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Musculoskeletal ailments in Indian injection-molded plastic furniture manufacturing shop-floor: Mediating role of work shift duration

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ABSTRACT

The present manuscript aims to investigate the occurrence of awkward working postures and the consequent prevalence of the Symptoms of Musculoskeletal Ailments (SMA) among the shop floor workers of Indian small and medium scale injection molded plastic furniture manufacturing factories. An attempt has also been made to assess the contributing role of Workstation Design (WD), Working Postures (WP) and Work Shift Duration (WSD) concerning symptoms of musculoskeletal ailments and to find out the inter-relationships among all these factors. Direct observation aided by photography helped to observe working methods, postures and the design of workstations. The prevalence of SMA was evaluated using Standardized Nordic Questionnaire and awkward WP by postural assessment tools like Ovako Working posture Analysis System (OWAS) and Rapid Entire Body Assessment (REBA). SMA was significantly ($p < 0.001$) higher for shop-floor workers compared to administrative and supervisory employees. Mediation statistics (using correlation and regression) was employed to analyze the stand-alone/cumulative impact(s) of WP, WD and WSD in determining SMA. Awkward WP, prolonged WSD and bad WD were established as the significant risk factors for higher prevalence of SMA for shop-floor workers. Influence of WP and WD on SMA was found to be significantly ($p < 0.05$) mediated through WSD. It was established through statistical modeling that occurrence of SMA due to awkward WP and bad WD is further exacerbated if WSD is prolonged. These findings would have constructive contributions in framing ergonomic intervention strategies and articulating methodological stipulations for work design to dwindle the SMA in shop-floor workers of the Indian small and medium scale injection-molded plastic furniture manufacturing factories.

Relevance to industry: Symptoms of Musculoskeletal Ailments (SMA) due to awkward working posture and bad workstation design are exacerbated in prolonged work shift duration. Regulating work shift duration could be a possible ergonomic intervention strategy to curb SMA, if the scope for workstation and work method redesign towards avoiding awkward posture is limited.

1. Introduction

Ensuring and promoting safe and healthy working conditions is the main aim of ergonomics; the science dealing with the interactions among human, machine and the surrounding environment. Physical ergonomics deals with human anatomical, anthropometric, physiological and biomechanical aspects as they relate to physical activity; whereas cognitive ergonomics emphasizes on issues like perception, memory, reasoning and motor response (International Ergonomics Association, 2000). Interactions between human and the industrial working environment create challenging problems, reportedly increasing during the last few years, especially in the manufacturing systems scenario (Cimino et al., 2009).

Musculoskeletal disorders are reported to be the most prevalent form of occupational hazards among majority of the industrialized nations (Whysall et al., 2006). Globalization, along with rapid industrial growth, has caused the emergence of occupational health related issues in developing countries, including India (Saiyed and Tiwari, 2004). Occupational health issues are indeed prevalent in India across a wide spectrum of professions. Physical risk factors

Full forms of abbreviations: SMA, Symptoms of Musculoskeletal Ailments; WSD, work shift duration; WP, working posture; WD, workstation design.

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have been reported from India in various durable goods manufacturing industries like foundries, steel factories, welding shops in small scale industries, electroplating industries, glass factories, electronic component manufacturing, lock manufacturing, pedestal oil lamp manufacturing etc. (Sanjog et al., 2013) and also in other unorganized sectors (Wani and Jaiswal, 2011; Das and Gangopadhyay, 2011). Ergonomists and occupational health researchers have highlighted multiple issues e.g., awkward working postures, repetitive activities, manual heavy load handling etc., leading to occupational hazards among the workers of Micro, Small and Medium Enterprises (MSMEs) located in India (Rai et al., 2012). Though the symptoms of musculoskeletal ailments (SMA) are widely noticeable in various industrial sectors, occupational health related issues in the Indian plastic processing industry have hardly been reported.

Plastic processing industries are extremely fragmented consisting of MSMEs offering enormous employment opportunities (Central Institute of Plastics Engineering and Technology, 2010). Petrochemical projects are catalyzing the establishment of plastic processing units (Assam Industrial Development Corporation Limited, 2010; Haldia Petrochemicals Limited, 2013). With the conspicuously growing numbers of small and medium scale plastic processing industries in India, evaluating the extent of the prevailing symptoms of musculoskeletal ailments has been identified by the authors as the need-of-the-hour. This would help in formulating guidelines and strategies in implementing ergonomic interventions which can be stipulated for the forthcoming industries. This piece of work therefore attempts to examine the stand-alone/cumulative impact(s) of workstation design (WD), working postures (WP) and work shift duration (WSD) on the symptoms of musculoskeletal ailments (SMA) and extrapolate their interdependence (if there be any).

2. Study population and methods

2.1. Selection of factories, workstations and workers for survey

Seven injection-molded plastic furniture manufacturing factories (in the small and medium scale sectors) located in the state of Assam, India were identified for the possibility of conducting research. However, the authors were permitted by the managements of four organizations to conduct ergonomic studies for their factories. Non-disclosure agreements regarding their identification compelled the authors to keep them anonymous.

Three shop-floor workstations namely, blending (mixing), granulator (grinding/scrap grinder) and injection-molding were selected to assess the various physical risk factors leading to the occurrence of the symptoms of musculoskeletal ailments. Work schedule of six days a week and work shift duration of 8 and 12 h was noticed among workers in the factories. Male workers were employed in the shop-floor workstations. Healthy adult male workers were selected as participants/responders as per the following pre-set inclusion criteria – similar age, weight, standing height and work experience (minimum one to less than five years of uninterrupted work in the present occupation); and no medical record of any chronic disease. Workers with work experience of more than five years were rarely present in any of the factories, leading to their exclusion in order to maintain a narrow range of work experience.

Twenty nine workers (29) from the blending workstations, ten (10) from the granulator workstations and forty six (46) from the injection-molding workstations participated in the study. Workers in the shop-floor workstations were considered as the experimental group. Fifteen (15) individuals with similar demographic characteristics, but involved in different activities (administrative and supervisory occupations), were selected to constitute the control group. None of the participants had any form of discomfort/pain/ache in any part of the body due to past accident/injury. Information regarding age and work experience was gathered by means of an interview, whereas weight and standing height were recorded by direct measurement.

2.2. Description of shop-floor workstations and the associated work activities

2.2.1. Blending workstation

Blending is done to mix the polymers uniformly with additives like fillers, plasticizers and coloring agents. The work activities observed in this workstation are illustrated in Fig. 1.

2.2.2. Granulator workstation

The granulator grinds rejected/defective finished goods and used plastic products collected from the open market, into plastic granules for reuse in the production process. The observed work activities in this workstation are depicted in Fig. 2.

2.2.3. Injection-molding workstation

The injection-molding machine is used to melt the plastic granules in order to facilitate their injection into the cold mold for manufacturing the finished products. The observed work activities in this workstation are depicted in Fig. 3.

2.3. Study of the symptoms of musculoskeletal ailments

The Standardized Nordic Questionnaire was used to investigate the prevalence of the symptoms of musculoskeletal ailments and identify the affected body parts (Kuorinka et al., 1987). The procedure involved showing a body map to volunteers and recording the responses to various queries in the questionnaire. Incidences of fatigue, injury and accident were not assessed as they were beyond the scope of the stated purposes of this study.

2.4. Study of awkward posture

Ovako Working posture Analysis System (OWAS) is an internationally accepted method for the analysis and control of poor working postures in the industry (Karhu et al., 1977). It analyzes the most common work postures for back, arms and legs including the weight of the load handled. OWAS technique was first employed to understand the overall scenario of the awkward postures during various activities. This technique lacks neck/elbows/wrist assessments and there is no distinct separation of right and left upper extremities (Battini et al., 2011). So for drawing clear inferences, Rapid Entire Body Assessment (REBA) (Hignett and McAtamney, 2000) was used subsequently for postural assessment. Rapid Entire Body Assessment evaluates the manual material handling operations and the validity of REBA has been established using numerous work postures from health care, manufacturing, electricity industries etc. (McAtamney and Hignett, 2005). The entire work cycle in each workstation was divided into different work elements (placing, lifting and cutting). Photographs of the workers performing different tasks (representing the major work elements) were taken from more than one view point for clear observation of relative positions of the body segments.

2.5. Statistical techniques for data analysis

Inferential statistics helps to obtain conclusions regarding the source of data (Hoel, 1976). Sample sizes were small and the