR-AKI) among US workers in a range of industries. METHODS: Two data sources were analysed: archived case files of the Occupational Safety and Health Administration's (OSHA) Office of Occupational Medicine and Nursing from 2010 through 2020; and a Severe Injury Reports (SIR) database of work-related hospitalisations that employers reported to federal OSHA from 2015 to 2020. Confirmed, probable and possible cases of HR-AKI were ascertained by serum creatinine measurements and narrative incident descriptions. Industry-specific incidence rates of HR-AKI were computed. A capture-recapture analysis assessed under-reporting in SIR. RESULTS: There were 608 HR-AKI cases, including 22 confirmed cases and 586 probable or possible cases. HR-AKI occurred in indoor and outdoor industries including manufacturing, construction, mail and package delivery, and solid waste collection. Among confirmed cases, 95.2% were male, 50.0% had hypertension and 40.9% were newly hired workers. Incidence rates of AKI hospitalisations from 1.0 to 2.5 hours per 100 000 workers per year were observed in high-risk industries. Analysis of overlap between the data sources found that employers reported only 70.6% of eligible HR-AKI hospitalisations to OSHA, and only 41.2% of reports contained a consistent diagnosis. CONCLUSIONS: Workers were hospitalised with HR-AKI in diverse industries, including indoor facilities. Because of under-reporting and

underascertainment, national surveillance databases underestimate the true burden of occupational HR-AKI. Clinicians should consider kidney risk from recurrent heat stress. Employers should provide interventions, such as comprehensive heat stress prevention programmes, that include acclimatisation protocols for new workers, to prevent HR-AKI.

Sinyai, C. and G. Barlet (2020). "Designing Occupational Safety and Health Training Materials for Clear Communication." J Occup Environ Med 62(6): 431-438.

INTRODUCTION: Printed materials are an essential part of occupational safety and health programs. Public health professionals at the Centers for Disease Control and Prevention (CDC) have created a Clear Communication Index (CCI) to guide design of health education materials for the general public. METHODS: We revised an existing handout on heat exposure hazards in construction using the CCI and tested the old and new versions of the handout with an audience of 425 construction apprentices and journey-level workers. RESULTS: Some features recommended by the CCI-such as the use of subheadings, numbering, and other visual cues-strongly conditioned the readers' understanding of the main message. CONCLUSIONS: Design and layout have a significant impact on the delivery of messages in written materials. A communications-based rubric such as the CCI can help writers preparing written occupational safety and health materials for workers and general audiences.

Smith, D. J., et al. (2022). "Using Occupational Histories to Assess Heat Exposure in Undocumented Workers Receiving Emergent Renal Dialysis in Georgia." Workplace Health Saf 70(5): 251-258.

BACKGROUND: Immigrants often work in jobs that are known as dirty, demanding, and dangerous. Globally, the agricultural occupations have been associated with the emergence of chronic kidney disease of unknown etiology (CKDu) primarily in outdoor worker populations. The disease has also been reported in immigrants in the United States who work in agricultural occupations, but little research has been done outside of agricultural workers to determine whether immigrants who work other occupations are at risk for developing CKDu. METHODS: This study assessed the self-reported occupational histories of undocumented immigrants receiving frequent, emergent-only dialysis in Atlanta, GA. We assessed demographics, employment status, and work history, using the Grady Dialysis Questionnaire and the Occupational/Environmental Health History Form. RESULTS: Fifty undocumented immigrants receiving frequent, emergent-only hemodialysis were recruited for this study. The average age was 49.5 years (SD +/- 11.5), and the majority (52%) were female and originated from Mexico (66%). A majority (74%) reported having worked in the past 5 years and 28% reported currently working. A total of 68 unique jobs were reported. In decreasing order of frequency, our sample worked in occupations with documented renal toxicant exposures, such as applying pesticides in landscaping, heat exposure in agriculture, construction, landscaping, and dry cleaning, and lead paint fumes in construction. DISCUSSION: Occupational histories provide a greater understanding of the exposures and working conditions of those receiving frequent, emergent-only hemodialysis. This exploratory study suggests that further research is needed to investigate and assess whether renal toxicants are associated with occupations with high numbers of undocumented workers. APPLICATION TO PRACTICE: A detailed and thorough occupational history should be conducted from those receiving frequent, emergent-only hemodialysis. Developing continuing education for nursing and medical staff in dialysis centers on taking an occupational history, mandatory State reporting requirements, and hazard communication training for workers should be considered. Collaborations between occupational

health professionals, public health authorities, employers, dialysis providers, and clinicians who see undocumented workers is required to understand and develop appropriate prevention measures for this population.

Spector, J. T., et al. (2019). "Heat Exposure and Occupational Injuries: Review of the Literature and Implications." Curr Environ Health Rep 6(4): 286-296.

PURPOSE OF REVIEW: The burden of heat-related adverse occupational health effects, as well as traumatic injuries, is already substantial. Projected increases in mean temperatures and extreme events may increase the risk of adverse heat health effects and enhance disparities among exposed workers. This article reviews the emerging literature on the relationship between heat exposure and occupational traumatic injuries and discusses implications of this work. RECENT FINDINGS: A recent meta-analysis of three case-crossover and five time series studies in industrialized settings reported an association of increasing occupational injuries with increasing heat exposure, with increased effect estimates for male gender and age less than 25 years, although heterogeneity in exposure metrics and sources of bias were demonstrated to varying degrees across studies. A subsequent case-crossover study in outdoor construction workers reported a 0.5% increase in the odds of traumatic injuries per 1 degrees C increase in maximum daily humidex (odds ratio 1.005 [95% CI 1.003-1.007]). While some studies have demonstrated reversed U-shaped associations between heat exposure and occupational injuries, different risk profiles have been reported in different industries and settings. Studies conducted primarily in industrialized settings suggest an increased risk of traumatic injury with increasing heat exposure, though the exact mechanisms of heat exposure's effects on traumatic injuries are still under investigation. The effectiveness of heat-related injury prevention approaches has not yet been established. To enhance the effectiveness of prevention efforts, prioritization of approaches should take into account not only the hierarchy of controls, social-ecological models, community and stakeholder participation, and tailoring of approaches to specific local work settings, but also methods that reduce local and global disparities and better address the source of heat exposure, including conservation-informed land-use planning, built environment, and prevention through design approaches. Participation of occupational health experts in transdisciplinary development and integration of these approaches is needed.

Trumbore, D. C., et al. (2015). "Airborne Exposures to Polycyclic Aromatic Compounds Among Workers in Asphalt Roofing Manufacturing Facilities." J Occup Environ Hyg 12(8): 564-576.

We studied exposure of 151 workers to polycyclic aromatic compounds and asphalt emissions during the manufacturing of asphalt roofing products-including 64 workers from 10 asphalt plants producing oxidized, straight-run, cutback, and wax- or polymer-modified asphalts, and 87 workers from 11 roofing plants producing asphalt shingles and granulated roll roofing. The facilities were located throughout the United States and used asphalt from many refiners and crude oils. This article helps fill a gap in exposure data for asphalt roofing manufacturing workers by using a fluorescence technique that targets biologically active 4-6 ring polycyclic aromatic compounds and is strongly correlated with carcinogenic activity in animal studies. Worker exposures to polycyclic aromatic compounds were compared between manufacturing plants, at different temperatures and using different raw materials, and to important external benchmarks. High levels of fine limestone particulate in the plant air during roofing manufacturing increased polycyclic aromatic compound exposure, resulting in the hypothesis that the particulate brought adsorbed polycyclic aromatic compounds to the worker

breathing zone. Elevated asphalt temperatures increased exposures during the pouring of asphalt. Co-exposures in these workplaces which act as confounders for both the measurement of total organic matter and fluorescence were detected and their influence discussed. Exposures to polycyclic aromatic compounds in asphalt roofing manufacturing facilities were lower than or similar to those reported in hot-mix paving application studies, and much below those reported in studies of hot application of built-up roofing asphalt. These relatively low exposures in manufacturing are primarily attributed to air emission controls in the facilities, and the relatively moderate temperatures, compared to built-up roofing, used in these facilities for oxidized asphalt. The exposure to polycyclic aromatic compounds was a very small part of the overall worker exposure to asphalt fume, on average less than 0.07% of the benzene-soluble fraction. Measurements of benzene-soluble fraction were uniformly below the American Conference of Governmental Industrial Hygienists' Threshold Limit Value for asphalt fume.

International Research

Abdelhamid, T. and J. Everett (2002). "Physiological Demands during Construction Work." Journal of Construction Engineering and Management-asce - J CONSTR ENG MANAGE-ASCE 128.

Notwithstanding the use of earthmoving equipment, cranes, and other machinery, physically strenuous and demanding tasks remain endemic to the construction industry. This research was motivated by the need to investigate the physical demands of construction work and to evaluate whether these physical demands are excessive. Physiological measures of energy expenditure, including oxygen consumption and heart rate data, were collected for 100 construction workers performing typical construction work. The average oxygen uptake for the measured construction activities was 0.82 L·min−1 (±0.22 L·min−1), and the average heart rate for the measured construction activities was 108 beats ·min−1 (±17 beats ·min−1). The measured data were evaluated against published guidelines for acceptable levels of physical performance in industrial settings indicating that a significant number of craft workers (20 to 40%) routinely exceed these physiological thresholds. The results clearly point to the need to promote and apply concepts of work physiology at the workplace to better the occupational health and safety of the construction workforce. This paper developed the foundation for further applied research regarding the physical demands of construction work.

Ahmed, H. O., et al. (2020). "Assessment of thermal exposure level among construction workers in UAE using WBGT, HSI and TWL indices." Ind Health 58(2): 170-181.

The study aimed to assess the heat stress of the construction workers in the United Arab Emirates (UAE), using Wet Bulb Globe temperature (WBGT) index, whereas also computing Heat stress index (HSI), and Thermal Work Limit (TWL) for comparison. Portable Area Heat Stress Monitor (HS-32) was used for measuring WBGToutdoor, Dry Bulb Temperature, Natural Wet Bulb Temperature, Globe Temperature in degrees C, and Relative humidity. The outcomes demonstrated that the WBGT exceeded the recommended Threshold Limit Value (TLV) and that workers are at risk of heat stress. According to HSI, only fit acclimatized young workers can tolerate work in this site, and workers should be selected by medical examination. As per TWL, the site was labeled as Acclimatization Zone implying that no un-acclimatized worker should work here and working alone should be avoided. The construction workers lie at a high or medium risk of heat stress. The contribution of the radiant heat load was very high compared with metabolic load and convective load. Furthermore, WBGT, HSI, and TWL are suitable to

assess thermal stress in construction environments. Scheduling of the work earlier or later (after sunset) along with breaks for rest on cool shaded areas are recommended.

Al-Bouwarthan, M., et al. (2019). "Assessment of Heat Stress Exposure among Construction Workers in the Hot Desert Climate of Saudi Arabia." Ann Work Expo Health 63(5): 505-520.

OBJECTIVES: Excessive heat exposure poses significant risks to workers in hot climates. This study assessed the intensity and duration of heat stress exposure among workers performing residential construction in southeastern Saudi Arabia (SA) during the summer, June-September 2016. Objectives were to: identify work factors related to heat stress exposure; measure environmental heat exposure at the construction sites; assess the heat stress risk among workers using the wet bulb globe temperature (WBGT) index; and determine if temperature-humidity indices can be appropriate alternatives to WBGT for managing heat stress risk at the construction sites. METHODS: Worksite walkthrough surveys and environmental monitoring were performed, indoors and outdoors, at 10 construction sites in Al-Ahsa Province. A heat stress exposure assessment was conducted according to the American Conference of Governmental Industrial Hygienists (ACGIH(R)) guidelines, which uses the WBGT index. WBGT measurements from two instruments were compared. Alternative heat stress indices were compared to the WBGT: the heat index (HI) and humidex (HD) index. RESULTS: Construction workers were exposed to excessive heat stress, indoors and outdoors over a large part of the work day. Complying with a midday outdoor work ban (12-3 p.m.) was not effective in reducing heat stress risk. The highest intensity of exposure was outdoors from 9 a.m. to 12 p.m.; a period identified with the highest hourly mean WBGT values (31-33 degrees C) and the least allowable working time according to ACGIH(R) guidelines. Comparison of the alternative indices showed that the HI is more reliable than the HD as a surrogate for the WBGT index in the climate studied. CONCLUSION: The extreme heat exposure represents a serious risk. The severity of heat stress and its impact are projected to increase due to climate change, emphasizing the need for immediate improvement of the current required protective measures and the development of occupational heat stress exposure guidelines in SA.

Al-Bouwarthan, M., et al. (2020). "A Field Evaluation of Construction Workers' Activity, Hydration Status, and Heat Strain in the Extreme Summer Heat of Saudi Arabia." Ann Work Expo Health 64(5): 522-535.

OBJECTIVES: Assess the impact of summer heat exposure (June-September) on residential construction workers in Al-Ahsa, Saudi Arabia by evaluating (i) heart rate (HR) responses, hydration status, and physical workload among workers in indoor and outdoor construction settings, (ii) factors related to physiological responses to work in hot conditions, and (iii) how well wet-bulb globe temperature-based occupational exposure limits (WBGTOELs) predict measures of heat strain. METHODS: Twenty-three construction workers (plasterers, tilers, and laborers) contributed 260 person-days of monitoring. Workload energy expenditure, HR, fluid intake, and pre- and postshift urine specific gravity (USG) were measured. Indoor and outdoor heat exposures (WBGT) were measured continuously and a WBGTOEL was calculated. The effects of heat exposure and workload on heart rate reserve (HRR), a measure of cardiovascular strain, were examined with linear mixed models. A metric called 'heat stress exceedance' (HSE) was constructed to summarize whether the environmental heat exposure (WBGT) exceeded the heat stress exposure limit (WBGTOEL). The sensitivity and specificity of the HSE as a predictor of cardiovascular strain (HRR >/=30%) were determined. RESULTS: The WBGTOEL was exceeded frequently, on 63 person-days indoors

(44%) and 91(78%) outdoors. High-risk HRR occurred on 26 and 36 person-days indoors and outdoors, respectively. The HSE metric showed higher sensitivity for HRR >/=30% outdoors (89%) than indoors (58%) and greater specificity indoors (59%) than outdoors (27%). Workload intensity was generally moderate, with light intensity work more common outdoors. The ability to self-pace work was associated with a lower frequency of HRR >/=30%. USG concentrations indicated that workers began and ended their shifts dehydrated (USG >/=1.020). CONCLUSIONS: Construction work where WBGTOEL is commonly exceeded poses health risks. The ability of workers to self-pace may help reduce risks.

Al-Bouwarthan, M., et al. (2020). "Risk of Kidney Injury among Construction Workers Exposed to Heat Stress: A Longitudinal Study from Saudi Arabia." Int J Environ Res Public Health 17(11).

Saudi Arabia (SA) is one of the hottest countries in the world. This study was conducted to assess the impact of summer heat stress in Southeastern SA on short-term kidney injury (KI) among building construction workers and to identify relevant risk factors. Measurements of urinary albumin-creatinine ratio (ACR), height, weight, hydration, symptoms, daily work and behavioral factors were collected in June and September of 2016 from a cohort of construction workers (n = 65) in Al-Ahsa Province, SA. KI was defined as ACR >/=30 mg/g. Multivariate linear regression analysis was used to assess factors related to cross-summer changes in ACR. A significant increase in ACR occurred among most workers over the study period; incidence of KI was 18%. Risk factors associated with an increased ACR included dehydration, short sleep, and obesity. The findings suggest that exposure to summer heat may lead to the development of KI among construction workers in this region. Adequate hydration and promotion of healthy habits among workers may help reduce the risk of KI. A reduction in work hours may be the most effective intervention because this action can reduce heat exposure and improve sleep quality.

Ashtekar, S., et al. (2019). "Workplace Heat Exposure Management in Indian Construction Workers Using Cooling Garment." Workplace Health Saf 67(1): 18-26.

Construction workers are at high risk of heat-related illnesses during summer months in India. The personal cooling garment (PCG) is a microclimate assistive device that provides protection from heat stress. The applicability and efficacy of wearing PCG for the physiological and subjective responses were tested on 29 healthy construction workers at actual field worksites. During the test, the climatic conditions were 103.64 +/- 38.3 degrees F dry bulb temperature, 41.2 +/- 13.4% relative humidity, and wet bulb globe temperature 91.43 +/- 39.92 degrees F. Mean weighted skin temperature was significantly lowered by 38.66 +/- 33.98 degrees F when wearing PCG as compared with wearing habitual clothing (HC), 32.36 +/- 33.44 degrees F ($p < .05$). Mean sweat loss was also significantly lower when wearing PCG: 0.365 +/- 0.257 kg as compared with wearing HC: 0.658 +/- 0.342 kg ($p < .05$). Heart rate, along with back and chest skin temperatures were significantly reduced with wearing PCG. The present study suggests that PCG provides an affordable way of alleviating the discomfort and physiological strain caused by environmental heat exposure.

Bates, G. P., et al. (2010). "Hydration status of expatriate manual workers during summer in the middle East." Ann Occup Hyg 54(2): 137-143.

BACKGROUND: Implicit in all indices used for risk assessment in the prevention of heat stress is the assumption that workers are healthy and well hydrated; studies in Australian

mine workers have shown that this is not the case. Where workers are poorly hydrated, the level of protection offered by management strategies based primarily on environmental monitoring is compromised. OBJECTIVES: To investigate the hydration status of expatriate workers during summer in a range of work environments in the Middle East as large numbers of expatriate workers are employed as manual labourers in construction and other industries under extreme heat stress conditions where heat illness is a significant concern. The aim was to ascertain whether the generally inadequate hydration status, previously documented in Australian workers, is also an issue in these workers and make practical recommendations for control. METHODS: Studies were carried out at four sites to document the hydration status of exposed workers in different workplaces using urine specific gravity at three time points over two different work shifts. RESULTS: Although the workers were found in general to be better hydrated than their Australian counterparts, a high proportion were still found to be inadequately hydrated both on presentation for work and throughout the shift. Hydration status did not alter greatly over the course of the day at individual or group level. CONCLUSIONS: Interventions are required to ensure that workers in extreme heat stress conditions maintain adequate levels of hydration. Failure to do so reduces the protection afforded by heat stress indices based on environmental monitoring.

Bates, G. P. and J. Schneider (2008). "Hydration status and physiological workload of UAE construction workers: A prospective longitudinal observational study." J Occup Med Toxicol 3: 21.

BACKGROUND: The objective of the study was to investigate the physiological responses of construction workers labouring in thermally stressful environments in the UAE using Thermal Work Limit (TWL) as a method of environmental risk assessment. METHODS: The study was undertaken in May 2006. Aural temperature, fluid intake, and urine specific gravity were recorded and continuous heart rate monitoring was used to assess fatigue. Subjects were monitored over 3 consecutive shifts. TWL and WBGT were used to assess the thermal stress. RESULTS: Most subjects commenced work euhydrated and maintained this status over a 12-hour shift. The average fluid intake was 5.44 L. There were no changes in core temperature or average heart rate between day 1 and day 3, nor between shift start and finish, despite substantial changes in thermal stress. The results obtained indicated that the workers were not physiologically challenged despite fluctuating harsh environmental conditions. Core body temperatures were not elevated suggesting satisfactory thermoregulation. CONCLUSION: The data demonstrate that people can work, without adverse physiological effects, in hot conditions if they are provided with the appropriate fluids and are allowed to self-pace. The findings suggested that workers will self-pace according to the conditions. The data also demonstrated that the use of WBGT (a widely used risk assessment tool) as a thermal index is inappropriate for use in Gulf conditions, however TWL was found to be a valuable tool in assessing thermal stress.

Bendak, S., et al. (2022). "Effects of high ambient temperature on construction workers performance: A longitudinal empirical study." J Safety Res 81: 197-202.

INTRODUCTION: The construction industry is known to be of high-risk when compared to other industries. Ambient temperature can also exacerbate this risk, where hot weather conditions can lead to increased physical and mental fatigue, reduced performance, slower reactions and more human errors. Yet this issue is rarely researched objectively. This paper describes a longitudinal empirical study that aimed to assess how high ambient

temperatures affect construction workers performance. METHOD: A sample of 120 randomly selected workers (age range 22-35 years) from a large construction company in Dubai participated in this study. Since construction workers performance cannot be directly measured due to the nature of work involved, performance of 60 participants was measured on a task battery involving single reaction time and choice reaction time in summer months before starting work and 5.5 h after starting work. Then the same procedure was repeated on 60 workers in winter months. Accident reports for one full year within the same company were also collected and analyzed. RESULTS: Results show that performance on both tasks before starting work was significantly lower in summer than in winter months possibly due to accumulated fatigue resulting from the high ambient temperature in summer. Results also show that performance on both tasks significantly deteriorated during the first 5.5 h of work to a greater extent in summer months than in winter months. Results also indicate that accidents showed an increasing trend in summer months. CONCLUSIONS: Accumulated fatigue due to high ambient temperature in Summer is thought to cause this drop in performance and increase in accidents. PRACTICAL IMPLICATIONS: Based on the findings, recommendations to enhance construction workers performance and reduce accidents are given.

Bolliet, C., et al. (2015). "Effect of Temperature and Process on Quantity and Composition of Laboratory-generated Bitumen Emissions." J Occup Environ Hyg 12(7): 438-449.

In this study we investigated the impact of temperature on emissions as related to various bitumen applications and processes used in commercial products. Bitumen emissions are very complex and can be influenced in quantity and composition by differences in crude source, refining processes, application temperature, and work practices. This study provided a controlled laboratory environment to study five bitumen test materials from three European refineries; three paving grade, one used for primarily roofing and some paving applications, and one oxidized industrial specialty bitumen. Emissions were generated at temperatures between 140 degrees C and 230 degrees C based on typical application temperatures of each product. Emissions were characterized by aerodynamic particle size, total organic matter (TOM), simulated distillation, 40 individual PACs, and fluorescence (FL-PACs) spectroscopy. Results showed that composition of bitumen emissions is influenced by temperature under studied experimental conditions. A distinction between the oxidized bitumen with flux oil (industrial specialty bitumen) and the remaining bitumens was observed. Under typical temperatures used for paving (150 degrees C-170 degrees C), the TOM and PAC concentrations in the emissions were low. However, bitumen with flux oil produced significantly higher emissions at 230 degrees C, laden with high levels of PACs. Flux oil in this bitumen mixture enhanced release of higher boiling-ranged compounds during application conditions. At 200 degrees C and below, concentrations of 4-6 ring PACs were </=6.51 mug/m(3) for all test materials, even when flux oil was used. Trends learned about emission temperature-process relationships from this study can be used to guide industry decisions to reduce worker exposure during processing and application of hot bitumen.

Bustos, D., et al. (2021). "Applicability of Physiological Monitoring Systems within Occupational Groups: A Systematic Review." Sensors (Basel) 21(21).

The emergence of physiological monitoring technologies has produced exceptional opportunities for real-time collection and analysis of workers' physiological information. To benefit from these safety and health prognostic opportunities, research efforts have explored the applicability of these devices to control workers' wellbeing levels during occupational activities.

A systematic review is proposed to summarise up-to-date progress in applying physiological monitoring systems for occupational groups. Adhering with the PRISMA Statement, five databases were searched from 2014 to 2021, and 12 keywords were combined, concluding with the selection of 38 articles. Sources of risk of bias were assessed regarding randomisation procedures, selective outcome reporting and generalisability of results. Assessment procedures involving non-invasive methods applied with health and safety-related goals were filtered. Working-age participants from homogeneous occupational groups were selected, with these groups primarily including firefighters and construction workers. Research objectives were mainly directed to assess heat stress and physiological workload demands. Heart rate related variables, thermal responses and motion tracking through accelerometry were the most common approaches. Overall, wearable sensors proved to be valid tools for assessing physiological status in working environments. Future research should focus on conducting sensor fusion assessments, engaging wearables in real-time evaluation methods and giving continuous feedback to workers and practitioners.

Chan Albert, P. C., et al. (2013). "Using the Thermal Work Limit as an Environmental Determinant of Heat Stress for Construction Workers." Journal of Management in Engineering 29(4): 414-423.

Construction workers are vulnerable to heat stress in summer as evidenced by deaths and injuries caused by heat stroke. Over the past centuries, many heat-stress indices have been developed to assist with the management of these problems. To address this pressing need of the industry, an enhanced model based on a multi-dimensional environmental indicator, the thermal work limit (TWL) index, is developed. Field studies were conducted between July and September 2010 in Hong Kong on ten apparently healthy and experienced construction rebar workers. Based upon 281 sets of synchronized meteorological and physiological data collected from four different construction sites, physiological, work-related, environmental, and personal parameters were measured to construct the heat-stress model. Multiple linear regression showed that a total of ten determining factors are able to predict the workers' subjective rating of perceived exertion (RPE) (adjusted $R2=0.79$, $p<0.05$). The accuracy of the TWL heat-stress model was found to be statistically acceptable (mean absolute percentage error = 4.3%, Theil's U inequality coefficient = 0.003). Alcohol-drinking habits, age, and work duration are the three most important predictors to determine the physiological responses of construction workers. The model reported in this paper provides a scientific prediction of the reality, which may benefit the construction industry to produce solid guidelines for workers working in hot weather.

Chan, A. P., et al. (2016). "The development of anti-heat stress clothing for construction workers in hot and humid weather." Ergonomics 59(4): 479-495.

The purpose of this study was to develop anti-heat stress clothing for construction workers in hot and humid weather. Following DeJonge's functional clothing design process, the design situation was explored, including clothing fabric heat/moisture transporting properties and UV protection and the aspects of clothing ergonomic design (mobility, convenience, and safety). The problem structure was derived from the results of the surveys in three local construction sites, which agreed well with the task requirements and observations. Specifications were consequently described and 30 commercially available fabrics were identified and tested. Fabric testing data and design considerations were inputted in S-smart system to predict the thermal functional performance of the clothing. A new uniform prototype

was developed and evaluated. The results of all measurements suggest that the new uniform which incorporated fabrics with superior heat/moisture transporting properties and loose-fitting design could reduce the workers' heat stress and improve their comfort and work performance. Practitioner Summary: The construction workers' uniform currently used in Hong Kong during summer was unsatisfactory. Following DeJonge's functional clothing design process, an anti-heat stress uniform was developed by testing 30 fabrics and predicting clothing thermal functional performance using S-smart system. The new uniform could reduce the workers' heat stress and improve their comfort and work performance.

Chan, A. P. and Y. Yang (2016). "Practical on-site measurement of heat strain with the use of a perceptual strain index." Int Arch Occup Environ Health 89(2): 299-306.

OBJECTIVES: There have been increased interests in research on quantifying heat strain of construction workers and formulating corresponding guidelines for working in hot weather. The aim of this study was to validate a subjective measurement tool, the perceptual strain index (PeSI), for measuring heat strain in real-work settings. METHODS: A total of sixteen construction workers were invited to participate in the field surveys. Empiric-based human monitoring was carried out with simultaneous micrometeorological (wet-bulb globe temperature, WBGT), physiological (heart rate, HR), and perceptual (perceived exertion, RPE; thermal sensation, TS) measurements throughout the test. The relative heart rate (RHR), the physiological strain index (PSIHR), and the PeSI were then calculated accordingly. RESULTS: The PeSI exhibited moderate correlations with WBGT and RHR ($r = 0.42$ and 0.40, respectively), which indicated the PeSI was sensitive to the variants of WBGT and RHR. The results of regression analysis indicated that the PeSI changed in the same general manner as the PSIHR, with a relatively large determination coefficient ($R(2) = 0.67$). The established perceptual strain zone illustrated that the PeSI ranging from 7 to 8 would be the exposure limit of construction workers in hot weather. CONCLUSION: The PeSI is a simple, robust, reliable, and user-friendly tool for heat strain assessment in occupational settings. The perceptual strain zone will provide practical guidelines for on-site heat strain monitoring for construction workers.

Chan, A. P., et al. (2018). "Evaluating the usability of a commercial cooling vest in the Hong Kong industries." Int J Occup Saf Ergon 24(1): 73-81.

OBJECTIVE: The provision of appropriate personal cooling vests is recognized as an effective measure to combat heat stress. However, personal cooling vests are not widely implemented in the Hong Kong industries. The current study aims to evaluate the usability of a hybrid cooling vest that is associated with the success of its application in industrial settings. METHODS: A self-administrated questionnaire focusing on 10 subjective attributes of cooling effect, ergonomic design and usability of a hybrid cooling vest was administered with 232 occupational workers in the construction, horticultural and cleaning, airport apron services and kitchen and catering industries. RESULTS: A structural equation model estimated by analysis of moment structures was constructed to evaluate the usability of the cooling vest, as influenced by cooling effect and ergonomic design. Results showed that cooling effect (path coefficient = 0.69, $p < 0.001$) and ergonomic design (path coefficient = 0.55, $p < 0.001$) significantly affect the usability of the cooling vest. CONCLUSIONS: The structural equation model is feasible to examine the complex nature of the structural relationships among the subjective perceptions of personal cooling vests. The empirical findings furnish sound evidence for further optimization

of the hybrid cooling vest in terms of cooling effect and ergonomic design for occupational workers.

Chan, A. P. C., et al. (2017). "A field study of the effectiveness and practicality of a novel hybrid personal cooling vest worn during rest in Hong Kong construction industry." J Therm Biol 70(Pt A): 21-27.

A novel hybrid cooling vest (HCV) incorporated with phase change materials (PCMs) and ventilation fans has been developed for construction workers in Hong Kong to attenuate heat stress and prevent heat-related illnesses, and its effectiveness and practicality have been validated in this study. A total of 140 wear trials involving of 140 workers were conducted in Hong Kong construction sites during the summer time. Each wear trial involves a two-day wear test, of which one day workers wore the HCV (denoted as VEST) during resting, and another day they wore traditional workwear (denoted as CON). Subjects were asked to rate their perceived exertion (RPE), thermal sensations (TS) and 7 other subjective attributes. There were significant differences in the effectiveness on reducing workers' heat strain between VEST and CON in terms of alleviations of heart rate (DeltaHR), DeltaTS, DeltaRPE as well as DeltaPeSI ($p < 0.001$). The practicality of HCV is evidenced by a significant improvement by 0.93-1.34 on the rating scores of perceived cooling effect, sensations of comfort and skin dryness during rest and fatigue recovery in VEST at the level of 0.05, and high ratings of 4.85-5 (rating scale from 1 to 7, and the higher the better) by subjects on the preference, fitness as well as effectiveness to combat heat stress. In addition, a remarkable proportion of 91 per cent of subjects prefer to use this newly designed HCV as a cooling measure during rest. The power to alleviate perceptual heat stain (PeSA) in VEST is about twice of that by rest, which means HCV can notably improve the workers' perceptual heat strain in a limited resting duration. However, the strain alleviation power of HCV nearly remains unchanged with the prolonged rest duration. Thus, the optimal work-rest schedule needs to be investigated in a further study.

Dehghan, H., et al. (2012). "Evaluation of wet bulb globe temperature index for estimation of heat strain in hot/humid conditions in the Persian Gulf." J Res Med Sci 17(12): 1108-1113.

BACKGROUND: Heat exposure among construction workers in the Persian Gulf region is a serious hazard for health. The aim of this study was to evaluate the performance of wet bulb globe temperature (WBGT) Index for estimation of heat strain in hot/humid conditions by the use of Physiological Strain Index (PSI) as the gold standard. MATERIAL AND METHODS: This cross-sectional study was carried out on 71 workers of two Petrochemical Companies in South of Iran in 2010 summer. The WBGT index, heart rate, and aural temperature were measured by Heat Stress Monitor (Casella Microtherm WBGT), Heart Rate Monitor (Polar RS100), and Personal Heat Strain Monitor (Questemp II), respectively. The obtained data were analyzed with descriptive statistics and Pearson correlation analysis. RESULTS: The mean (SD) of WBGT values was 33.1 (2.7). The WBGT values exceed from American Conference of Governmental Industrial Hygienists (ACGIH) standard (30 degrees C) in 96% work stations, whereas the PSI values were more than 5.0 (moderate strain) in 11% of workstations. The correlation between WBGT and PSI values was 0.61 ($P = 0.001$). When WBGT values were less and more than 34 degrees C, the mean of PSI was 2.6 (low strain) and 5.2 (moderate strain), respectively. CONCLUSION: In the Persian Gulf weather, especially hot and humid in the summer months, due to the WBGT values exceeding 30 degrees C (in 96% of cases) and weak correlation between WBGT and PSI, the work/rest cycles of WBGT Index is

not suitable for heat stress management. Therefore, in Persian Gulf weather, heat stress evaluation based on physiologic variables may have higher validity than WBGT index.

Doueihy, C., et al. (2022). "Occupational Heat Exposure as a Risk Factor for End-Stage Kidney Disease: A Case-Control Study." J Occup Environ Med 64(3): e103-e108.

OBJECTIVE: More patients are reaching end-stage kidney disease without evident cause. This study aims to explore occupational risk factors associated with hemodialysis. METHODS: A multicenter matched case-control study included dialysis patients and age, sex, and diabetes-matched controls (normal kidney function). Conditional logistic regression analysis assessed occupational factors associated with dialysis. RESULTS: Two hundred thirty eight hemodialysis patients and 238 controls were included. History of occupational heat exposure (odds ratio [OR] = 1.93; 95% confidence interval [CI]: 1.24 to 3.00), working as a cook (OR = 12; 95% CI: 1.56 to 92.29), as construction worker (OR = 10; 95% CI: 1.28 to 78.12) were associated with higher risk of dialysis. These results were significant in men and in those with kidney disease of unknown etiology. CONCLUSIONS: Occupational heat exposure was found to be associated with hemodialysis. This is an important step for future development of preventive strategies in high-risk professions.

Dutta, P., et al. (2015). "Perceived heat stress and health effects on construction workers." Indian J Occup Environ Med 19(3): 151-158.

INTRODUCTION: Increasing heat waves-particularly in urban areas where construction is most prevalent, highlight a need for heat exposure assessment of construction workers. This study aims to characterize the effects of heat on construction workers from a site in Gandhinagar. MATERIALS AND METHODS: This study involved a mixed methods approach consisting of a cross sectional survey with anthropometric measurements (n = 219) and four focus groups with construction workers, as well as environmental measurements of heat stress exposure at a construction site. Survey data was collected in two seasons i.e., summer and winter months, and heat illness and symptoms were compared between the two time periods. Thematic coding of focus group data was used to identify vulnerability factors and coping mechanisms of the workers. Heat stress, recorded using a wet bulb globe temperature monitor, was compared to international safety standards. RESULTS: The survey findings suggest that heat-related symptoms increased in summer; 59% of all reports in summer were positive for symptoms (from Mild to Severe) as compared to 41% in winter. Focus groups revealed four dominant themes: (1) Non-occupational stressors compound work stressors; (2) workers were particularly attuned to the impact of heat on their health; (3) workers were aware of heat-related preventive measures; and (4) few resources were currently available to protect workers from heat stress. Working conditions often exceed international heat stress safety thresholds. Female workers and new employees might be at increased risk of illness or injury. CONCLUSION: This study suggests significant health impacts on construction workers from heat stress exposure in the workplace, showed that heat stress levels were higher than those prescribed by international standards and highlights the need for revision of work practices, increased protective measures, and possible development of indigenous work safety standards for heat exposure.

El-Shafei, D. A., et al. (2018). "Exertional heat illness: knowledge and behavior among construction workers." Environ Sci Pollut Res Int 25(32): 32269-32276.

Construction workers are considered one of the most vulnerable health group workers. Exertional heat illness (EHI) is a well-recognized health hazard that causes significant sickness and death. The purpose of this study was to assess construction workers' environment and hydration status and to evaluate the effect of health education program on workers. An interventional study was conducted on 89 construction workers in Port Said City. Assessments of workplace environment and workers' hydration status were done by using workplace evaluation checklist, wet-bulb globe temperature, urine specific gravity, and urine color chart. A pre-post-test design was used in the evaluation of workers' knowledge and behavior regarding EHI. A health education program was conducted to improve workers' knowledge and behavior; then, evaluation was done after 1 month. The most reported symptoms of heat illness were sweating (100.0%), dizziness (98.0%), and muscle pain (82.0%). Most workers showed signs of minimal dehydration (78.7%). There was a significant improvement in workers' knowledge about EHI and behavioral action for prevention after health education. Construction workers are at high risk of exposure to EHI which raised the attention to provide educational programs which can guide workers to follow healthy behaviors and prevent EHI.

Farshad, A., et al. (2014). "Heat Stress Level among Construction Workers." Iran J Public Health 43(4): 492-498.

BACKGROUND: The purpose of this study was to determine the level of heat stress to construction workers using Thermal Work Limit (TWL) and Wet Bulb Globe Temperature (WBGT) indices and by measuring Urine Specific Gravity (USG) among construction workers in Iran and comparing the appropriateness of these indices for measuring heat stress in Iran climate. METHODS: This comparative and experimental study was conducted during September 2012 in Baghe Ketabe Tehran, one of the large size construction sites in Tehran City, Iran. Sixty participants were randomly selected in two groups (exposed to sun and non-exposed) among the construction workers in a construction campus with similar work type, climate and diet. TWL and WBGT and USG were measured in two consequent days and at the beginning, mid and end of the work shift, for both groups. RESULTS: The mean WBGT index was 22.6 +/- 0.9 degrees C for control group and 27.5 +/- 1.2 degrees C for exposure group, the mean TWL index measure was 215.8 +/- 5.2 W/m(2) for control group and 144 +/- 9.8 W/m(2) for exposure group and the mean USG was 1.0213 +/- 0.0054 in control group and 1.026 +/- 0.005 in exposure group. There was a significant difference in TWL, WBGT and USG between exposed and non-exposed group ($P<0.01$). CONCLUSION: workers were at an allowed level of heat stress. TWL, WBGT and USG measures were significantly correlated; however as TWL level enabled classification based on required intervention, it had some merit over WBGT index.

Fatima, S. H., et al. (2021). "Extreme heat and occupational injuries in different climate zones: A systematic review and meta-analysis of epidemiological evidence." Environ Int 148: 106384.

BACKGROUND: The link between heat exposure and adverse health outcomes in workers is well documented and a growing body of epidemiological evidence from various countries suggests that extreme heat may also contribute to increased risk of occupational injuries (OI). Previously, there have been no comparative reviews assessing the risk of OI due to extreme heat within a wide range of global climate zones. The present review therefore aims to summarise the existing epidemiological evidence on the impact of extreme heat (hot temperatures and heatwaves (HW)) on OI in different climate zones and to assess the individual risk factors associated with workers and workplace that contribute to heat-associated OI risks.

METHODS: A systematic review of published peer-reviewed articles that assessed the effects of extreme heat on OI among non-military workers was undertaken using three databases (PubMed, Embase and Scopus) without temporal or geographical limits from database inception until July 2020. Extreme heat exposure was assessed in terms of hot temperatures and HW periods. For hot temperatures, the effect estimates were converted to relative risks (RR) associated with 1 degrees C increase in temperature above reference values, while for HW, effect estimates were RR comparing heatwave with non-heatwave periods. The patterns of heat associated OI risk were investigated in different climate zones (according to Koppen Geiger classification) based on the study locations and were estimated using random-effects meta-analysis models. Subgroup analyses according to workers' characteristics (e.g. gender, age group, experience), nature of work (e.g. physical demands, location of work i.e. indoor/outdoor) and workplace characteristics (e.g. industries, business size) were also conducted. RESULTS: A total of 24 studies published between 2005 and 2020 were included in the review. Among these, 22 studies met the eligibility criteria, representing almost 22 million OI across six countries (Australia, Canada, China, Italy, Spain, and USA) and were included in the meta-analysis. The pooled results suggested that the overall risk of OI increased by 1% (RR 1.010, 95% CI: 1.009-1.011) for 1 degrees C increase in temperature above reference values and 17.4% (RR 1.174, 95% CI: 1.057-1.291) during HW. Among different climate zones, the highest risk of OI during hot temperatures was identified in Humid Subtropical Climates (RR 1.017, 95% CI: 1.014-1.020) followed by Oceanic (RR 1.010, 95% CI: 1.008-1.012) and Hot Mediterranean Climates (RR 1.009, 95% CI: 1.008-1.011). Similarly, Oceanic (RR 1.218, 95% CI: 1.093-1.343) and Humid Subtropical Climates (RR 1.213, 95% CI: 0.995-1.431) had the highest risk of OI during HW periods. No studies assessing the risk of OI in Tropical regions were found. The effects of hot temperatures on the risk of OI were acute with a lag effect of 1-2 days in all climate zones. Young workers (age < 35 years), male workers and workers in agriculture, forestry or fishing, construction and manufacturing industries were at high risk of OI during hot temperatures. Further young workers (age < 35 years), male workers and those working in electricity, gas and water and manufacturing industries were found to be at high risk of OI during HW. CONCLUSIONS: This review strengthens the evidence on the risk of heat-associated OI in different climate zones. The risk of OI associated with extreme heat is not evenly distributed and is dependent on underlying climatic conditions, workers' attributes, the nature of work and workplace characteristics. The differences in the risk of OI across different climate zones and worker subgroups warrant further investigation along with the development of climate and work-specific intervention strategies.

Han, S.-R., et al. (2021). "Perceptions of workplace heat exposure and adaption behaviors among Chinese construction workers in the context of climate change." BMC Public Health 21(1): 2160.

Workplace heat exposure can cause a series of heat-related illnesses and injuries. Protecting workers especially those undertake work outdoors from the risk of heat strain is a great challenge for many workplaces in China under the context of climate change. The aim of this study is to investigate the perceptions and adaptation behaviors of heat exposure among construction workers and to provide evidence for the development of targeted heat adaptation strategies nationally and internationally.

Havet, N., et al. (2020). "Disparate exposure to physically demanding working conditions in France." Rev Epidemiol Sante Publique 68(6): 327-336.

BACKGROUND: Our study was aimed at examining disparate exposure to physically demanding working conditions in France, a key objective being to identify the types of employees/jobs requiring high-priority preventive actions. METHODS: We analyzed the data from the 2017 French nationwide cross-sectional survey (SUMER) on occupational hazards to which French employees in various sectors were subjected. The prevalence of several types of physically demanding working conditions (lifting of heavy loads, awkward body postures, vibrations, noise, and extreme temperatures) was explored. Potential associations of individual and job characteristics with these factors of hardship at work were studied by multivariate logistic regression. RESULTS: In total, 48% of employees were exposed to at least one physically demanding working condition and 24.8% were exposed to multiple constraints. While managers and intellectual professionals were exposed relatively infrequently to physical constraints, blue-collar workers experienced the highest frequency of exposure. On the one hand, the role of company size depended on the factor of hardship at work considered; on the other hand, employees in large-scale companies were generally less exposed. As expected, employees in the construction industry were the most exposed to physical constraints; that said, our results also show that some activities in the services sector (e.g., personal care, administrative and support services) were quite significantly affected by a wide array of physically demanding working conditions. CONCLUSION: Notwithstanding the establishment in France of Plans de Sante au travail (preventive workplace health and safety plans), occupational risks were found to be high, and above all, they were unevenly distributed among the various socio-professional categories, and strongly contributed to social inequalities in health. Our results identify the types of publics to be designated as high-priority targets for preventive measures aimed at reducing the adverse impacts of physically demanding working conditions and the incidence of associated musculoskeletal disorders.

Inaba, R. and S. M. Mirbod (2007). "Comparison of subjective symptoms and hot prevention measures in summer between traffic control workers and construction workers in Japan." Ind Health 45(1): 91-99.

In the present study, a survey on subjective symptoms and hot prevention measures in summer was conducted in 204 male traffic control workers and 115 male construction workers. Work loads of traffic control workers and construction workers were estimated at RMR 1-2 and RMR 2-4, respectively. A self-administered questionnaire was used to collect information on age, occupational career, working habit, present or past history of diseases, individual preventive measures to the heat, and subjective symptoms in the summer. Daily working hours in the sunshine of the traffic control workers were significantly longer than those of the construction workers. Prevalence rates of changing clothes frequently, avoiding direct exposure of face and neck to sunlight using towel like materials, and wearing sunglasses in the traffic control workers were significantly lower than the construction workers. Prevalence rates of symptoms in the upper extremities in the traffic control workers were significantly lower than those in the construction workers. Prevalence of work difficulty due to hot weather during work in the traffic control workers was significantly lower than the construction workers. On the basis of the results obtained, some preventive countermeasures to improve working environment are presented.

Ionita, G., et al. (2023). "Development of a Prototype Observatory of Heat-Related Occupational Illnesses and Injuries through the Collection of Information from the Italian Press, as Part of the WORKLIMATE Project." Int J Environ Res Public Health 20(5).

Exposure to heat is a recognized occupational risk factor. Deaths and accidents at work caused by high temperatures are underestimated. With the aim of detecting and monitoring heat-related illnesses and injuries, a prototype database of occupational events attributable to critical thermal conditions reported in Italian newspapers was created. Information was analyzed from national and local online newspapers using a web application. The analysis was conducted from May to September during the three-year period 2020-2022. Articles concerning 35 occupational heat-related illnesses and injuries were selected; 57.1% of the events were reported in 2022, and 31.4% of total accidents occurred in the month of July 2022, when the Universal Thermal Climate Index daily mean values corresponded to "moderate heat stress" (51.0%) and "strong heat stress" (49.0%). Fatal heat-related illnesses were the most frequent conditions described. In most cases, workers had been involved in outdoor activities in the construction sector. A comprehensive report was created by compiling all relevant newspaper articles to enhance awareness of this issue among relevant stakeholders and promote heat-risk prevention strategies in the current context where heatwaves are becoming increasingly frequent, intense and long-lasting.

Jia, Y. A., et al. (2016). "Climatic and psychosocial risks of heat illness incidents on construction site." Appl Ergon 53 Pt A: 25-35.

The study presented in this paper aims to identify prominent risks leading to heat illness in summer among construction workers that can be prioritised for developing effective interventions. Samples are 216 construction workers' cases at the individual level and 26 construction projects cases at the organisation level. A grounded theory is generated to define the climatic heat and psychosocial risks and the relationships between risks, timing and effectiveness of interventions. The theoretical framework is then used to guide content analysis of 36 individual onsite heat illness cases to identify prominent risks. The results suggest that heat stress risks on construction site are socially constructed and can be effectively managed through elimination at supply chain level, effective engineering control, proactive control of the risks through individual interventions and reactive control through mindful recognition and response to early symptoms. The role of management infrastructure as a base for effective interventions is discussed.

Kahkonen, E., et al. (1992). "Estimation of heat stress in Tanzania by using ISO heat stress indices." Appl Ergon 23(2): 95-100.

The aim of this study was to evaluate the usefulness of the ISO heat stress standards in estimating the heat stress and strain in workplaces in Tanzania. Another aim was to select and to develop simplified methods for measuring physiological parameters in developing countries. The methods were tested in four hot factories and at a construction site. It seems that in tropical working environments the climatic conditions for which the ISO 7933 standard is applicable are too narrow. For instance, the mean skin temperature was incorrectly estimated by ISO 7933. An approximate analysis of the working situation can nevertheless be carried out by assuming the mean skin temperature to be 34.5 degrees C. During the study, heat stress and strain were not as high as expected; deep body temperatures were usually lower than 38 degrees C, sweat rates lower than 400 g/h and heart rates below 100 beats/min for about 72% of the measuring time. This is due to the job rotation of the workers and the long rest periods, because the number of workers is large in the factories, and the weather was not at its hottest during the survey.

Kakamu, T., et al. (2021). "Heat-related illness risk and associated personal and environmental factors of construction workers during work in summer." Sci Rep 11(1): 1119.

Heat-related illness (HRI) is a common occupational injury, especially in construction workers. To explore the factors related to HRI risk in construction workers under hot outdoor working conditions, we surveyed vital and environmental data of construction workers in the summer season. Sixty-one workers joined the study and the total number of days when their vital data during working hours and environmental data were recorded was 1165. Heart rate with high-risk HRI was determined using the following formula: 180 - 0.65 x age. As a result of the logistic regression analysis, age, working area, maximum skin temperature, and heart rate immediately after warming up were significantly positively related, and experience of construction was significantly negatively related to heart rate with high-risk HRI. Heart rate immediately after warming up may indicate morning fatigue due to reasons such as insufficient sleep, too much alcohol intake the night before, and sickness. Asking morning conditions may lead to the prevention of HRI. For occupational risk management, monitoring of environmental and personal conditions is required.

Karthick, S., et al. (2023). "Analysis of the Health and Safety Challenges Faced by Construction Workers in Extreme Hot Weather Conditions." Journal of Legal Affairs and Dispute Resolution in Engineering and Construction 15(1): 04522048.

The increasing number of extremely hot days globally has made outdoor workers more vulnerable to heat-related illnesses such as heat syncope, heat exhaustion, heat edema, and heat stress. The objective of this article is to identify and analyze the challenges experienced by construction workers who work in extremely hot weather conditions for extended periods of time. To achieve this objective, a questionnaire was developed and distributed through the online platform QuestionPro. The 100 responses that were collected were analyzed using the Kruskal-Wallis test, and analyses were performed based on physiological indicators such as heart rate and blood pressure and personal indicators such as climate acclimatization and clothing comfort. The results of the analyses revealed that challenges such as physical fatigue, dehydration, excessive sweating, inability to concentrate, and frequent mood fluctuations were unique to individuals based on their acclimatization level, heart rate, and blood pressure. Optimized work-rest hours, the provision of adequate time for workers to acclimate to extreme conditions, and adoption of technologies such as cooling vests and continuous monitoring of workers' physical parameters are some of the strategies that can be used to protect workers from heat-related health hazards. The article also briefly discusses the practices and regulations that are currently in effect to protect construction workers who are exposed to prolonged hot weather conditions. The findings presented in this article will help professionals in the construction sector effectively manage and safeguard workers' health in extreme hot weather conditions.

Kim, J. H., et al. (2020). "Development of an IoT-Based Construction Worker Physiological Data Monitoring Platform at High Temperatures." Sensors (Basel) 20(19).

This study presents an IoT-based construction worker physiological data monitoring platform using an off-the-shelf wearable smart band. The developed platform is designed for construction workers performing under high temperatures, and the platform is composed of two parts: an overall heat assessment (OHS) and a personal management system (PMS). OHS manages the breaktimes for groups of workers based using a thermal comfort index (TCI), as provided by the Korea Meteorological Administration (KMA), while PMS assesses the

individual health risk level based on fuzzy theory using data acquired from a commercially available smart band. The device contains three sensors (PPG, Acc, and skin temperature), two modules (LoRa and GPS), and a power supply, which are embedded into a microcontroller (MCU). Thus, approved personnel can monitor the status as well as the current position of a construction worker via a PC or smartphone, and can make necessary decisions remotely. The platform was tested in both indoor and outdoor environment for reliability, achieved less than 1% of error, and received satisfactory feedback from on-site users.

Langkulsen, U., et al. (2010). "Health impact of climate change on occupational health and productivity in Thailand." Glob Health Action 3.

BACKGROUND: The rise in global temperature is well documented. Changes in temperature lead to increases in heat exposure, which may impact health ranging from mild heat rashes to deadly heat stroke. Heat exposure can also aggravate several chronic diseases including cardiovascular and respiratory disease. OBJECTIVE: This study examined the relationship between climate condition and health status and productivity in two main categories of the occupational setting - where one setting involves heat generated from the industry and the other with heat in a natural setting. DESIGN: This cross-sectional study included four industrial sites (pottery industry, power plant, knife industry, and construction site) and one agricultural site in the Pathumthani and Ayutthaya provinces. Exposure data were comprised of meteorological data and heat exposure including relative humidity (RH) measured by Wet Bulb Globe Temperature (WBGT) monitor. Heat index was calculated to measure the effects of heat exposure on the study population, which consisted of 21 workers at five worksites; a questionnaire was also used to collect data on workers. RESULTS: Among the five workplaces, the outdoor WBGT was found to be highest at 34.6 degrees C during 12:00 and 1:00 PM at the agricultural site. It was found that four out of five study sites had heat indices in the 'extreme caution,' where heat cramp and exhaustion may be possible and one site showed a value of 41 degrees C that falls into the category of 'danger,' where sunstroke and heat exhaustion are likely and prolonged exposure may lead to heatstroke. Productivity as perceived by the workers revealed that only the construction and pottery industry workers had a loss of productivity ranged from 10 to 60 %. CONCLUSIONS: Climate conditions in Thailand potentially affect both the health and productivity in occupational settings.

Levi, M., et al. (2018). "Impact of climate change on occupational health and productivity: a systematic literature review focusing on workplace heat." Med Lav 109(3): 163-179.

BACKGROUND: With climate change, mean annual air temperatures are getting hotter and extreme weather events will become more and more common in most parts of the world. OBJECTIVES: As part of the EU funded project HEAT-SHIELD we conducted a systematic review to summarize the epidemiological evidence of the effects of global warming-related heat exposure on workers' health and productivity. METHODS: Three separate searches, focused, respectively, on: i) heat-related illness (HRI), cardiovascular, respiratory and kidney diseases; ii) traumatic injuries; and iii) vector-borne diseases or vectors distribution, were conducted in PubMed. EMBASE was also consulted to retrieve relevant studies focused on the health effects of climate change. A fourth search strategy to assess the effects on work productivity was conducted both in PubMed and in the SCOPUS database. RESULTS: A significant proportion of studies reported findings regarding the Mesoamerican nephropathy issue. This is a disease occurring especially among young and middle-aged male sugarcane workers, without conventional risk factors for chronic kidney disease. For injuries, there is a reversed U-shaped

exposure-response relationship between Tmax and overall daily injury claims. Outdoor workers are at increased risk of vector-borne infectious diseases, as a positive correlation between higher air temperatures and current or future expansion of the habitat of vectors is being observed. As for productivity, agriculture and construction are the most studied sectors; a day with temperatures exceeding 32 degrees C can reduce daily labour supply in exposed sectors by up to 14%. CONCLUSIONS: The present findings should inform development of further research and related health policies in the EU and beyond with regard to protecting working people from the effects of workplace heat during climate change.

Lin, R., et al. (2017). "No Difference Between Noxious and Innocuous Thermal Stimulation on Motor Recovery of Upper Extremity in Patients With Acute Stroke: A Randomized Controlled Trial With 6-Month Follow-up." PM R 9(12): 1191-1199.

BACKGROUND: Thermal stimulation (TS) has been developed and incorporated into stroke rehabilitation. However, whether noxious and innocuous TS induce the same effects on motor function recovery after stroke is still unknown. A comparative study of different temperature combination regimens is needed. OBJECTIVE: To compare the short- and long-term effectiveness between noxious and innocuous TS on motor recovery of upper extremity in patients with acute stroke. DESIGN: Randomized, controlled trial with concealed allocation, intention-to-treat analysis and blinded outcome assessors. SETTING: A university hospital rehabilitation department in Taiwan. PARTICIPANTS: A total of 79 patients with acute ischemic stroke were recruited. The majority had moderate to severe motor impairment of the upper extremity (UE). INTERVENTION: In addition to traditional rehabilitation, the experimental group (n = 39) underwent noxious TS (heat pain 46-47 degrees C/cold pain 7-8 degrees C), and the control group (n = 40) received innocuous TS (heat 40-41 degrees C/cold 20-21 degrees C). TS intervention was applied for 30 minutes once per day and for a total of 20-24 times during hospital stay. A custom-made TS instrument, comprising 2 thermal stimulators and their respective thermal pads constructed in a closed-loop system, was used. OUTCOMES: The Fugl-Meyer upper extremity score (the primary outcome), Action Research Arm Test, Motricity Index, Barthel Index, and modified Ashworth scale (the secondary outcomes) were administered by a blinded assessor at baseline, post-12th TS, post-intervention, 1-month, and 6-month follow-ups. RESULTS: No significant differences between groups were found on the primary outcome at postintervention and follow-up assessments. At 1-month follow-up, the innocuous group showed a small effect (partial eta(2) = 0.02) that was greater than that of the noxious group, but that effect was eliminated at 6 months. Both groups presented significant within-group improvements over time (both $P < .001$). CONCLUSIONS: Combining noxious TS with traditional rehabilitation did not yield better short-term or long-term results than combining innocuous TS with traditional rehabilitation on UE functional recovery for individuals with acute stroke. LEVEL OF EVIDENCE: II.

Lin, R. T. and C. C. Chan (2009). "Effects of heat on workers' health and productivity in Taiwan." Glob Health Action 2.

BACKGROUND: The impact of global warming on population health is a growing concern and has been widely discussed. The issue of heat stress disorders and consequent productivity reduction among workers has not yet been widely addressed. Taiwan is an island straddling the Tropic of Cancer in the West Pacific and has both subtropical and tropical climates. As of 2008, the economy of Taiwan accounts for 1.1% of the world gross domestic product at purchasing power parity and is listed as 19th in the world and eighth in Asia,

according to International Monetary Fund data. OBJECTIVE: The aim of this paper is to identify occupations at risk and the potential health impacts of heat on workers in Taiwan. DESIGN: Historical data relating to meteorology, population, the labour force and economy were obtained from publicly available databases from the Taiwanese government. RESULTS: Hot seasons with an average maximum temperature above 30 degrees C and relative humidity above 74%, lasting for four to six months from May to October, pose health threats to construction, farming and fishery workers. In particular, populations of ageing farmers and physically overloaded construction workers are the two most vulnerable worker categories in which high temperature impacts on health and productivity. CONCLUSIONS: Currently, regulations and preventive actions for heat relief are difficult to enforce for several reasons, including lack of equipment for measuring environmental conditions, lack of awareness of potential hazards and strict time constraints imposed on workers. There is an urgent need to systematically and comprehensively assess the impact of a warming climate on workers' health and productivity to provide effective prevention strategies for a better working and living environment in Taiwan.

Lohrey, S., et al. (2021). "Perceptions of heat-health impacts and the effects of knowledge and preventive actions by outdoor workers in Hanoi, Vietnam." Sci Total Environ 794: 148260.

Extreme heat is an increasing climate threat, most pronounced in urban areas where poor populations are at particular risk. We analyzed heat impacts and vulnerabilities of 1027 outdoor workers who participated in a KAP survey in Hanoi, Vietnam in 2018, and the influence of their mitigation actions, their knowledge of heat-risks, and access to early warnings. We grouped respondents by their main income (vendors, builders, shippers, others, multiple jobs, and non-working) and analyzed their reported heat-health impacts, taking into consideration socioeconomics, knowledge of heat impacts and preventive measures, actions taken, access to air-conditioning, drinking amounts and use of weather forecasts. We applied linear and logistic regression analyses using R. Construction workers were younger and had less knowledge of heat-health impacts, but also reported fewer symptoms. Older females were more likely to report symptoms and visit a doctor. Access to air-conditioning in the bedroom depended on age and house ownership, but did not influence heat impacts as cooling was too expensive. Respondents who knew more heat exhaustion symptoms were more likely to report impacts ($p < 0.01$) or consult a doctor ($p < 0.05$). Similarly, those who checked weather updates were more likely to report heat impacts ($p < 0.01$) and experienced about 0.6 more symptoms ($p < 0.01$). Even though occupation type did not explain heat illness, builders knew considerably less (40%; $p < 0.05$) about heat than other groups but were twice as likely to consult a doctor than street vendors ($p < 0.01$). Knowledge of preventive actions and taking these actions both correlated positively with reporting of heat-health symptoms, while drinking water did not reduce these symptoms ($p < 0.01$). Child carers and homeowners experienced income losses in heatwaves ($p < 0.01$). The differences support directed actions, such as dissemination of educational materials and weather forecasts for construction workers. The Red Cross assisted all groups with cooling tents, provision of drinks and health advice.

Longuenesse, E. (1985). "[Indian workers in Oman]." Tiers Monde (1960) 26(103): 567-582.

Until recently Oman was a country of emigration, but by 1980 an estimated 200,000 foreign workers were in the country due to the petroleum boom. Almost 1/3 of the estimated 300,000 Indian workers in the Gulf states were in Oman, a country whose colonial heritage was closely tied to that of India and many of whose inhabitants still speak Urdu. The number of

work permits granted to Indians working in the private sector in Oman increased from 47,928 in 1976 to 80,787 in 1980. An estimated 110,000 Indians were working in Oman in 1982, the great majority in the construction and public works sector. A few hundred Indian women were employed by the government of Oman, as domestics, or in other capacities. No accurate data is available on the qualifications of Indian workers in Oman, but a 1979 survey suggested a relatively low illiteracy rate among them. 60-75% of Indians in Oman are from the state of Kerala, followed by workers from the Punjab and the southern states of Tamil Nadu and Andhra Pradesh and Bombay. Indian workers are recruited by specialized agencies or by friends or relatives already employed in Oman. Employers in Oman prefer to recruit through agencies because the preselection process minimizes hiring of workers unqualified for their posts. Officially, expenses of transportation, visas, and other needs are shared by the worker and the employer, but the demand for jobs is so strong that the workers are obliged to pay commissions which amount to considerable sums for stable and well paying jobs. Wages in Oman are however 2 to 5 times the level in India. Numerous abuses have been reported in recruitment practices and in failure of employers in Oman to pay the promised wages, but Indian workers have little recourse. At the same level of qualifications, Indians are paid less then non-Omani Arabs, who in turn receive less than Oman nationals. Indians who remain in Oman long enough nevertheless are able to support families at home and to accumulate considerable savings. Working and living conditions are difficult: the hours are long, the weather is hot, housing conditions are primitive and provide no relief from the heat, the food supply is the minimum required, and almost no diversions are available. There are no unions even among Omani workers, and troublemakers are quickly repatriated. The Indian embassy occasionally intercedes for workers, brief work stoppages may occur if pay is delayed, and some conflicts are settled individually. Resistence among Indian workers may take less visible forms, especially absenteeism and requests for leave.

Lucas, R. A., et al. (2014). "Excessive occupational heat exposure: a significant ergonomic challenge and health risk for current and future workers." Extrem Physiol Med 3: 14.

Occupational heat exposure threatens the health of a worker not only when heat illness occurs but also when a worker's performance and work capacity is impaired. Occupational contexts that involve hot and humid climatic conditions, heavy physical workloads and/or protective clothing create a strenuous and potentially dangerous thermal load for a worker. There are recognized heat prevention strategies and international thermal ergonomic standards to protect the worker. However, such standards have been developed largely in temperate western settings, and their validity and relevance is questionable for some geographical, cultural and socioeconomic contexts where the risk of excessive heat exposure can be high. There is evidence from low- and middle-income tropical countries that excessive heat exposure remains a significant issue for occupational health. Workers in these countries are likely to be at high risk of excessive heat exposure as they are densely populated, have large informal work sectors and are expected to experience substantial increases in temperature due to global climate change. The aim of this paper is to discuss current and future ergonomic risks associated with working in the heat as well as potential methods for maintaining the health and productivity of workers, particularly those most vulnerable to excessive heat exposure.

Lumley, S. H., et al. (1991). "Clothing ventilation - update and applications." Appl Ergon 22(6): 390-394.

The Environmental Ergonomics Unit at the P.O.W. provided a forum for the discussion and consolidation of ideas regarding the origins, current progress and the future development of the Clothing Ventilation Index. Crockford et al (1972) first developed the concept of clothing ventilation. The basic technique employs a trace gas dilution method for measuring the ventilation of the clothing microclimate. Ventilation is vital to the removal of sensible and insensible heat and, therefore, an important determinant of thermal comfort. Two techniques (Lotens and Havenith, 1986, 1988; Reischl et al, 1987) have subsequently been developed. The former method results in an average ventilation value for the total clothed-body surface area, whereas the latter method also takes into consideration regional changes in garment design as separate entities from the total ventilation, allowing for local modification in garment design. The Clothing Ventilation Index is a quantitative, relatively inexpensive, fast, reliable and repeatable technique. It can be used in context, in the working environment to predict the effectiveness, preference and suitability of garments and clothing assemblies; firstly, to ensure that protective clothing is worn and used correctly, and secondly, to improve performance by minimising heat strain, sweat retention and thermal discomfort. Further work on validating the techniques in terms of human responses to the thermal environment is required. Questions were also raised as to whether human beings or manikins should be used. The use of human beings in dynamic situations is of paramount importance; however, manikins could be used for purely physical measurements to test various assumptions in evaluating clothing ventilation. It is essential that body dimensions and posture are always specified. The seminar enabled researchers to identify with the proposed techniques, outline the advantages and importance of the Clothing Ventilation Index and focus future studies.

Lundgren, K., et al. (2013). "Effects of heat stress on working populations when facing climate change." Ind Health 51(1): 3-15.

It is accepted that the earth's climate is changing in an accelerating pace, with already documented implications for human health and the environment. This literature review provides an overview of existing research findings about the effects of heat stress on the working population in relation to climate change. In the light of climate change adaptation, the purpose of the literature review was to explore recent and previous research into the impacts of heat stress on humans in an occupational setting. Heat stress in the workplace has been researched extensively in the past however, in the contemporary context of climate change, information is lacking on its extent and implications. The main factors found to exacerbate heat stress in the current and future workplace are the urban 'heat island effect', physical work, individual differences, and the developing country context where technological fixes are often not applicable. There is also a lack of information on the effects on vulnerable groups such as elderly people and pregnant women. As increasing temperatures reduce work productivity, world economic productivity could be condensed, affecting developing countries in the tropical climate zone disproportionately. Future research is needed taking an interdisciplinary approach, including social, economic, environmental and technical aspects.

Maiti, R. (2008). "Workload assessment in building construction related activities in India." Appl Ergon 39(6): 754-765.

A field study was conducted to highlight the occupational risk factors related to building construction activities in India among female workers. These workers were engaged in eight different types of activities and related work parameters were studied in detail. From field environmental parameters, the calculated WBGT was obtained as 30.26+/-1.52 degrees C,

indicated that these workers worked under a positive heat load condition. Whole day work study was conducted on 11 adult female workers performing concreting operation. They were having age of 28-32 years with 5-7 years of work experience. These workers were mainly performing two types of operations in the field: (A) asymmetric lifting during concreting a boundary wall formwork of a lift unit and (B) carrying the concrete mixture. During asymmetric lifting, the average field working heart rate (HR) was calculated as 124.1+/-12.5 beats min(-1), equivalent to 45.03+/-6.93% of VO(2) max level. These working heart rates (HRs) were significantly (p<or=0.005) correlated with pause time (P.T.) and lifting frequency, but not with lifting time. A method was proposed to determine the average steady P.T. from fluctuating working HR and the lifting frequency was calculated as 6.1 lifts min(-1). This type of load handling task showed lower work efficiency and higher relative HR (%RHR). The required resting time was calculated as 61.47%, whereas the actual rest time (R.T.) in the field was 23.56+/-10.28%. Using Neibel and Frivalds equation, the rest allowance (RA) due to muscular fatigue and environmental load were calculated as 50.46% and 45.02 min/h, respectively. These results showed that the workers were not getting sufficient rest in the field. With work parameter modification, in optimum condition, the RWL value could be achieved as 7.19 kg, which was much lesser than the actual lifted load of 12.02 kg. Therefore, modification of workplace and work methods was suggested to compensate the health hazard conditions.

Marinaccio, A., et al. (2019). "Nationwide epidemiological study for estimating the effect of extreme outdoor temperature on occupational injuries in Italy." Environ Int 133(Pt A): 105176.

BACKGROUND: Despite the relevance for occupational safety policies, the health effects of temperature on occupational injuries have been scarcely investigated. A nationwide epidemiological study was carried out to estimate the risk of injuries for workers exposed to extreme temperature and identify economic sectors and jobs most at risk. MATERIALS AND METHODS: The daily time series of work-related injuries in the industrial and services sector from the Italian national workers' compensation authority (INAIL) were collected for each of the 8090 Italian municipalities in the period 2006-2010. Daily air temperatures with a 1 x 1 km resolution derived from satellite land surface temperature data using mixed regression models were included. Distributed lag non-linear models (DLNM) were used to estimate the association between daily mean air temperature and injuries at municipal level. A meta-analysis was then carried out to retrieve national estimates. The relative risk (RR) and attributable cases of work-related injuries for an increase in mean temperature above the 75th percentile (heat) and for a decrease below the 25th percentile (cold) were estimated. Effect modification by gender, age, firm size, economic sector and job type were also assessed. RESULTS: The study considered 2,277,432 occupational injuries occurred in Italy in the period 2006-2010. There were significant effects for both heat and cold temperatures. The overall relative risks (RR) of occupational injury for heat and cold were 1.17 (95% CI: 1.14-1.21) and 1.23 (95% CI: 1.17-1.30), respectively. The number of occupational injuries attributable to temperatures above and below the thresholds was estimated to be 5211 per year. A higher risk of injury on hot days was found among males and young (age 15-34) workers occupied in small-medium size firms, while the opposite was observed on cold days. Construction workers showed the highest risk of injuries on hot days while fishing, transport, electricity, gas and water distribution workers did it on cold days. CONCLUSIONS: Prevention of the occupational exposure to extreme temperatures is a concern for occupational health and safety policies, and will become a critical issue in future years considering climate change. Epidemiological studies may help identify

vulnerable jobs, activities and workers in order to define prevention plans and training to reduce occupational exposure to extreme temperature and the risk of work-related injuries.

Messeri, A., et al. (2019). "Heat Stress Perception among Native and Migrant Workers in Italian Industries-Case Studies from the Construction and Agricultural Sectors." Int J Environ Res Public Health 16(7).

Climate change will increase the frequency and severity of hazard events such as heat waves, with important effects in several European regions. It is of importance to consider overall effects as well as specific impact on vulnerable population groups such as outdoor workers. The agricultural and construction sectors represent two strategic occupational fields that in relatively recent years involve an increasing number of migrant workers, and therefore require a better management of cultural aspects, that may interact with and impact on heat-related health risk. For this reason, the present study evaluated heat-stress perception and management among native and immigrant workers in Europe. As part of the EU's Horizon 2020 HEAT-SHIELD project (grant agreement No. 668786), two agricultural and one construction companies, traditionally employing migrant workers, were evaluated with a questionnaire survey during the summer months of 2017. The data collected (104 case studies) were analyzed using descriptive statistics (Chi-squared tests) and the analysis of variance was performed with ANOVA test. From the results, migrant workers declared that work required greater effort than do native Italian workers ($\chi^2 = 17.1$, $p = 0.001$) but reported less impact from heat on productivity ($\chi^2 = 10.6$; $p = 0.014$) and thermal discomfort. In addition, migrant workers were mainly informed through written or oral communications, while native workers received information on heat-health issues through training courses. These findings are of importance for future information and mitigation actions to address socio-cultural gaps and reduce heat-stress vulnerability.

Montazer, S., et al. (2013). "Assessment of construction workers' hydration status using urine specific gravity." Int J Occup Med Environ Health 26(5): 762-769.

OBJECTIVES: The study objective was to assess hydration status by measuring USG among construction workers in Iran. MATERIALS AND METHODS: The study design was comparative and experimental. Sixty participants were randomly selected from the construction workers from a construction campus with a similar type of work, climate and diet and formed 2 groups (individuals exposed to the sun and non-exposed individuals). TWL and USG were measured in both groups on 2 consequent days, at the beginning, mid and end of the work shift. RESULTS: USG test showed that mean USG was 1.0213+/-0.0054 in the control group and in the exposed group, where it was significantly higher, it amounted to 1.026+/-0.005. In the exposed group, 38% of workers had a USG level between 1.026-1.030, representing a higher risk of heat illness and impaired performance and 12.72% had a USG level above 1.030 representing a clinically dehydrated status, while this proportion in the control group was 15.2% and 0.58%, respectively. The mean TWL index measure was 215.8+/-5.2 W/m2 for the control group and 144+/-9.8 W/m2 for the exposed group, where, again, it was significantly higher. The Pearson correlation measure showed a significant correlation between USG and TWL. CONCLUSIONS: Strong correlation between TWL, as an indicator of thermal stress and USG shows that USG can be considered as a predictor of thermal stress. The difference between USG among the exposed and non-exposed workers and the increase in USG during midday work show the sensitivity of this measure in different thermal and climatic conditions, whereas, the high level of dehydration among workers despite acceptable TWL level, shows

that heat stress management without considering the real hydration status of workers, is insufficient.

Moohialdin, A., et al. (2022). "Physiological impacts on construction workers under extremely hot and humid weather." Int Arch Occup Environ Health 95(2): 315-329.

PURPOSE: Construction worker health and safety is a primary concern for construction companies and researchers. Arabian Gulf region, like Saudi Arabia, has been experiencing extremely hot and humid (EHH) weather, which directly affects construction workers' health and safety. This study aims to address the problem of EHH weather conditions and their impacts on construction workers' physiological status. METHODS: This study assesses the impacts of EHH weather on construction workers' physiological status through the measurement of workers' physical body parameters (age, height, and weight); type of activities; and assigned tasks. Thirty-five multinational workers participated in the measurements, which were conducted in real construction site conditions A quantitative analysis was then applied to quantify the physiological impacts of the weather conditions. Several hypotheses were tested to identify the significant impacts of individual and working aspects on the workers' physiological responses. RESULTS AND CONCLUSION: The results provide empirical evidence that the recorded Heart Rate (HR) exceeded the acceptable physiological zones for construction workers exposed to extremely hot and humid weather conditions. Physical body parameters, work activities, and worker status significantly influence construction workers' physiological responses. This study recommends adopting a continuous monitoring approach as an early warning system under extremely hot and humid weather conditions.

Morioka, I., et al. (2006). "Hot environment and health problems of outdoor workers at a construction site." Ind Health 44(3): 474-480.

The aim of this research was to understand hot working environment at a construction site in summer and its effects on health of workers. In the subjective construction site, some measures, such as taking a break during work, setting tents and electric fans, and drinking cool water, had already been taken to reduce heat stress. Twelve male workers were examined. The WBGT outdoors during work varied from 23 to 34 degrees C. The time-motion study revealed that one subject worked exceeding 7 hours, and that the other one had little rest time and drank little water during work. Few items of subjective symptoms increased after work compared with before work. In blood chemical data, electrolytes and blood urea nitrogen did not change. Blood sugar before work was significantly higher than before lunch and after work. Two subjects showed serum osmotic pressures increased after work. Two had the tendency to increase the blood pressure during work. The measures seemed effective, because the effects of work were not remarkable in general. However, some problems were still pointed out. Thus, stricter work control and health care for workers are necessary, such as controlling working hours strictly and monitoring the water intake during work.

Oksa, J., et al. (2014). "Muscular, cardiorespiratory and thermal strain of mast and pole workers." Ergonomics 57(5): 669-678.

This field study evaluated the level of muscular, cardiorespiratory and thermal strain of mast and pole workers. We measured the muscular strain using electromyography (EMG), expressed as a percentage in relation to maximal EMG activity (%MEMG). Oxygen consumption (VO2) was indirectly estimated from HR measured during work and expressed as a percentage of maximum VO2 (%VO2max). Skin and deep body temperatures were measured

to quantify thermal strain. The highest average muscular strain was found in the wrist flexor (24 +/- 1.5%MEMG) and extensor (21 +/- 1.0%MEMG) muscles, exceeding the recommendation of 14%MEMG. Average cardiorespiratory strain was 48 +/- 3%VO2max. Nearly half (40%) of the participants exceeded the recommended 50%VO2max level. The core body temperature varied between 36.8 degrees C and 37.6 degrees C and mean skin temperature between 28.6 degrees C and 33.4 degrees C indicating possible occasional superficial cooling. Both muscular and cardiorespiratory strain may pose a risk of local and systemic overloading and thus reduced work efficiency. Thermal strain remained at a tolerable level.

Pangtey, B. S., et al. (2004). "An environmental profile of brick kilns in Lucknow." J Environ Sci Eng 46(3): 239-244.

Twenty two kilns in Lucknow were studied to identify the environmental hazards posed by the brick kilns and to quantify the environmental degradation which could be attributed to this industry. Study variables comprised SPM and RSPM levels, metal concentrations and total silica content in soil, temperature, humidity and noise levels in the work environment. Information's about the nature and type of kiln, fuel and water sources was also collected. 18.18 per cent of the kilns had moving steel chimneys with less than prescribed height. Approximately 1.89 + 0.87 acre of fertile agricultural land was used for manufacturing of clay brick per kiln, resulting in land degradation decrease in herb density and nutrient disorders in plants/trees in immediate vicinity. SPM level (93.3 mg/m3) was found to be much higher than the prescribed limit. The workers engaged in these kilns were at risk from dust and heat related diseases.

Phanprasit, W., et al. (2021). "Climate Warming and Occupational Heat and Hot Environment Standards in Thailand." Saf Health Work 12(1): 119-126.

BACKGROUND: During the period 2001 to 2016, the maximum temperatures in Thailand rose from 38-41(o)C to 42-44(o)C. The current occupational heat exposure standard of Thailand issued in 2006 is based on wet bulb globe temperature (WBGT) defined for three workload levels without a work-rest regimen. This study examined whether the present standard still protects most workers. METHODS: The sample comprised 168 heat acclimatized workers (90 in construction sites, 78 in foundries). Heart rate and auditory canal temperature were recorded continuously for 2 hours. Workplace WBGT, relative humidity, and wind velocity were monitored, and the participants' workloads were estimated. Heat-related symptoms and signs were collected by a questionnaire. RESULTS: Only 55% of the participants worked in workplaces complying with the heat standard. Of them, 79% had auditory canal temperature </= 38.5(o)C, compared with only 58% in noncompliant workplaces. 18% and 43% of the workers in compliant and noncompliant workplaces, respectively, had symptoms from heat stress, the trend being similar across all workload levels. An increase of one degree (C) in WBGT was associated with a 1.85-fold increase (95% confidence interval: 1.44-2.48) in odds for having symptoms. CONCLUSION: Compliance with the current occupational heat standard protects 4/5 of the workers, whereas noncompliance reduces this proportion to one half. The reasons for noncompliance include the gaps and ambiguities in the law. The law should specify work/rest schedules; outdoor work should be identified as an occupational heat hazard; and the staff should include occupational personnel to manage heat stress in establishments involving heat exposure.

Poulianiti, K. P., et al. (2019). "Metabolic energy cost of workers in agriculture, construction, manufacturing, tourism, and transportation industries." Ind Health 57(3): 283-305.

The assessment of energy cost (EC) at the workplace remains a key topic in occupational health due to the ever-increasing prevalence of work-related issues. This review provides a detailed list of EC estimations in jobs/tasks included in tourism, agriculture, construction, manufacturing, and transportation industries. A total of 61 studies evaluated the EC of 1,667 workers while performing a large number of tasks related to each of the aforementioned five industries. Agriculture includes the most energy-demanding jobs (males: 6.0 +/- 2.5 kcal/min; females: 2.9 +/- 1.0 kcal/min). Jobs in the construction industry were the 2nd most demanding (males: 4.9 +/- 1.6 kcal/min; no data for females). The industry with the 3rd highest EC estimate was manufacturing (males: 3.8 +/- 1.1 kcal/min; females: 3.0 +/- 1.3 kcal/min). Transportation presented relatively moderate EC estimates (males: 3.1 +/- 1.0 kcal/min; no data for females). Tourism jobs demonstrated the lowest EC values (2.5 +/- 0.9 kcal/min for males and females). It is hoped that this information will aid the development of future instruments and guidelines aiming to protect workers' health, safety, and productivity. Future research should provide updated EC estimates within a wide spectrum of occupational settings taking into account the sex, age, and physiological characteristics of the workers as well as the individual characteristics of each workplace.

Pradhan, B., et al. (2019). "Heat Stress Impacts on Cardiac Mortality in Nepali Migrant Workers in Qatar." Cardiology 143(1): 37-48.

BACKGROUND: Qatar is a major destination country for Nepali migrant workers (NMWs; main age range 25-35 years) in the construction trade. These 120,000+ NMWs are exposed to various occupational hazards, including excessive heat, and 3-4 workers die each week. Our study aimed to show whether heat exposure caused deaths. METHODS: The worker population and mortality data of NMWs were retrieved from government institutions in Nepal. Heat exposure was assessed by monthly estimates of daily wet bulb globe temperature (WBGT), for in-shade conditions, from data collected at the Doha weather station from 2009 to 2017. Working in the sun during the middle of the day would add 2-3 degrees C to the in-shade WBGT values. Daily deaths and their causes were obtained from the records of the Foreign Employment Promotion Board (FEPB) in Nepal, 2009-2017. Interviews with returning NMWs about their working conditions and the impacts of these conditions added information. The association between the heat variable and mortality was tested with standard statistical methods. RESULTS: The average annual death rate for NMWs in Qatar was 150 deaths/100,000. According to interviews, the majority of NMWs were found working in high WBGT (>31 degrees C) each working day during hot months. The major cause of these deaths was recorded as cardiovascular problems (cardiovascular disease; CVD). Unfortunately, the causes of death were poorly described, and many deaths were listed as "cardiac arrest." We included these deaths in the broader category of "cardiovascular causes." There was a strong correlation between average monthly afternoon heat levels (WBGT) and CVD mortality. It is likely that a large proportion of these CVD deaths during hot months were due to serious heat stroke. Global studies show that approximately 15% of deaths in the age group 25-35 years are due to CVD causes. However, in this NMW population, the figures were 22% during the cool season and 58% during the hot season. CONCLUSIONS: The increased CVD mortality during hot periods is most likely due to severe heat stress. As many as 200 of the 571 CVD deaths during 2009-2017 could have been prevented if effective heat protection had been implemented as a part of local occupational health and safety programs. There is an urgent need for protection against

such heat effects among NMWs, and rising temperatures from ongoing climate change are further increasing the health risks. Cause of death records for workers dying in hot conditions should be more precise than "cardiac arrest."

Presbitero, A., et al. (2021). "A unifying model to estimate the effect of heat stress in the human innate immunity during physical activities." Sci Rep 11(1): 16688.

Public health is threatened by climate change and extreme temperature events worldwide. Differences in health predispositions, access to cooling infrastructure and occupation raises an issue of heat-related health inequality in those vulnerable and disadvantaged demographic groups. To address these issues, a comprehensive understanding of the effect of elevated body temperatures on human biological systems and overall health is urgently needed. In this paper we look at the inner workings of the human innate immunity under exposure to heat stress induced through exposure to environment and physical exertion. We couple two experimentally validated computational models: the innate immune system and thermal regulation of the human body. We first study the dynamics of critical indicators of innate immunity as a function of human core temperature. Next, we identify environmental and physical activity regimes that lead to core temperature levels that can potentially compromise the performance of the human innate immunity. Finally, to take into account the response of innate immunity to various intensities of physical activities, we utilise the dynamic core temperatures generated by a thermal regulation model. We compare the dynamics of all key players of the innate immunity for a variety of stresses like running a marathon, doing construction work, and leisure walking at speed of 4 km/h, all in the setting of a hot and humid tropical climate such as present in Singapore. We find that exposure to moderate heat stress leading to core temperatures within the mild febrile range (37, 38][Formula: see text], nudges the innate immune system into activation and improves the efficiency of its response. Overheating corresponding to core temperatures beyond 38[Formula: see text], however, has detrimental effects on the performance of the innate immune system, as it further induces inflammation, which causes a series of reactions that may lead to the non-resolution of the ongoing inflammation. Among the three physical activities considered in our simulated scenarios (marathon, construction work, and walking), marathon induces the highest level of inflammation that challenges the innate immune response with its resolution. Our study advances the current state of research towards understanding the implications of heat exposure for such an essential physiological system as the innate immunity. Although we find that among considered physical activities, a marathon of 2 h and 46 min induces the highest level of inflammation, it must be noted that construction work done on a daily basis under the hot and humid tropical climate, can produce a continuous level of inflammation triggering moieties stretched at a longer timeline beating the negative effects of running a marathon. Our study demonstrates that the performance of the innate immune system can be severely compromised by the exposure to heat stress and physical exertion. This poses significant risks to health especially to those with limited access to cooling infrastructures. This is due in part to having low income, or having to work on outdoor settings, which is the case for construction workers. These risks to public health should be addressed through individual and population-level measures via behavioural adaptation and provision of the cooling infrastructure in outdoor environments.

Rameezdeen, R. and A. Elmualim (2017). "The Impact of Heat Waves on Occurrence and Severity of Construction Accidents." Int J Environ Res Public Health 14(1).

The impact of heat stress on human health has been extensively studied. Similarly, researchers have investigated the impact of heat stress on workers' health and safety. However, very little work has been done on the impact of heat stress on occupational accidents and their severity, particularly in South Australian construction. Construction workers are at high risk of injury due to heat stress as they often work outdoors, undertake hard manual work, and are often project based and sub-contracted. Little is known on how heat waves could impact on construction accidents and their severity. In order to provide more evidence for the currently limited number of empirical investigations on the impact of heat stress on accidents, this study analysed 29,438 compensation claims reported during 2002-2013 within the construction industry of South Australia. Claims reported during 29 heat waves in Adelaide were compared with control periods to elicit differences in the number of accidents reported and their severity. The results revealed that worker characteristics, type of work, work environment, and agency of accident mainly govern the severity. It is recommended that the implementation of adequate preventative measures in small-sized companies and civil engineering sites, targeting mainly old age workers could be a priority for Work, Health and Safety (WHS) policies.

Ricco, M., et al. (2020). "Air temperatures and occupational injuries in the construction industries: a report from Northern Italy (2000-2013)." Ind Health 58(2): 182-192.

The aim of this study was to assess the relationship between environmental temperatures and occupational injuries (OIs) in construction workers (CWs) from a subalpine region of North-Eastern Italy. Data about OIs from 2000 to 2013, and daily weather for the specific site of the events were retrieved. Risk for daily OIs was calculate through a Poisson regression model. Estimated daily incidence for OIs was 5.7 (95%CI 5.5-5.8), or 2.8 OIs/10,000 workers/d (95%CI 2.7-2.9), with higher rates for time periods characterized by high temperatures (daily maximum >/=35 degrees C), both in first 2 d (3.57, 95%CI 3.05-4.11) and from the third day onwards (i.e. during Heat Waves: 3.43, 95%CI 3.08-3.77). Higher risk for OIs was reported in days characterized temperatures >/=95th percentile (OR 1.145, 95%CI 1.062-1.235), summer days (daily maximum >/=25 degrees C , OR 1.093, 95%CI 1.042-1.146). On the contrary, no significant increased risk was found for OIs having a more severe prognosis (>/=40 d or more; death). In conclusion, presented findings recommend policymakers to develop appropriate procedures and guidelines, in particular aimed to improve the compliance of younger CWs towards severe-hot daily temperatures.

Rowlinson, S. and Y. A. Jia (2014). "Application of the predicted heat strain model in development of localized, threshold-based heat stress management guidelines for the construction industry." Ann Occup Hyg 58(3): 326-339.

Existing heat stress risk management guidelines recommended by international standards are not practical for the construction industry which needs site supervision staff to make instant managerial decisions to mitigate heat risks. The ability of the predicted heat strain (PHS) model [ISO 7933 (2004). Ergonomics of the thermal environment analytical determination and interpretation of heat stress using calculation of the predicted heat strain. Geneva: International Standard Organisation] to predict maximum allowable exposure time (D lim) has now enabled development of localized, action-triggering and threshold-based guidelines for implementation by lay frontline staff on construction sites. This article presents a protocol for development of two heat stress management tools by applying the PHS model to its full potential. One of the tools is developed to facilitate managerial decisions on an optimized

work-rest regimen for paced work. The other tool is developed to enable workers' self-regulation during self-paced work.

Rowlinson, S., et al. (2014). "Management of climatic heat stress risk in construction: a review of practices, methodologies, and future research." Accid Anal Prev 66: 187-198.

Climatic heat stress leads to accidents on construction sites brought about by a range of human factors emanating from heat induced illness, and fatigue leading to impaired capability, physical and mental. It is an occupational characteristic of construction work in many climates and the authors take the approach of re-engineering the whole safety management system rather than focusing on incremental improvement, which is current management practice in the construction industry. From a scientific viewpoint, climatic heat stress is determined by six key factors: (1) air temperature, (2) humidity, (3) radiant heat, and (4) wind speed indicating the environment, (5) metabolic heat generated by physical activities, and (6) "clothing effect" that moderates the heat exchange between the body and the environment. By making use of existing heat stress indices and heat stress management processes, heat stress risk on construction sites can be managed in three ways: (1) control of environmental heat stress exposure through use of an action-triggering threshold system, (2) control of continuous work time (CWT, referred by maximum allowable exposure duration) with mandatory work-rest regimens, and (3) enabling self-paced working through empowerment of employees. Existing heat stress practices and methodologies are critically reviewed and the authors propose a three-level methodology for an action-triggering, localized, simplified threshold system to facilitate effective decisions by frontline supervisors. The authors point out the need for "regional based" heat stress management practices that reflect unique climatic conditions, working practices and acclimatization propensity by local workers indifferent geographic regions. The authors set out the case for regional, rather than international, standards that account for this uniqueness and which are derived from site-based rather than laboratory-based research.

Rushton, L. and J. H. S (2017). "The burden of occupationally-related cutaneous malignant melanoma in Britain due to solar radiation." Br J Cancer 116(4): 536-539.

BACKGROUND: Increasing evidence highlights the association of occupational exposure and cutaneous malignant melanoma (CMM). We estimated the burden of CMM and total skin cancer burden in Britain due to occupational solar radiation exposure. METHODS: Attributable fractions (AF) and numbers were estimated for CMM mortality and incidence using risk estimates from the published literature and national data sources for proportions exposed. We extended existing methods to account for the exposed population age structure. RESULTS: The estimated total AF for CMM is 2.0% (95% CI: 1.4-2.7%), giving 48 (95% CI: 33-64) deaths in (2012) and 241 (95% CI: 168-325) registrations (in 2011) attributable to occupational exposure to solar radiation. Higher exposure and larger numbers exposed led to much higher numbers for men than women. Industries of concern are construction, agriculture, public administration and defence, and land transport. CONCLUSIONS: These results emphasise the urgent need to develop appropriate strategies to reduce this burden.

Sett, M. and S. Sahu (2014). "Effects of occupational heat exposure on female brick workers in West Bengal, India." Glob Health Action 7: 21923.

BACKGROUND: Manual brick-manufacturing units in India engage a large number of female workers on a daily-wage basis for a period of 8 months per year. There are two groups of female workers in the brickfields: the brick molders and the brick carriers. These brickfields

are mostly unorganized, and the workers are exposed to extreme conditions such as very high seasonal heat. The present trend of increasing temperatures, as a result of global warming and climate change, will put an additional burden on them. OBJECTIVE: This study aims to evaluate the effect of workplace heat exposure on the well-being, physiological load, and productivity of female brickfield workers in India. DESIGN: A questionnaire study (n=120), environmental temperature, and weekly work productivity analyses were evaluated for 8 months in the brickfields. Cardiac strain and walking speed (subset, n=40) were also studied and compared in hotter and colder days amongst the female brickfield workers. RESULTS: The subjects experience summer for about 5 months with additional heat stress radiating from the brick kiln. The weekly productivity data show a linear decline in productivity with increased maximum air temperature above 34.9 degrees C. The cardiac parameters (peak heart rate (HRp), net cardiac cost (NCC), relative cardiac cost (RCC), and recovery heart rates) were significantly higher on hotter days (Wet Bulb Globe Temperature (WBGTout) index: 26.9 degrees C to 30.74 degrees C) than on cooler days (WBGTout index: 16.12 degrees C to 19.37 degrees C) for the brick molders; however, this is not the case for the brick carriers. As the brick carriers adapt to hotter days by decreasing their walking speed, their productivity decreases. CONCLUSION: We conclude that high heat exposure in brickfields during summer caused physiological strain in both categories of female brickfield workers. A coping strategy employed by the brick carriers was to reduce their walking speed and thus lose part of their earnings. The lost productivity for every degree rise in temperature is about 2% in the brickfields. This reduction will be exacerbated by climate change and may undermine the quality of life of female brickfield workers.

Shahzad, A., et al. (2020). "Acute Myocarditis in a Patient with Exertional Heat Illness: A Rare Association." Eur J Case Rep Intern Med 7(12): 002027.

INTRODUCTION: Exertional heat illness (EHI) is common in hot weather among young athletes, outdoor manual workers and military personnel. EHI can involve multiple organs of the body, including the muscles, kidneys and brain; however, myocardium involvement is infrequent. MATERIALS AND METHODS: We present the case of a 26-year-old male construction worker who worked outdoors in a hot arid environment. He presented with acute kidney injury and rhabdomyolysis and was diagnosed with EHI. During his hospital stay, he developed complete heart block, and cardiac MRI showed features of myocarditis. Work-up to identify other aetiologies of myocarditis was normal. This case highlights the effects of EHI on the myocardium. CONCLUSION: It is important to keep in mind the various effects of EHI on the myocardium. Myocarditis due to EHI is rare, and conduction defects resulting from it might persist, necessitating specialist intervention. LEARNING POINTS: Exertional heat illness (EHI) can cause end-organ damage and it is imperative to keep in mind the various effects of EHI on the myocardium.Myocarditis due to EHI is rare, and conduction defects resulting from it might persist, requiring specialist intervention.

Shakerian, S., et al. (2021). "Assessing occupational risk of heat stress at construction: A worker-centric wearable sensor-based approach." Safety Science 142: 105395.

Construction workers are at a high risk of exposure to excessive heat generated by several factors such as intensive physical activities, personal protective clothing, and frequent heat events at construction sites. Previous studies attempted to evaluate the occupational risk of heat stress by concentrating on environmental variables or the self-assessment measures of perceived heat. Despite their potentials, most of these approaches were intrusive, inaccurate,

and intermittent. More importantly, they mainly overlooked the disparities in workers' physical and physiological characteristics. To address these limitations, this study proposes a heat-stress risk-assessment process to evaluate workers' bodily responses to heat – heat strain – based on the continuous measurement of their physiological signals. To this end, workers' physiological signals were captured using a wristband-type biosensor. Subsequently, their physiological signals were decontaminated from noises, resampled into an array of informative features, and finally interpreted into distinct states of individuals' heat strain by employing several supervised learning algorithms. To examine the performance of the proposed process, physiological signals were collected from 18 subjects while performing specific construction tasks under three predetermined environmental conditions with a different probability of exposure to heat stress. The analysis results revealed the proposed process could predict the risk of heat strain with more than 92% accuracy, illuminating the potentials of wearable biosensors to continuously assess workers' heat strain. The long-term implications of this study can be capitalized as guidelines to improve systematic evaluation of heat strain and promote workers' occupational safety and well-being through early detection of heat strain at construction sites.

Sheng, R., et al. (2018). "Does hot weather affect work-related injury? A case-crossover study in Guangzhou, China." Int J Hyg Environ Health 221(3): 423-428.

BACKGROUND: Despite increasing concerns about the health effects of climate change, the extent to which workers are affected by hot weather is not well documented. This study aims to investigate the association between high temperatures and work-related injuries using data from a large subtropical city in China. METHODS: We used workers' compensation claims to identify work-related injuries in Guangzhou, China during 2011-2012. To feature the heat effect, the study period was restricted to the warm seasons in Guangzhou (1 May-31 October). We conducted a time-stratified case-crossover study to examine the association between ambient outdoor temperatures, including daily maximum and minimum temperatures, and cases of work-related injury. The relationships were assessed using conditional Poisson regression models. RESULTS: Overall, a total of 5418 workers' compensation claims were included over the study period. Both maximum and minimum temperatures were significantly associated with work-related injuries, but associations varied by subgroup. One degrees C increase in maximum temperature was associated with a 1.4% (RR = 1.014, 95%CIs 1.012-1.017) increase in daily injury claims. Significant associations were seen for male and middle-aged workers, workers in small and medium-sized enterprises, and those working in manufacturing sector. And 1 degrees C increase in minimum temperature was associated with 1.7% (RR = 1.017, 95%CIs 1.012-1.021) increase in daily injury claims. Significant associations were observed for female and middle-aged workers, workers in large-sized enterprises, and those working in transport and construction sectors. CONCLUSIONS: We found a higher risk of work-related injuries due to hot weather in Guangzhou, China. This study provides important epidemiological evidence for policy-makers and industry that may assist in the formulation of occupational safety and climate adaptation strategies.

Spickenheuer, A., et al. (2011). "Levels and determinants of exposure to vapours and aerosols of bitumen." Arch Toxicol 85 Suppl 1: S21-28.

Bitumen (referred to as asphalt in the United States) is a widely used construction material, and emissions from hot bitumen applications have been a long-standing health concern. One objective of the Human Bitumen Study was to identify potential determinants of the exposure to bitumen. The study population analysed comprised 259 male mastic asphalt

workers recruited between 2003 and 2008. Personal air sampling in the workers' breathing zone was carried out during the shift to measure exposure to vapours and aerosols of bitumen. The majority of workers were engaged in building construction, where exposure levels were lower than in tunnels but higher than at road construction sites. At building construction sites, exposure levels were influenced by the room size, the processing temperature of the mastic asphalt and the job task. The results show that protective measures should include a reduction in the processing temperature.

Szer, I., et al. (2022). "Using meteorological data to estimate heat stress of construction workers on scaffolds for improved safety standards." Automation in Construction 134: 104079.

The analysis of susceptibility of construction workers to heat stress, the results of which are presented in this paper, was an important research module of the large research project focused on safety of workers on construction sites. The paper assesses the possibility of using different sets of data gathered in full scale on the scaffolding and on the meteorological station to estimate the heat stress of people working on scaffolding. The main purpose is to check if the use of public data from meteorological stations can provide reliable estimation. A simplified formula of Universal Thermal Climate Index (UTCI*) is used in analyses. The values of UTCI* calculated on the basis of two sets of input parameters are compared to each other and analysed. The measurements and UTCI* calculations are presented for 24 scaffolding structures located in Poland in Łódź and Lower Silesian provinces. Test results based on construction sites and meteorological stations data are different, but statistical analysis shows their correlation. A stronger correlation occurs for scaffolding structures located in Łódź province, while it is weaker for the results obtained in Lower Silesian province. The results show the possibility of simplified evaluation of comfort/discomfort of people working on scaffolding on the basis of publicly available environmental data measured at meteorological stations.

Ueno, S., et al. (2018). "Heat Strain and Hydration of Japanese Construction Workers during Work in Summer." Ann Work Expo Health 62(5): 571-582.

OBJECTIVES: The aim was to ascertain hydration and heat strain of construction workers in Japan during the summer who are at the highest risk of heat-related disorders. METHODS: The subjects were 23 construction workers, whose average age was 41, average weight was 69 kg, and average height was 170 cm. We measured thermal working conditions with a wet bulb globe temperature (WBGT) measurement instrument affixed to the helmet of each worker, at fixed points outdoors in the sun and indoors. Heat strain was evaluated for water intake, urine specific gravity (Usg), urine temperature (UT), heart rate (HR), and body weight during work. RESULTS: The average WBGT measured on the worker helmets over 3 consecutive days was 28.0 +/- 0.7, 27.6 +/- 0.8, and 27.6 +/- 1.1 degrees C. The average water intake was 2.6 l during a work shift. The average Usg, UT, and % HR reserve were the highest in the first half of afternoon work. Seventy-eight percent of the subjects exceeded at least one of the ACGIH TLV physiological guidelines for heat strain in terms of HR and weight loss or a clinically dehydrated level of Usg. CONCLUSIONS: Heat strain was the highest in the first half of afternoon work. The number of dehydrated workers increased during this shift because of insufficient water intake. Adequate hydration is required to decrease the risk of heat-related disorders among construction workers in the summer.

Umar, T. and C. Egbu (2018). "Heat Stress, a Hidden Cause of Accidents in Construction." Proceedings of the Institution of Civil Engineers - Municipal Engineer 173: 1-30.

Extreme heat stress has a deep impact on physiological reactions, which results in occupational injuries and deaths. In this paper, an attempt is made to understand the impact of heat stress on construction accidents in Oman. A literature review on heat stress is discussed in the first section followed by an analysis of 623 accidents that occurred in a highway project. The analysis of these accidents reveals that more severe accidents on this project took place from 11:00 to 17:00. The semi-structured interview held with some of the workers involved in these accidents confirmed excessive heat as one of the main reason behind these accidents. The health profile of the same workers is measured in terms of their body mass index and blood pressure. The results show that 80% of the workers from the selected sample were found to be overweight or obese and 40% of the participants were hypertensive. The safety performance of such workers is particularly discussed in relation to heat stress. The effective implementations of day time break in summer, a healthy diet, appropriate sleeping habit, scheduling physically demanding tasks during early morning and evening and adopting light colour and loose fitting uniform could reduce the impact of heat stress.

Vatani, J., et al. (2016). "Applicability of Universal Thermal Climate Index (UTCI) in occupational heat stress assessment: a case study in brick industries." Ind Health 54(1): 14-19.

The present study aimed to investigate the applicability of Universal Thermal Climate Index (UTCI) as an innovative and science-based index in public health researches, in occupational heat stress assessment. All indoor and outdoor workers (200 people) of Brick industries of Shahroud, Iran participated in the research. First, the environmental variables such as air temperature, wet-bulb temperature, globe temperature, air velocity and relative humidity were measured; then UTCI and WBGT (wet-bulb globe temperature) indices were calculated. Simultaneously, physiological parameters including systolic and diastolic blood pressure, oral temperature, skin temperature, tympanic temperature and heart rate of workers were measured. UTCI and WBGT indices were 34.2 +/- 2 degrees C, 21.8 +/- 1.8 degrees C in the outdoor environments and 38.1 +/- 4.4 degrees C, 24.7 +/- 3.3 degrees C at the indoor environments, respectively. There were the weak inverse relationships between UTCI and WBGT indices at the outdoor environments and physiological responses such as systolic blood pressure, and diastolic blood pressure. However, there were no similar results for indoor environments. The significant relationships were found between UTCI and WBGT at both indoor and outdoor environments. Both UTCI and WBGT indices are suitable for assessing the occupational heat stress. Although, UTCI index seems more appropriate for heat stress assessment in the environments with low humidity and air velocity.

Velasco Garrido, M., et al. (2018). "A cross-sectional survey of physical strains among offshore wind farm workers in the German exclusive economic zone." BMJ Open 8(3): e020157.

OBJECTIVES: To assess the physical strains of employees in the German offshore wind industry, according to job type and phase of the wind farm (under construction or operation). DESIGN: Web-based cross-sectional survey. SETTING: Offshore wind farm companies operating within the German exclusive economic zone. PARTICIPANTS: Male workers with regular offshore commitments and at least 28 days spent offshore in the past year (n=268). OUTCOME MEASURES: Physical strains (eg, climbing, noise, working overhead, with twisted upper body or in confined spaces, vibration, heavy lifting, humidity, odours). RESULTS: The most frequently mentioned physical strain was 'climbing' with 63.8% of the respondents reporting to be always or frequently confronted with climbing and ascending stairs during offshore work. Work as a technician was associated with a greater exposition to noise,

vibrations, humidity, cold, heat, chemical substances, lifting/carrying heavy loads, transport of equipment, working in non-ergonomic positions and in cramped spaces, as well as climbing.Indeed, statistical analyses showed that, after adjusting for phase of the wind farm, age, nationality, offshore experience, work schedule and type of shift, compared with non-technicians, working as a technician was associated with more frequently lifting/carrying of heavy loads (OR 2.58, 95% CI 1.58 to 4.23), transport of equipment (OR 2.06 95% CI 1.27 to 3.33), working with a twisted upper body (OR 2.85 95% CI 1.74 to 4.69), working overhead (OR 2.77 95% CI 1.67 to 4.58) and climbing (OR 2.30 95% CI 1.40 to 3.77). Working in wind farms under construction was strongly associated with increased and decreased exposure to humidity (OR 2.32 95% CI 1.38 to 3.92) and poor air quality (OR 0.58 95% CI 0.35 to 0.95), respectively. CONCLUSIONS: Workers on offshore wind farms constitute a heterogeneous group, including a wide variety of occupations. The degree of exposure to detrimental physical strains varies depending on the type of job. Technicians are more exposed to ergonomic challenges than other offshore workers.

Venugopal, V., et al. (2016). "The Social Implications of Occupational Heat Stress on Migrant Workers Engaged in Public Construction." The International Journal of the Constructed Environment 7: 25-36.

Health deterioration due to multiple exposures to hazards is not uncommon among construction workers. Migrant workers contribute a lion's share (~79%) to public construction in India and about two-thirds of the migrant workforce lives in temporary habitats with minimal basic amenities. The implications of occupational heat stress on the health and social lives of the migrant workers engaged in construction of public metro railway was explored. One hundred and forty-two migrant workers were engaged in the study after obtaining informed consent. Quantitative data on environmental heat exposures and qualitative information on the impacts of heat stress on health, productivity losses, and social lives via interviews was collected. Seventy-seven percent of workers reported a range of health impacts and 68 percent reported productivity losses and lost wages due to heat. Seventy-six percent of women workers complained of significant impacts on their social lives in the form of disruptions in children education, addictions, and inability to care for family due to frequent sickness. Women also reported that heat stress, plus lack of access to toilets, further aggravated urinary tract infections and kidney related illnesses. Unsanitary living conditions and competition for limited resources in habitats were reported to increase theft and social violence among adults/children. In an increasingly warmer global climate and an increasing constructed demand, stronger policies to prevent morbidity/mortality among vulnerable migrant workers in the construction sector is imperative. Better health, literacy rates, and decreased crime statistics among migrant community are potential positive implications of protective policies.

Watson, C., et al. (2021). "Industrial workwear for hot workplace environments: thermal management attributes." Int J Biometeorol 65(10): 1751-1765.

Personal protective clothing (PPC) is critical for worker safety and wellbeing from both protection and thermal management perspectives, particularly as PPC typically covers more than 90% of the body. Research of PPC in low-risk categories such as mining, oil, gas, and construction and their thermal management attributes is limited, although these industries represent a significant proportion of the industrial workforce, work across a broad range of major industries, and frequently work in hot and/or humid thermal environments. This study evaluated and characterized the thermal management attributes of a selection of commercial

low-level risk PPC ensembles currently used around the world as well as a civilian/corporate wear ensemble, using a sweating thermal manikin. The results demonstrate that there are substantially poorer thermal attributes for the PPC ensembles. Predicted Heat Strain Index (PHS) results for hot conditions reveal significantly lower duration limited exposure (DLE) and considerably greater body water loss for the wearers of PPC. Opportunities to substantially reduce PPC material mass and improve construction for these low-level risk categories in order to enhance thermal management performance are identified. Relationships between the thermal attributes of PPC and civilian clothing, and their garment construction, fit, and material characteristics are identified, providing new and important knowledge for current performance and direction for development of new improved PPC. This study provides researchers, developers, and garment designers with valuable insights for future improvement of PPC to create improved PPC for industrial workwear worn in hot environments.

Wesseling, C., et al. (2016). "Heat stress, hydration and uric acid: a cross-sectional study in workers of three occupations in a hotspot of Mesoamerican nephropathy in Nicaragua." BMJ Open 6(12): e011034.

OBJECTIVES: To study Mesoamerican nephropathy (MeN) and its risk factors in three hot occupations. DESIGN: Cross-sectional. SETTING: Chinandega and Leon municipalities, a MeN hotspot on the Nicaraguan Pacific coast, January-February 2013. PARTICIPANTS: 194 male workers aged 17-39 years: 86 sugarcane cutters, 56 construction workers, 52 small-scale farmers. OUTCOME MEASURES: (1) Differences between the three occupational groups in prevalences/levels of socioeconomic, occupational, lifestyle and health risk factors for chronic kidney disease (CKD) and in biomarkers of kidney function and hydration; (2) differences in prevalences/levels of CKD risk factors between workers with reduced estimated glomerular filtration rate (eGFR(CKD-EPI) <80 mL/min/1.73 m(2)) and workers with normal kidney function (eGFR(CKD-EPI) >/=80 mL/min/1.73 m(2)). RESULTS: Sugarcane cutters were more exposed to heat and consumed more fluid on workdays and had less obesity, lower blood sugar, lower blood pressure and a better lipid profile. Reduced eGFR occurred in 16%, 9% and 2% of sugarcane cutters, construction workers and farmers, respectively (trend cane > construction > farming, p=0.003). Significant trends (cane > construction > farming) were also observed for high serum urea nitrogen (blood urea nitrogen (BUN) >20 mg/dL), high serum creatinine (SCr >1.2 mg/dL), low urinary pH (</=5.5) and high BUN/SCr ratio (>20) but not for high urinary specific gravity (>/=1.030). Sugarcane cutters also more often had proteinuria and blood and leucocytes in the urine. Workers with eGFR <80 mL/min/1.73 m(2) reported a higher intake of water and lower intake of sugary beverages. Serum uric acid levels related strongly and inversely to eGFR levels (adj beta -10.4 mL/min/1.73 m(2), 95% CI -12.2 to -8.5, p<0.001). No associations were observed for other metabolic risk factors, pesticides, non-steroidal anti-inflammatory drugs or alcohol. Among cane cutters, consumption of electrolyte hydration solution appeared preventive (adj beta 8.1 mL/min/1.73 m(2), p=0.09). CONCLUSIONS: Heat stress, dehydration and kidney dysfunction were most common among sugarcane cutters. Kidney dysfunction also occurred to a lesser extent among construction workers, but hardly at all among small-scale farmers. High serum uric acid was associated with reduced kidney function.

Wong del, P. L., et al. (2014). "Comparing the physiological and perceptual responses of construction workers (bar benders and bar fixers) in a hot environment." Appl Ergon 45(6): 1705-1711.

This study aimed to (1) quantify the respective physical workloads of bar bending and fixing; and (2) compare the physiological and perceptual responses between bar benders and bar fixers. Field studies were conducted during the summer in Hong Kong from July 2011 to August 2011 over six construction sites. Synchronized physiological, perceptual, and environmental parameters were measured from construction rebar workers. The average duration of the 39 field measurements was 151.1 +/- 22.4 min under hot environment (WBGT = 31.4 +/- 2.2 degrees C), during which physiological, perceptual and environmental parameters were synchronized. Energy expenditure of overall rebar work, bar bending, and bar fixing were 2.57, 2.26 and 2.67 Kcal/min (179, 158 and 186 W), respectively. Bar fixing induced significantly higher physiological responses in heart rate (113.6 vs. 102.3 beat/min, $p < 0.05$), oxygen consumption (9.53 vs. 7.14 ml/min/kg, $p < 0.05$), and energy expenditure (2.67 vs. 2.26 Kcal/min, $p < 0.05$) (186 vs. 158 W, $p < 0.05$) as compared to bar bending. Perceptual response was higher in bar fixing but such difference was not statistically significant. Findings of this study enable the calculation of daily energy expenditure of rebar work.

Xiang, J., et al. (2014). "Health impacts of workplace heat exposure: an epidemiological review." Ind Health 52(2): 91-101.

With predicted increasing frequency and intensity of extremely hot weather due to changing climate, workplace heat exposure is presenting an increasing challenge to occupational health and safety. This article aims to review the characteristics of workplace heat exposure in selected relatively high risk occupations, to summarize findings from published studies, and ultimately to provide suggestions for workplace heat exposure reduction, adaptations, and further research directions. All published epidemiological studies in the field of health impacts of workplace heat exposure for the period of January 1997 to April 2012 were reviewed. Finally, 55 original articles were identified. Manual workers who are exposed to extreme heat or work in hot environments may be at risk of heat stress, especially those in low-middle income countries in tropical regions. At risk workers include farmers, construction workers, fire-fighters, miners, soldiers, and manufacturing workers working around process-generated heat. The potential impacts of workplace heat exposure are to some extent underestimated due to the underreporting of heat illnesses. More studies are needed to quantify the extent to which high-risk manual workers are physiologically and psychologically affected by or behaviourally adapt to workplace heat exposure exacerbated by climate change.

Xiang, J., et al. (2014). "The impact of heatwaves on workers' health and safety in Adelaide, South Australia." Environ Res 133: 90-95.

This study aims to investigate the impact of heatwaves on worker's health and safety; to identify workers at higher risk of prevalent illnesses and injuries due to heatwaves; and to provide evidence for policy-makers and service providers. South Australian workers' compensation claims data for 2001-2010 were transformed into time series format, merged with meteorological data and analysed using generalized estimating equation (GEE) models. For total injury claims there was no significant difference detected between heatwave and non-heatwave periods. However, for outdoor industries, daily claims increased significantly by 6.2% during heatwaves. Over-represented in hot weather were male labourers and tradespersons aged >/= 55 years, and those employed in 'agriculture, forestry and fishing' and 'electricity, gas and water'. Occupational burns, wounds, lacerations, and amputations as well as heat illnesses were significantly associated with heatwaves. Similarly, moving objects, contact with chemicals, and injuries related to environmental factors increased significantly during heatwaves, especially

among middle-aged and older male workers. With the predicted increase of extremely hot weather, there is a need for relevant adaptation and prevention measures at both practice and policy levels for vulnerable work groups.

Xiang, J., et al. (2014). "Association between high temperature and work-related injuries in Adelaide, South Australia, 2001-2010." Occup Environ Med 71(4): 246-252.

OBJECTIVES: (1) To investigate the association between temperature and work-related injuries and (2) to identify groups of workers at high risk of work-related injuries in hot environments in Adelaide, South Australia. METHODS: Workers' compensation claims in Adelaide, South Australia for 2001-2010 were used. The relationship between temperature and daily injury claims was estimated using a generalised estimating equation model. A piecewise linear spline function was used to quantify the effect of temperature on injury claims below and above thresholds. RESULTS: Overall, a 1 degrees C increase in maximum temperature between 14.2 degrees C and 37.7 degrees C was associated with a 0.2% increase in daily injury claims. Specifically, the incidence rate ratios (IRRs) for male workers and young workers aged </=24 were (1.004, 95% CI 1.002 to 1.006) and (1.005, 95% CI 1.002 to 1.008), respectively. Significant associations were also found for labourers (IRR 1.005, 95% CI 1.001 to 1.010), intermediate production and transport workers (IRR 1.003, 95% CI 1.001 to 1.005) and tradespersons (IRR 1.002, 95% CI 1.001 to 1.005). Industries at risk were agriculture, forestry and fishing (IRR 1.007, 95% CI 1.001 to 1.013), construction (IRR 1.006, 95% CI 1.002 to 1.011), and electricity, gas and water (IRR 1.029, 95% CI 1.002 to 1.058). CONCLUSIONS: There is a significant association between injury claims and temperature in Adelaide, South Australia, for certain industries and groups. Relevant adaptation and prevention measures are required at both policy and practice levels to address occupational exposure to high temperatures.

Yang, Y. and A. P. Chan (2015). "Perceptual strain index for heat strain assessment in an experimental study: an application to construction workers." J Therm Biol 48: 21-27.

Although the physiological strain index (PhSI) is universal and comprehensive, its restrictions are recognized in terms of invasive on-site measurements and the requirement of accurate instruments. The perceptual strain index (PeSI) has been proposed as a user-friendly and practical indicator for heat strain. However, the application of this index in assessing the heat strain of construction workers has yet to be examined and documented. This study aims to ascertain the reliability and applicability of PeSI in an experimental setting that simulates a stressful working environment (i.e., environment, work uniform, and work pace) experienced by construction workers. Ten males and two females performed intermittent exercise on a treadmill while wearing a summer work uniform at 34.5 degrees C and 75% relative humidity in a climatic chamber. Physiological parameters (core temperature, heart rate) and perceptual variables (thermal sensation, perceived exertion) were collated synchronously at 3 min intervals. The results of two-way repeated measures analysis of variance (clothingxtime) revealed that the PeSI was useful in differentiating the heat strain levels between different work uniforms. Not only did the PeSI change in the same general manner with the PhSI, but it was also powerful in reflecting different levels of physiological strain. Thus, the PeSI offers considerable promise for heat strain assessment under simulated working conditions.

Yang, Y. and A. P. Chan (2017). "Heat stress intervention research in construction: gaps and recommendations." Ind Health 55(3): 201-209.

Developing heat stress interventions for construction workers has received mounting concerns in recent years. However, limited efforts have been exerted to elaborate the rationale, methodology, and practicality of heat stress intervention in the construction industry. This study aims to review previous heat stress intervention research in construction, to identify the major research gaps in methodological issues, and to offer detailed recommendations for future studies. A total of 35 peer-reviewed journal papers have been identified to develop administrative, environmental or personal engineering interventions to safeguard construction workers. It was found that methodological limitations, such as arbitrary sampling methods and unreliable instruments, could be the major obstacle in undertaking heat stress intervention research. To bridge the identified research gaps, this study then refined a research framework for conducting heat stress intervention studies in the construction industry. The proposed research strategy provides researchers and practitioners with fresh insights into expanding multidisciplinary research areas and solving practical problems in the management of heat stress. The proposed research framework may foster the development of heat stress intervention research in construction, which further aids researchers, practitioners, and policymakers in formulating proper intervention strategies.

Yang, Y. and A. P. Chan (2017). "Role of work uniform in alleviating perceptual strain among construction workers." Ind Health 55(1): 76-86.

This study aims to examine the benefits of wearing a new construction work uniform in real-work settings. A field experiment with a randomized assignment of an intervention group to a newly designed uniform and a control group to a commercially available trade uniform was executed. A total of 568 sets of physical, physiological, perceptual, and microclimatological data were obtained. A linear mixed-effects model (LMM) was built to examine the cause-effect relationship between the Perceptual Strain Index (PeSI) and heat stressors including wet bulb globe temperature (WBGT), estimated workload (relative heart rate), exposure time, trade, workplace, and clothing type. An interaction effect between clothing and trade revealed that perceptual strain of workers across four trades was significantly alleviated by 1.6-6.3 units in the intervention group. Additionally, the results of a questionnaire survey on assessing the subjective sensations on the two uniforms indicated that wearing comfort was improved by 1.6-1.8 units when wearing the intervention type. This study not only provides convincing evidences on the benefits of wearing the newly designed work uniform in reducing perceptual strain but also heightens the value of the field experiment in heat stress intervention studies.

Yi, W. and A. Chan (2014). "Optimal Work Pattern for Construction Workers in Hot Weather: A Case Study in Hong Kong." Journal of Computing in Civil Engineering 29.

Having established a Monte Carlo simulation-based algorithm to optimize work–rest schedule in a hot and humid environment, this paper attempts to develop the algorithm and identify an optimal work pattern, which may maximize the direct-work rates and minimize the health hazard due to heat stress to the workers concerned. Traditionally, construction workers in Hong Kong start work at 8:00 a.m. and finish work at 6:00 p.m., having one hour lunch break between 12:00 p.m. and 1:00 p.m., and an additional break of 30 min at 3:15 p.m. Construction workers can beat the heat by starting earlier to avoid some extreme conditions, which may occur at certain times of a day. By maintaining the current practice of 9-h working duration for a day, 21 additional work patterns with different start and finish times were proposed and evaluated by the developed optimization algorithm. An optimized schedule (direct-work rate of 87.8%) of working from 7:30 a.m. to 12:00 p.m. with a 20 min break at 9:40 a.m., having lunch

break between 12:00 p.m. and 1:00 p.m., and working from 1:00 p.m. to 5:30 p.m. with a 30 min break at 3:00 p.m. is proposed. The proposed work pattern not only maximizes direct-work rates but also minimizes the occurrence of heat stress on construction site. This will enable policy makers to derive solid guidelines for working in hot weather. Because the proposed work pattern is developed specifically for the construction industry, more work is needed to further investigate other industries and other climates to provide a holistic view in the future.

Yi, W. and A. P. C. Chan (2017). "Effects of Heat Stress on Construction Labor Productivity in Hong Kong: A Case Study of Rebar Workers." Int J Environ Res Public Health 14(9).

Global warming is bringing more frequent and severe heat waves, and the result will be serious for vulnerable populations such as construction workers. Excessive heat stress has profound effects on physiological responses, which cause occupational injuries, fatalities and low productivity. Construction workers are particularly affected by heat stress, because of the body heat production caused by physically demanding tasks, and hot and humid working conditions. Field studies were conducted between August and September 2016 at two construction training grounds in Hong Kong. Onsite wet-bulb globe temperature (WBGT), workers' heart rate (HR), and labor productivity were measured and monitored. Based on the 378 data sets of synchronized environmental, physiological, construction labor productivity (CLP), and personal variables, a CLP-heat stress model was established. It was found that WBGT, percentage of maximum HR, age, work duration, and alcohol drinking habits were determining factors for predicting the CLP (adjusted $R^2 = 0.68$, $p < 0.05$). The model revealed that heat stress reduces CLP, with the percentage of direct work time decreasing by 0.33% when the WBGT increased by 1 °C. The findings in this study extend the existing practice notes by providing scientific data that may be of benefit to the industry in producing solid guidelines for working in hot weather.

Yi, W., et al. (2017). "Evaluating the Effectiveness of Cooling Vest in a Hot and Humid Environment." Ann Work Expo Health 61(4): 481-494.

OBJECTIVE: This study aims to evaluate the effectiveness of a newly designed hybrid cooling vest for construction workers in alleviating heat stress. METHOD: Two types of cooling vests, namely, a commonly worn Vest A and a newly designed Vest B, were tested in a climatic chamber environment (34.0 degrees C temperature, 60% relative humidity, and 0.4 m s-1 air velocity) using a sweating thermal manikin. Four test scenarios were included: fan off with no phase change materials (PCMs) (Fan-off), fan on with no PCMs (Fan-on), fan off with completely solidified PCMs (PCM + Fan-off), and fan on with completely solidified PCMs (PCM + Fan-on). RESULT: Test results showed that Vests A and B provided a continuous cooling effect during the 3-h test. The average cooling power for the torso region of Vest B was 67 W, which was higher than that of Vest A (56 W). The addition of PCMs offered a cooling effect of approximately 60 min. Ventilation fans considerably improved the evaporative heat loss compared with the Fan-off condition. CONCLUSION: The newly designed hybrid cooling vest (Vest B) may be an effective means to reduce heat strain and enhance work performance in a hot and humid environment.

Yih, W. K., et al. (2019). "Investigating Possible Infectious Causes of Chronic Kidney Disease of Unknown Etiology in a Nicaraguan Mining Community." Am J Trop Med Hyg 101(3): 676-683.

A chronic kidney disease of unknown etiology (CKDu) has been killing workers in Central America. Occupational heat stress is thought to play an important role. Leptospirosis and hantavirus have been suggested as additional possible risk factors. In a case-control study in a Nicaraguan mining community, a structured survey was administered to adults, and biological measurements and specimens were taken. Serum was analyzed for antibodies to Leptospira and hantavirus. Before statistical analysis, a board-certified nephrologist determined final case and control status based on serum creatinine and other laboratory values. Multivariable analysis was by logistic regression. In sensitivity analyses, cases were restricted to those diagnosed with CKDu in the previous 3 years. Of 320 eligible participants, 112 were classified as presumptive cases, 176 as controls and 32 as indeterminant. The risk of CKDu in those ever having worked in mining or construction was 4.4 times higher than in other participants (odds ratio = 4.44, 95% CI: 1.96-10.0, P = 0.0003). Eighty-three (26%) of the 320 participants were seropositive for at least one tested strain of Leptospira. No evidence of a causal link between leptospirosis or hantavirus and CKDu was found. The sensitivity analyses provide some evidence against the hypotheses that leptospirosis or hantavirus leads to CKDu within a few years. A major limitation was the impossibility of determining the absolute or relative timing of infection and CKDu onset. A prospective cohort design, with repeated collection of specimens over several years, could yield clearer answers about infections as potential etiologic agents in CKDu.

Yoopat, P., et al. (2002). "Ergonomics in practice: physical workload and heat stress in Thailand." Int J Occup Saf Ergon 8(1): 83-93.

This study consists of assessments of the thermal environment and physiological strain in tasks associated with airport, construction, and metal jobs. The number of male and female participants was 108. Environmental heat stress was evaluated with the WBGT index. Physiological strain was evaluated by the relative cardiovascular load (%CVL) based on the measurements of heart rate. Also the increase of body temperature, weight loss, and perceived discomfort were determinated. At work sites the assessments lasted for 2 to 4 hrs for each participant. The mean physiological strain exceeded the level of 30%CVL. Severe peaks (over 60% CVL) were observed in specific tasks being in agreement with perceived discomfort ratings. The increase of body temperature and weight loss in most cases remained within acceptable limits. For the most strenuous tasks, various ergonomic improvements were developed in consultation with workers and managers.

Zhao, Y., et al. (2018). "Impacts of cooling intervention on the heat strain attenuation of construction workers." Int J Biometeorol 62(9): 1625-1634.

This study aimed to evaluate the effectiveness and practicality of a cooling intervention with a newly designed cooling vest on heat strain attenuation in the construction industry. Fourteen construction workers volunteered to participate in the field study. Each participant took part in two trials, i.e., cooling and control. Construction work included morning and afternoon sessions. Cooling intervention was implemented for 15 and 30 min during the morning and afternoon rest periods, respectively, between repeated bouts of work. Micrometeorological (wet-bulb globe temperature [WBGT]), physiological (tympanic temperature and heart rate), and perceptual (ratings of perceived exertion [RPE] and thermal sensation) measurements were taken during the test. Heat strain indices, including physiological strain index (PSI(HR)) and perceptual strain index (PeSI), were estimated accordingly. During the study, construction workers were exposed to a hot environment with a mean WBGT of

31.56 +/- 1.87 degrees C. Compared with the control, physiological and perceptual strain were significantly reduced in the cooling condition during rest and subsequent work periods ($p < 0.05$; $d = 0.24$-1.07, small to large cooling effect). Cooling intervention significantly alleviates heat strain in the construction industry. The effectiveness and practicality of a proposed cooling intervention were tested in a field study. Results provide a reference for setting guidelines and promoting application on a range of construction sites.

Zhao, Y., et al. (2017). "Evaluating the Physiological and Perceptual Responses of Wearing a Newly Designed Cooling Vest for Construction Workers." Ann Work Expo Health 61(7): 883-901.

Construction workers are subjected to heat stress because of the hot environment, physically demanding tasks, and/or personal protective equipment. A tailor-made cooling vest that protects construction workers from heat-related injuries was developed. The purpose of the study is to examine a newly designed cooling vest's effectiveness in alleviating physiological and perceptual strain in a hot and humid environment. Twelve male participants performed two trials, i.e., cooling vest (VEST) and control (CON) in a climatic chamber controlled at 37 degrees C temperature, 60% relative humidity, 0.3 m/s air velocity, and 450 W/m2 solar radiation to simulate the summer working environment of construction sites. Two bouts of treadmill exercise intermitted with 30-minute passive recovery were designed to simulate the practical work-rest schedule of the construction industry. The cooling vest was used during the passive recovery period in the VEST condition, and the results were compared with that of no cooling vest in the CON condition. The results revealed that the newly designed cooling vest can significantly alleviate heat strain and improve thermal comfort, based on the decrease in body temperature, heart rate, and subjective perceptions (including perceived exertion, thermal, wetness, and comfort sensation) of the participants. It can also prolong work duration in the subsequent exercise. The cooling countermeasures proposed in this study will be able to provide an effective solution in situations that involve repeated bouts of outdoor construction work.

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