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Mini Review

Smart Work Wear to Enhance Construction Workers' Health and Safety in Hot Weather

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Abstract

Heat stress may cause serious health hazards to construction workers. The Hong Kong Observatory recorded 9th August as the hottest day in 2019 with the highest temperature of 35.1°C. At least 75 construction workers suffered heat related injuries and deaths between 1998 and 2013 in Hong Kong. Researchers from The Hong Kong Polytechnic University have spent the past decade conducting research to improve the wellbeing and safety of construction workers. The research conducted followed an integrated strategy to develop occupational interventions against heat stress covering: (1) Clothing Design, (ii) Experimental Design and (iii) Coordination and Implementation. Their main practical output is an anti-heat stress uniform which reduces heat strain in working hours and a personal cooling vest that accelerates recovery during rest periods. Their recommended work-rest schedule was now part of the Construction Industry Council's guidelines, while their anti-heat stress uniform is now the standard attire for all public work contracts in Hong Kong.

Introduction

While it is common sense to avoid staying outdoor and performing strenuous activities for an extended time in hot summer, not all workers have that option, construction workers are no exception. They are at risk of heat stress that not only increases incident rate and reduces productivity, but also leads to serious health hazards, such as heat exhaustion and heat stroke, and even death [1]. As a continuous effort to improve the wellbeing and safety of construction workers in Hong Kong, a research team in The Hong Kong Polytechnic University (PolyU) has spent the past decade to tackle the risk of heat stress among construction workers in the hot and humid summer. Their findings on the optimal work-rest schedule to minimize the occurrence of heat stress were now part of the Construction Industry Council (CIC)'s guidelines. Their interdisciplinary project to devise the optimal work clothing on construction site gave rise to the multi-award winning Anti-Heat Stress Uniform (AHSU), which offers a 28.8% reduction in heat storage and a 14.2% improvement in thermal comfort [2]. The uniform was licensed to the CIC in 2015 and is now standard attire for all public works contracts commissioned by the government. Over 116,000 anti-heat stress shirts and 36,000 pairs of trousers have been sold to over 100 organizations to date. Besides Hong Kong, AHSU is also adopted for other work sectors including cleaning, gardening, and logistics in Hong Kong, Macao, Cambodia, and Saudi Arabia, benefitting workers who need to work constantly under direct sunlight across the board.

Optimal Work-Rest Schedule

Heat stress is the condition when the human body can no longer get rid of excess heat and regulates its internal temperature [3]. It is caused by environmental factors such as air temperature, humidity, solar radiation and ventilation, as well as the clothing worn and strenuousness of the work [4]. A heat stress simulation model was developed to determine an optimal work-rest schedule that strikes a balance between productivity and worker's health. The findings indicated that a 15-minute break after working for 120 minutes continuously in the morning, and a 20-minute break after working for 115 minutes continuously in the afternoon could effectively maximize productivity and minimize the occurrence of heat stress [5]. These recommendations were adopted in the Guidelines on Site Safety Measures for Working in Hot Weather by the CIC.

Anti-Heat Stress Uniform (AHSU)

Another method to prevent heat stress is by improving the heat and moisture performance of workers' attire. In the past, most local male workers went shirtless in summer to keep themselves cool, yet exposing themselves to harmful ultraviolet rays and other hazards. The research team partnered with experts in occupational safety, textile science and sports science from universities in the Chinese mainland, Taiwan, Hong Kong and the U.K. to design the optimal clothing for construction workers. The resulting multi-award winning AHSU offers protection against ultraviolet rays and has outstanding breathability and sweating wicking properties. The uniform is made up of a polo shirt top and cargo pants bottom, both made with advanced fabrics that leverage nanotechnology to wick sweat away from the skin so that the wearers feel drier and more comfortable. At the same time, sweat is evaporated more effectively because of a larger surface area while heat is absorbed from the skin.

The design of AHSC started with an empirical study with frontline workers to identify the required attributes of appropriate clothing in hot weather. Based on the identified criteria, thirty-nine types of fabrics (12 for polo shirts, 18 for trousers and 9 for reflective strips) were sourced, tested, and evaluated. Tests on air resistance, water vapour permeability, moisture management capacity, UV protection factor and abrasion were conducted to identify the physical properties of the selected fabrics. These characteristics were input into a purpose-developed Computer Aided Design (S-smart) system to identify the

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most appropriate fabrics with the best thermal-moisture performance [6]. Ultimately, 'Coolmax 100%' was selected as the best fabric for the polo shirt. This was further enhanced by trimming the inside of the polo shirt with nest mesh fabrics to foster better ventilation. The trousers were made from the 'Dry-inside' fabric, which incorporates a new moisture management technology developed by the research team. The fabric allows rapid one-way moisture transfer away from the skin to the surface of the garment. The unique features of ergonomic design include meshed warp knit fabric on the inside surfaces, porous reflective strips, loose-fit design to aid better ventilation, and different front and back designs to improve visibility.

Traditional research on clothing physiology relies heavily on the results of randomized controlled trials in laboratory settings. However, their results are questionable in terms of reliable and valid application to real-life settings. To bridge this gap, a novel occupational invention research methodology was adopted to evaluate the efficacy, effectiveness and acceptability of the AHSU [7]. Participants were randomly assigned to wear AHSU and a traditional uniform (TRADE). Firstly, a laboratory experiment was conducted to evaluate the efficacy of AHSU in a climatic chamber maintained at 34.5°C temperature and 75% relative humidity. The results showed that wearing AHSC lowered heat storage by 28.8%and improved thermal comfort by 14.2% as compared to TRADE. In particular, core temperature decreased significantly by 0.53°C [2] and the recovery rate in physiological strain rose by 9% when the AHSU system was used to aid recovery over a rest period [8]. The lower core temperature and a greater relief of heat strain, improves worker comfort and can accelerate recovery from fatigue. A field experiment was then undertaken to ascertain the effectiveness of the AHSU in alleviating perceptual strain among construction workers, showing a significant reduction of perceptual strain index by 7% when workers wore AHSU during work period [9]. Finally, a field survey was run with 189 construction workers to evaluate their personal perceptions of the thermal, pressure, tactile comfort of the alternative AHSU and TRADE garments. In the trial, workers wearing anti-heat stress uniform exhibited lower core temperature, reduced heart rate and better physiological strain index comparing to those in their usual work attire. Over 85% of the subjects preferred AHSU to their regular uniform.

Impact of the Research

In 2015, the AHSU technology was licensed to the CIC for a nominal value of HK$1 as a service to the community. Since then, AHSU has been available for sale via an on-line platform managed by the CIC. Between September 2016 and December 2018, a total of 116,000 pieces of anti-heat stress shirts and 36,000 pairs of trousers have been ordered by over 100 construction companies and HK Government Departments/public bodies/NGOs. The AHSU was further licensed to the Labour Affairs Bureau (LAB) of the Macao Government to benefit outdoor workers in sectors such as construction, gardening, logistics, and drainage on 21st November 2017. A total of 2,762 AHSU pieces had been distributed to outdoor workers in Macao by June 2019. Cambodian workers have also tried the AHSU uniforms and reported improved comfort and heat tolerance compared to their usual clothes. More recently, Administration of King AbdulAziz University, Saudi Arabia purchased the AHSU uniforms for trial by their workers'. Their initial step opens the prospect of a potential untapped market that stretches well beyond Hong Kong.

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