



Association between objective and subjective assessments of environmental ergonomic factors in manufacturing plants



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ARTICLE INFO

Article history:

Received 31 December 2014

Accepted 24 December 2015

Available online 15 January 2016

Keywords:

Environmental ergonomics

Heat

Illuminance

Noise

Satisfaction

WBGT

ABSTRACT

The association between objective and subjective assessments of environmental ergonomic factors including noise, lighting and heat were conducted in a field study in three manufacturing plants. Data were collected from 130 workstations using questionnaire and physical measurements of the noise (noise dosimetry), lighting (task area illuminance) and heat (wet bulb globe temperature – WBGT) levels. The recommended noise, illuminance and WBGT levels were not met in about half of the workstations surveyed, which was in agreement with low satisfaction levels with the environmental factors in the workplace. A considerable effect of the environmental factors was found on perceived workers' job performance, safety and health. The results from contingency coefficient analysis indicated a relatively good agreement between the measured noise, illuminance and WBGT levels and the workers' perception of these factors. The results suggest that quantitative physical measurements should be supplemented by qualitative subjective assessments to provide more specific and additional details about the environmental conditions in each workplace and consequently to improve workers' satisfaction, job performance, safety and health.

Relevance to industry: The findings highlight the importance of environmental ergonomics and have implications for improvements in the design of the workplace to enhance workers' satisfaction, job performance, safety and health on areas where the environmental factors are not favourable. A better understanding of the environmental conditions and their effects in each working environment has the potential for a notable impact on productivity and workers' quality of life.

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1. Introduction

Environmental ergonomics can be defined as the scientific study of the effects of ambient environmental conditions on human comfort, performance and health (Hedge, 2000). Interaction between workers and their surrounding environment is one of the key important issues in almost all workplaces. In a work environment, there is a continuous and dynamic interaction between the workers and their surrounding environment that causes a number of physiological and psychological responses in workers, and consequently affects their comfort, performance, productivity, safety and health (Parsons, 2000). The effects of environmental factors on the workers can, therefore, be studied in terms of the effects on satisfaction, performance, health and safety. The

importance of the environmental conditions in different workplace settings have been well documented in the literature (Räsänen et al., 2000; Dawal and Taha, 2006; Kahya, 2007; Newsham et al., 2009; Lundh et al., 2011; Nazari et al., 2012; Dianat et al., 2013). The results from these studies indicate the adverse effects of environmental factors on workers' satisfaction, job performance, health and safety. Obviously, workers in different workplaces may be exposed to various environmental conditions. It has also been acknowledged that the human responses to the environmental factors depend on a number of factors including physical, physiological and psychological as well as individual differences (Parsons, 2000). Thus, it is necessary to conduct studies in each working environment to find out how these factors will affect the workers in that work setting.

It has been suggested that for reliable assessment of the environmental factors in each working environments it would be helpful to take into account both objective and subjective aspects (Küller et al., 2006; Dianat et al., 2013). Moreover, the combination

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of both objective and subjective evaluations may lead to a better understanding and a more detailed analysis of several different parameters of the environmental factors. Several previous studies on this issue have considered both objective measurements (e.g. physical measurements of noise, lighting and heat) along with subjective assessments (e.g. satisfaction, comfort, perceived job performance and health and safety consequences) (Küller et al., 2006; Gavhed and Toomingas, 2007; Newsham et al., 2009; Dianat et al., 2013). Also, consideration of various aspects of environmental factors through subjective assessments seems to be helpful because physical measurements might be complex, time consuming or not available. A better understanding of the environmental conditions and their effects in each working environment has the potential for a notable impact on productivity and workers' quality of life.

Based on the above-mentioned background, the purposes of this field study were to: (1) evaluate the physical noise, illuminance and heat levels in indoor workplaces in three packing plants as an exemplar manufacturing setting (objective assessments), (2) examine the workers' subjective assessments of the environmental factors (including noise, lighting and heat) and their effects on workers' satisfaction, perceived job performance, safety and health (subjective assessments), (3) determine how objective and subjective assessments are related, and (4) propose possible solutions for improving environmental factors based on the subjective ratings.

2. Methodology

2.1. Study design and setting

This field study was conducted in three packing plants in Saveh in central Iran. The research sites included different indoor working areas such as services, paper production, paperboard conversion, pasting, cutting, printing and puncture sites. The data collection was performed using both subjective (questionnaire) and objective (physical measurements of the environmental factors) methods. A questionnaire, developed by the authors, was administered to collect data about the environmental factors (e.g. noise, lighting, and heat conditions) in the working environment, and their influences on subjective assessments for employee satisfaction, perceived job performance, safety and health. Questions regarding potential improvements to the environmental conditions were also included. The questionnaire was used as a basis for semi-structured interviews conducted by one of the authors. The physical measurements included illuminance (in lux), noise dosimetry (in dB) and wet bulb globe temperature (WBGT) (in °C) measurements throughout research sites. The physical measurements were taken during data collection and evaluated based on the recommended standards for lighting (EN 12464-1, 2002), noise (OSHA, 1983) and thermal conditions (ISO 7243, 1989). These standards were used as a criterion to determine whether or not the environmental conditions in each workstation met the standard. Each workstation was scored as “met” if the noise or WBGT levels measured in that workstation were equal or lower than the recommended standard and if the illumination level was equal or higher than the recommended standard; otherwise it was scored as “not met”. The study protocol was reviewed and approved by Ethical Review Committee of the Tabriz University of Medical Sciences.

2.2. Participants

The three plants had a total number of approximately 300 employees at the time of study. To calculate sample size for the study, basic information was obtained from a study conducted by Dawal

and Taha (2006) on the primary endpoint of correlation between environmental factors and job satisfaction. For this, a minimum effect size of 0.2 was considered to obtain the maximum sample size. Considering a confidence level of 95%, a power of 80% and two tailed tests, the minimum sample size determined as 134 by G-power software (version 3.1.2). Being in good general health and not having any visual and hearing problems were considered as inclusion criteria for the study. Participants were all male volunteers, with their ages ranging from 20 to 44 years (mean = 31.6 years, SD = 6.3 years), and had been working in their current job between 1 and 8 years (mean = 3.97 years, SD = 2.1 years). The majority of participants were married (74.6%) and had secondary education (62.3%). Each participant signed a written informed consent form before participation in the study and was not paid for his participation.

2.3. Data collection

A questionnaire was developed by the authors to collect data about the environmental factors including noise, lighting and heat in the working environment, and their influences on subjective assessments for employee satisfaction, perceived job performance, health and safety. Demographic data including age, educational level and marital status, as well as job details (job category, job experience and daily working hours) were recorded in the first part of the questionnaire. The questionnaire also evaluated the effects of noise (15 questions), lighting (16 questions) and heat (13 questions) in the working environment on employee satisfaction, perceived job performance, safety and health. Using a 5-point Likert scale (where 1 = very low, 2 = low, 3 = moderate, 4 = high and 5 = very high) participants rated their reactions to environmental conditions as well as to improvements to working environment. The content and face validity of the measure were evaluated by a panel of 10 experts in the field of ergonomics and occupational health, and slight word modifications were made on some items in the questionnaire. The internal consistency reliability of the constructs was evaluated by Cronbach's α in a pilot study by 30 subjects. The reliability coefficients for the constructs indicated good internal consistency (with Cronbach's α coefficients ranging between 0.71 and 0.92). The whole questionnaire took about 20 min to complete.

Physical measurements of the environmental factors (including noise dosimetry, task area illuminance and thermal stress using wet bulb globe temperature [WBGT]) were also taken throughout research sites during data collection. A noise dose meter (model TES-1354) together with a calibrator (model TES-1356) was used for noise dosimetry. The illuminance levels (in lx) were measured at the horizontal task area of each of the employees using a calibrated luxmeter (Hanger Digital Lux Meter, model EC1). Measurement of the heat stress in the working environment was performed using WBGT index.

2.4. Data analysis

The analysis of the data, including descriptive statistics, was performed using SPSS software version 16.0 (SPSS Inc., Chicago, IL). Non-parametric Friedman tests were employed to test whether the ratings observed were significantly different between categories of each environmental factor. This analysis was followed by related post hoc tests adjusted for error rate by Bonferroni method. The agreement between employees' perception of the environmental factors and the actual measurements was evaluated by contingency coefficient test to fulfil the assumptions with regard to ordinal measurement of the variables. For the same reason, Spearman's correlation coefficients were used to examine possible relationships between the study variables. A significance level of $P < 0.05$

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