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Climatic and psychosocial risks of heat illness incidents on construction site

Yunyan Andrea Jia [a,*], Steve Rowlinson [b,c], Marina Ciccarelli [d]

[a] School of Built Environment, Faculty of Humanity, Curtin University, Perth, Australia
[b] Department of Real Estate and Construction, The University of Hong Kong, Pokfulam, Hong Kong
[c] Key Laboratory of Eco-environment in Three Gorges Reservoir Region under Ministry of Education, Chongqing University, Chongqing, China
[d] School of Occupational Therapy and Social Work, Faculty of Health Sciences, Curtin University, Perth, Australia

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ABSTRACT

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.

1. Introduction

The effect of global warming is leading to growing numbers of heat related diseases (Lin et al., 2009) and a general increase in mortality (Vaneckova et al., 2008). Continuous increase in ambient temperature amplifies the risk of occupational heat stress to outdoor workers, with construction workers being a vulnerable population (Xiang et al., 2014). This creates a challenge to the adaptability of existing international standards that provide benchmarks for heat stress management in the workplace (Parsons, 2013). Over decades, interventions on occupational heat stress have been developed using predominantly a "hot room" experimental method (Wyndham et al., 1967) – a setting that can hold control variables constant, yet isolated from the complexity of real life working environment. As a result, existing threshold-based intervention strategies (e.g. ACGIH, 2013; ISO 7243, 1989) are developed to manage the risks among homogeneous work crews in highly structured environments such as military training or steel mill works where decision making can be centralised and work-rest regimens can be routinely exercised. This assumed context is however a far cry from the nature of a dynamic workplace such as a construction site, where moving-around laborious tasks are performed under rapidly changing weather conditions. Unlike the manufacturing industry, the construction industry is organised in project-based organisations and operated through numerous instant decisions made by frontline personnel. These decisions are results of prioritisation among conflicting and short-term goals, in which progress pressure and financial incentives often prevail over safety concerns. In such a context, the experimentally defined environmental thresholds are found to be "security biased" (Budd, 2008) for being over-conservative and counterproductive, and thus never progress beyond the policy stage. The laboratory-validated interventions are implemented as competing tasks with the production tasks, leading to the elimination of one risk while introducing another, and therefore are rarely effective. To bridge this gap, a comprehensive, contextualised theoretical model is needed to explain and predict the effectiveness of interventions of heat stress management in a complex work context. Meanwhile, primary risks for heat illness incidents need to be identified to inform management decisions for prioritisation of resources and attentions. The objective of this study is to develop a theoretical model of heat stress management in construction project organisations and

* Corresponding author. School of Built Environment, Faculty of Humanity, Curtin University, GPO Box U1987, Perth, WA 6845, Australia.
E-mail address: yunyanbright@gmail.com (Y.A. Jia).

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to identify primary heat risk factors contributing to heat illness incidents happened on construction sites.

2. Methodology

A dilemma in the dominant positivist epistemology underpinning existing heat stress studies is that the subject must be taken out of the natural work context in order to test the effect of a set of predetermined, ‘objectively’ existing heat stress factors or interventions (e.g. Fujii et al., 2008). Yet once taken out of the context, both the subject and the factors are no longer the same. This, to a large extent, accounts for why scientifically validated interventions need to be customised in order to be useful in real world environments. We based our research on a social constructivist stance (Berger and Luckmann, 1966). Starting from the well-established rational model which defines six factors for heat stress, i.e., air temperature, humidity, radiant heat, air velocity, clothing effect and metabolic heat (Malchaire, 1995; Parsons, 2003), we explore how stakeholders in the construction industry make sense of these factors and henceforth how the heat risk factors as social constructs are linked to effectiveness of the interventions being practiced. On this stance, we treated participants of the study as both subjects and informants, and self-reported data with equal importance as the objectively measured environmental and physiological data during the triangulation analysis.

We decided to use a naturalistic, non-intrusive and triangulation approach (Lincoln and Guba, 1985) for this study on three concerns. First, the study must be non-intrusive to the on-going work process so to preserve the natural working environment. Second, all stakeholders who have a role in heat stress interventions on site needed to be involved in data collection in order for triangulation to work. Third, while the variables suggested by the rational heat stress model are measured quantitatively and continuously, we did not assume we had known the risks and the interventions needed. Rather, we assumed that little was known and new factors were to be elicited, therefore a grounded theory approach was necessary (Strauss and Corbin, 1990).

2.1. Instrumentation

Continuous data including worker heart rates and environmental heat stress (temperature, humidity, solar radiant heat, and Wet Bulb Globe Temperature (WBGT)) were recorded at 1-min intervals. Data on risks and interventions in the specific socio-managerial environment of each construction site were collected with three instruments. They included a data collection sheet for the construction workers sample, a questionnaire and interview guide for the managers sample and a site observation checklist. The three instruments share two sets of core questions, i.e., perceptions of risks and effectiveness of interventions. The items in the questionnaire for measuring perception of heat risks and perceived effectiveness of interventions were designed based on a review of the literature [key references include (HSE, 2002; Leithead and Lind, 1964; Parsons, 1995, 2006), existing guidelines on heat stress management (Abu Dhabi EHS Center, 2012a, 2012b; ACGIH, 2009; AIOH, 2003; CIC, 2008; CSAO, 2000; OSHA, 1999) and findings from a pilot study by the research team in 2010]. The items were designed using a five-point Likert scale. Equipment used for collecting environmental and physiological data are presented in Table 1.

A section of critical incident report was included in the worker data collection sheet to obtain workers' personal heat illness experiences. This included an exploratory question of whether the respondent had personal experience of heat illness on site, and if so, a brief description of the incident scenario, time, the work environment, perceived symptoms, treatment, perceived causes of the incident, and any other background information the respondent regarded as relevant to the incident. The critical incident technique (CIT) is a qualitative data collection method that guides participant to focus on personally experienced event and describes factual details around the event. It was first developed in the Aviation Psychology Program of the US Air Forces (Flanagan, 1954) and has been widely used in various research fields since (Butterfield et al., 2005; Tuuli and Rowlinson, 2010). Compared with the commonly used qualitative methods in which respondents are asked to provide general opinions about certain topics, CIT gives the respondents a focus and directs their attention to factual observations; therefore it elicits more valid data.

2.2. Sampling

Sampling of data collection was stratified by three criteria. First, by the types of projects, i.e., building work, civil engineering work, and RMAA (repair, maintenance, minor alteration and addition) work, which were having different organisational forms, workforce cultures and site environment characteristics. A second criterion for stratification of sampling was indoor and outdoor work; and the third criterion was to include major trades vulnerable to heat stress, including bar bender, bar fixer, carpenter, concreter, bricklayer, plasterer, welder, scaffolder, HAVC (heat, air ventilation and cooling) fitter, MEP (mechanical electrical plumbing) worker, demolition worker, tunnelling worker, and an open list to be suggested by site managers.

2.3. Data collection protocol

As any ethnographic study that needs to be informed of insiders' view of the target group, this study needed to identify ‘gatekeepers’ as initial contacts to lead the researchers to get access to other informants in the field (Lincoln and Guba, 1985). However, unlike a cultural group as a typical ‘field’ in an ethnographic study, target groups in this study were construction project organisations structured in hierarchies. For both safety and commercial reasons, access to construction sites had to be endorsed top-down by senior management. Therefore the research team first contacted senior management of clients or contractors, through the second author's network, to identify available sites that met the criteria of the research brief. Site managers or safety managers were then assigned to lead the researchers to the selected construction sites. However, these ‘gatekeepers’ who provided access to the site workers, were not part of the workers' community per se. Approaching the workers through their supervisors has a potential risk of introducing defensive attribution bias into the interview data (Hofmann and Stetzer, 1998), and therefore the researchers needed to build direct rapport and reciprocal trust with the workers to eliminate the ‘top-down’ effect such that workers can provide valid information (Bailey, 2007).

Argyris (1952) identifies four factors that lead to bias in data collected by formal interviews: (i) interviews are new psychological situations that are associated with tension and uncertainty; (ii) a formal interview setting represents an authoritarian relationship that triggers a defensive mechanism within the respondent; (iii) the formal interview represents intrusion by an outsider into the respondents' personal relationship with their leaders; and (iv) disparities in language and mannerisms between the researchers and the workers and practitioners can trigger defence mechanism among the respondents. Trust building between the researcher and the respondents is thus of vital importance for validity of field research and is more than keeping confidentiality of their personal information. Trust is to be developed through prolonged