UNIVERSITI PUTRA MALAYSIA

EFFECTIVENESS OF PARTICIPATORY ERGONOMICS INTERVENTION TO IMPROVE MUSCULOSKELETAL HEALTH AND PSYCHOSOCIAL FACTORS AMONG SELECTED MANUFACTURING INDUSTRYWORKERS IN SELANGOR, MALAYSIA

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By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

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EFFECTIVENESS OF PARTICIPATORY ERGONOMICS INTERVENTION TO IMPROVE MUSCULOSKELETAL HEALTH AND PSYCHOSOCIAL FACTORS AMONG SELECTED MANUFACTURING INDUSTRY WORKERS IN SELANGOR, MALAYSIA

By

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March 2017

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Introduction: Musculoskeletal diseases (MSDs) are the most reported occupational diseases worldwide, as well as in Malaysia. Participatory ergonomics (PE) intervention was recommended as one of the promising strategy to prevent musculoskeletal problems at the workplace. However, the evidence for its effectiveness was lacking and was not found in the manufacturing industry of Malaysia.

Objective: The primary aim of this study was to determine the effectiveness of PE intervention to improve musculoskeletal health and psychosocial factors among manufacturing industry workers.

Methodology: A total of 436 workers who fulfilled the inclusive and exclusive criteria were selected from 9 manufacturing companies in Selangor using multistage sampling method. The study design of this study was Solomon-four group, in which the participants were randomly assigned into 4 groups by departmental levels: pretested intervention or control group, or non-pretested intervention or control group. The PE intervention program could be divided into 3 phases. Phase 1 was the walkthrough survey at workplace and development of PE intervention module, phase 2 was PE training and implementation of changes, and phase 3 was follow up. The intervention group was given PE intervention while the control group was given hearing conservation program. The main outcomes measured included musculoskeletal symptoms (MSS) and levels of musculoskeletal pain at 9 body regions (Nordic Questionnaire), perceived stress (PSS-10), chronic stress (CSSS), depression and anxiety (DASS-21), and psychosocial work factors (JCQ). Data were collected by using validated questionnaire before intervention (pretest) and 3 months after intervention (posttest).

Results: This study suggested high prevalence of overall MSS (78.3%) and multi-site pain (MSP) (48.3%), with lower back (57.9%) being the most complained anatomical

sites. Several characteristics such as female, obese, current and former smokers, having sleep problems occasionally and longer work duration were associated with higher prevalence of MSS. The psychosocial factors remained healthy, with majority of respondents reported low level of mental stress, emotional states and psychosocial work factors. Higher level of chronic stress, depression and anxiety were reported among workers with following characteristics: males, work position as supervisors, migrant, long work duration and low work salary. After adjusting for sociodemographic, health and work characteristics, psychosocial factors and MSS were reciprocally associated, where chronic stress, depression, anxiety and job strain significantly predicted MSS and, vice versa, MSS at neck, upper back and MSP significantly predicted chronic stress, depression, anxiety and job strain. In addition, Structural Equation Modelling (SEM) concluded the roles of mental stress and emotional states ($\beta = 0.17$) as the mediators for the relationship between psychosocial work factors and MSS. The effectiveness of PE intervention was evaluated using sequential analyses for Solomon four-group design. The PE intervention had accounted for about 11% to 28% of reduction to the prevalence of MSS at single anatomical region and 30% of reduction to that of MSP among pretested workers. A two-way MANOVA revealed significant main effect of intervention on the reduction of total musculoskeletal pain collectively. Levels of musculoskeletal pain at almost all the anatomical sites had reduced significantly in the intervention group, except for elbow, hand and thigh regions. The findings also revealed that PE intervention was more effective than the control group in improving psychosocial factors by lowering the levels of chronic stress, depression, anxiety and psychological job demand.

Conclusion: This study showed that PE intervention could effectively improve musculoskeletal health and psychosocial factors among manufacturing industry workers. Psychosocial factors and musculoskeletal health were reciprocally associated, with mental stress and emotional states mediated the relationship between psychosocial work factors and MSS.

Keywords: Participatory ergonomics intervention, musculoskeletal symptoms, psychosocial factors, Solomon four-group, manufacturing industry

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

KEBERKESANAN INTERVENSI ERGONOMIK PARTISIPATORI UNTUK MENAMBAHBAIKKAN KESIHATAN OTOT RANGKA DAN FAKTOR-FAKTOR PSIKOSOSIAL DI KALANGAN PEKERJA DALAM INDUSTRI PEMBUATAN TERPILIH DI SELANGOR, MALAYSIA

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Pengenalan: Penyakit otot rangka (MSDs) merupakan peyakit pekerjaan yang paling kerap dilaporkan di seluruh dunia, termasuk Malaysia. Intervensi ergonomik partisipatori (PE) merupakan salah satu strategi yang berkesan untuk mencegah masalah otot rngka di tempat kerja. Walaubagimanapun, bukti-bukti keberkesanan PE terutamanya dalam industry pembuatan di Malaysia adalah kurang.

Objektif: Tujuan utama kajian ini adalah untuk menentukan keberkesanan intervensi PE dalam menambahbaikkan kesihatan otot rangka dan faktor-fakto psikososial di kalangan pekerja dalam industri pembuatan.

Methodologi: Sejumlah 436 pekerja yang memenuhi kriteria inklusif dan eksklusif telah dipilih dari 9 kilang pembuatan di Selangor dengan menggunakan kaedah persampelan pelbagai tahap. Reka bentuk kajian ini adalah jenis Solomon kumpulan empat. Responden kajian telah dibahagikan kepada 4 kumpulan secara rawak di peringkat jabatan: kumpulan intervensi atau kawalan yang akan diprauji, atau kumpulan intervensi atau kawalan yang tidak akan diprauji. Program PE boleh dibahagi kepada 3 peringkat. Peringkat pertama merupakan penyiasatan di tempat kerja dan pembangunan modul latihan PE, peringkat kedua merupakan latihan PE dan perlaksanaan penambahbaikan di tempat kerja manakala peringkat ketiga merupakan susulan kepada program. Kumpulan intervensi diberikan intervensi PE manakala kumpulan kawalan diberikan program pemulihan pendengaran. Hasil kajian utama yang diukur termasuklah simtom otot rangka (MSS) dan tahap kesakitan otot rangka pada 9 bahagian badan (Nordic Questionnaire), persepsi stres (PSS-10), stres kronik (CSSS), kemurungan dan kegelisahan (DASS-21) serta faktor-faktor persekitaran kerja (JCQ). Data kajian dikumpulkan dengan menggunakan borang soal selidik yang sudah dikenal pasti sebelum intervensi kajian (ujian pra) dan 3 bulan selepas program intervensi (ujian pasca).

Keputusan: Kajian kita menunjukkan bahawa pervalensi MSS secara keseluruhan (78.3%) dan penyakit otot berbagai (MSP) (48.3%) adalah sangat tinggi. Bahagian pinggang (57.9%) merupakan bahagian badan yang paling bermasalah. Ciri-ciri seperti perempuan, obesiti, perokok dan bekas perokok, masalah tidur dan tempoh kerja yang panjang adalah berkaitan dengan prevalensi MSS yang lebih tinggi. Faktor-faktor psikososial di kalangan responden adalah sihat, di mana majoriti daripada mereka melaporkan tahap stres, keadaan emosi dan faktor-faktor persekitaran kerja yang rendah. Tahap stress, kemurungan dan kegelisahan yang lebih tinggi diperhatikan di kalangan pekerja dengan ciri-ciri berikut: lelaki, bekerja sebagai penyelia, pekerja asing, tempoh kerja yang panjang dan gaji yang rendah. Setelah ciri-ciri sosiodemografik, kesihatan dan kerja dikawal, kita mendapati bahawa factor psikososial dan MSS adalah saling berkaitan, di mana stres kronik, kemurungan, kegelisahan dan tekanan kerja dapat meramalkan masalah MSS, dan secara songsangnya, masalah stress kronik, kemurungan, kegelisahan dan tekanan kerja boleh meramalkan masalah MSS di bahagian leher, belakang dan MSP. Selain daripada itu, Permodelan Pengiraan Berstruktur (SEM) telah menyimpulkan peranan stres mental dan keadaan emosi (β= 0.17) sebagai perantara di antara faktor persekitaran kerja dan masalah MSS. Keberkesanaan intervensi PE telah dinilai dengan menggunakan kaedah analisa berturutan untuk kajian Solomon kumpulan empat. Intervensi PE telah menyumbang kepada penurunan sebanyak 11% hingga 28% ke atas prevalensi MSS pada satu bahagian badan dan sebanyak 30% ke atas pervalensi MSP di kalangan pekerja yang telah diprauji. Analisa MANOVA dua-hala menunjukkan kesan utama intervensi yang signifikan ke atas pengurangan tahap kesakitan otot rangka secara keseluruhan. Hampir kesemua bahagian badan telah mencatatkan pengurangan dari segi tahap kesakitan otot rangka melainkan bahagian siku, tangan dan paha. Hasil kajian kita juga menunjukkan bahawa intervensi PE adalah lebih berkesan daripada kumpulan kawalan dalam menambahbaikkan faktor-faktor psikososial dengan mengurangkan tahap stres kronik, kemurungan, kegelisahan dan psikologi beban kerja.

Kesimpulan: Kajian ini telah menunjukkan bahawa intervensi PE boleh menmbahbaikkan kesihatan otot rangka dan faktor-faktor psikososial di kalangan pekerja dalam industri pembuatan. Faktor-faktor psikososial dan kesihatan otot rangka adalah saling berkaitan, di mana stres mental dan keadaan emosi menjadi perantara kepada hubungan di antara faktor-faktor persekitaran kerja dan MSS.

Kata kunci: Intervensi ergonomik partisipatori, penyakit otot rangka, faktor psikososial, Solomon kumpulan empat, industry pembuatan

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I certify that a Thesis Examination Committee has met on (date of viva voce) to conduct the final examination of LIM CHEE SIANG on his thesis entitled "Participatory Ergonomics Intervention to Improve Musculoskeletal Health and Psychosocial Factors among Manufacturing Industry Workers in Selangor, Malaysia" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the (Doctor of Philosophy of Occupational Health and Safety).

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LIST OF ABBREVIATIONS

AGFI	Adjusted Goodness-of-Fit Index
AMOS	Analysis of Moment Structures
ANCOVA	Analysis of covariance
ANOVA	Analysis of variance
BMI	Body Mass Index
CFI	Comparative Fit Index
CONSORT	Consolidated Standards of Reporting Trials
COPSOQ	Copenhagen Psychosocial Questionnaire
CSSS	Chronic Stress Screening Scale
DALYs	Disability-adjusted life years
DASS-21	Depression, Anxiety and Stress Scale
DOSH	Department of Occupational Safety and Health
EMG	Electromyography
EODS	European Occupational Diseases Statistics
ERI	Effort-Reward Imbalance Questionnaire
EU	European Union
GDP	Gross Domestic Product
GFI	Goodness-of-Fit Index
HADS	Hospital Anxiety and Depression Scale
ILO	International Labour Organization
JCQ	Job Content Questionnaire
JSS	Job Stress Survey
MANOVA	Multivariate analysis of variance

MSDs	Musculoskeletal disorders
MSP	Multi-site pain
MSS	Musculoskeletal symptoms
NESDA	Netherlands Study of Depression and Anxiety
NHIS	National Health Interview Survey
NIOSH	National Institute for Occupational Safety and Health
NSDC	National SME Development Council
OLS	Ordinary Least Squares
OSH	Occupational safety and health
OSH-MP 15	Occupational Safety and Health Master Plan for Malaysia, 2015
PE	Participatory ergonomics
PEF	Participatory Ergonomics Framework
PHQ	Patient Health Questionnaire
PPE	Personal protective equipment
PSS-10	Perceived Stress Scale
PWC	Psychosocial Working Conditions
RMSEA	Root Mean Square Error of Approximation
SEM	Structural Equation Modeling
SMEs	Small medium enterprises
SOCSO	Social Security Organization
SPSS	Statistical Package for the Social Sciences
TICS	Trier Inventory of Chronic Stress
UK	United Kingdom
UPM	Universiti Putra Malaysia

US	United States
VAS	Visual analogue scale
WHO	World Health Organization
WISE	Work Improvement in Small Enterprises
YLDs	Years lived with disability

CHAPTER 1

INTRODUCTION

According to National Institute for Occupational Safety and Health (NIOSH) of the US Centers for Disease Control and Prevention, musculoskeletal disorders (MSDs) are injuries or disorders of the muscles, nerves, tendons, joints, cartilage, an disorders of the nerves, tendons, muscles and supporting structures of the upper and lower limbs, neck, and lower back that are caused, precipitated or exacerbated by sudden exertion or prolonged exposure to physical factors such as repetition, force, vibration, or awkward posture (Barondess et al., 2001) It is consistently one of the most commonly reported occupational health problem worldwide.

In European Union (EU) countries, MSDs caused by work affected more than 4 million workers and accounted for about half of all work-related disorders (Gauthy, 2007). The European Working Conditions Survey published by the European Foundation has shown that almost a quarter of workers across the EU report experiencing backache and muscular pain (Parent-Thirion et al., 2007). According to the Bureau of Labor Statistics, MSDs accounted for about 29 to 35% of all injuries and illnesses involving days away from work and remain the biggest category of injury and illness in the United States (US) from year 1992 to 2014 (US Bone and Joint Initiative, 2014).

Musculoskeletal problems do not only cause pain and disability to individual (Côté et al., 2008), but also bring pervasive impacts to the society and companies in both direct and indirect costs through loss of work productivity, absenteeism, medical fees and compensation (Zheltoukhova et al., 2012). In view of these impacts and burden, effective prevention or intervention program must be taken to tackle the problems of musculoskeletal diseases. Most of the intervention studies have focused on physical factors (changes of work environment, redesign of tools and lifting aids), behavioral factors (changes of work method, use of personal protective equipment (PPE) and physical training) and psychosocial factors (job rotation, job demand and job control). Although enormous prevention studies on MSDs have been done by researchers, systematic reviews in this area found that high-quality studies on the effectiveness of ergonomics interventions with sound evidence was lacking (Linton & van Tulder, 2001; Volinn, 1999).

A promising strategy to prevent musculoskeletal problems at the workplace is participatory ergonomics (PE) intervention. It is defined as the involvement of people in planning and controlling a significant amount of their own work activities, with sufficient knowledge and power to influence both processes and outcomes in order to achieve desirable goals (Wilson & Haines, 1997). A characteristic feature of PE is the formation of an ergonomics 'team' typically made up of employees or their representatives, managers, ergonomists, health and safety personnel, and research experts. The newly formed team will then undergo ergonomics training to become familiar with ergonomics principles. With a foundation of ergonomics concepts and methods in place, the group

uses its newly developed knowledge to make improvements in their workplace (Rivilis et al., 2008; Haims & Carayon, 1998).

The PE approach has been recognized as an effective approach to reduce MSDs and its potential to also improve psychosocial work factors in the workplace (Rivilis et al., 2008; Kogi, 2006). However, few high quality studies have been reported and evidence on the effectiveness of PE continues to be scanty. This study is the first that evaluated the effects of PE intervention on musculoskeletal health and psychosocial factors among manufacturing industry workers in the small medium enterprises (SMEs) using Solomon-four group design.

1.1 Problem Statement

In Malaysia, MSDs represent the most commonly reported occupational disease. Statistics from the Social Security Organization (SOCSO) show that the number of MSDs cases reported to the organization increases every year (SOCSO, 2015). A recent study by Jafri et al. (2016) using database from SOCSO suggested that manufacturing industry has the highest number of MSDs work compensation claims of all major industries nationally. Although automation has been taking place in many of the manufacturing operations, many works still required manual handling by workers (Spallek et al., 2010). Blue collar workers and operators in the manufacturing industry usually exposed to works requiring manual material handling, awkward postures, forceful exertion and repetitive movements (Chee et al., 2004; US Department of Labor, 2000).

Several studies in Malaysia found that the prevalence of MSDs and musculoskeletal symptoms (MSS) among manufacturing industry workers are very high (Foong et al., 2014; Deros et al., 2010; Chandrasakaran et al., 2003). On top of that, some authors even found that very high percentage of manufacturing industry workers reported high perceived stress, psychological job demand, depression and anxiety (Yakub & Sidik, 2014; Edimansyah et al., 2008). Nevertheless, most of the studies were conducted on one company only and the results might not reflect the real situation of manufacturing industry in Malaysia.

The etiology of MSDs is multifactorial and complex, which includes the roles of physical, organizational, psychosocial, and personal factors in its development (Bernard, 1997), but previous studies have largely emphasized on the impact of physical factors on MSDs. Growing evidence have shown that most of the MSDs are non-specific in nature, with no clear evidence of underlying injury to tissues (Endean et al., 2011). Plentiful of research have addressed psychosocial factors as the predictors for MSDs over the past decade, nonetheless, little research about the reciprocal relationship that MSDs are the predictors for psychosocial factors have been conducted (Devereux et al., 2011; Haukka et al., 2011). Generalized linear model analyses that are commonly used in previous studies to understand the association between risk factors and MSDs might not be that effective when several intermediate variables and effect modifiers are present in the model (Park et al., 2010). Structural equation modelling (SEM), which is a second

generation multivariate analysis technique, can overcome this limitation and it is very useful in the assessment of complex interrelationship between risk factors (Lee et al., 2007; Bystrom et al., 2004). However, the use of SEM in the study of MSDs risk factor is very rare, especially in Malaysia. In fact, analysis of the factors related to development and progression of MSDs is important in its prevention and management in the workplace.

The increasing trend of MSDs cases is a critical and worrisome problem for Malaysia given that MSDs has been closely related with organization such as absenteeism, turnover, time performance, productivity, morale, work disability and accidents (Punnett et al., 2005; Buckle, 2005). In view of these impacts, there is an urgent need for effective prevention strategies. Although PE approach is commonly recommended as a sustainable solution to reduce the burden of MSDs, the evidence for its effectiveness is lacking, especially its effects on psychosocial factors (Haukka et al., 2010; Driessen et al., 2010). Furthermore, it should be noted that most studies on the effectiveness of PE intervention suffered from methodological shortcomings (eg: small sample size, lack of proper randomization procedure, lack of control group) that the causality in terms of internal validity were less established (van Eerd et al., 2015; Rivilis et al., 2006).

Most importantly, ergonomics intervention using participatory approach were rarely been done in Malaysia. The only study in the area of PE was conducted recently among harvesters in oil palm plantation by Ng and colleagues (Ng et al., 2014). PE intervention program specifically tailored made to cater the needs and work environment of manufacturing industry in Malaysia was not found. In addition, previous studies have suggested that pretesting or baseline assessment would have effects on behaviour change intervention (McCambridge et al., 2011). None of the research on PE intervention so far had identified the issue of pretest sensitization, that the effects of pretest sensitization might be overlooked. It is very important because PE intervention has been known as a behaviour change intervention, and pretest sensitization would largely affected the generalizability of results. In order to draw more definite conclusions on the effectiveness of PE intervention, this study was conducted to understand the risk factors of MSDs and to evaluate the effectiveness of PE intervention in tackling MSDs and psychosocial factors of workers in manufacturing industry.

1.2 Research Questions

i. What are the prevalence of MSS, level of musculoskeletal pain and psychosocial factors among workers in the manufacturing industry?
ii. Is there any significant difference in the MSS and psychosocial factors by sociodemographic, health and work characteristics of respondents?
iii. Is there a significant reciprocal relationship between psychosocial factors and MSS?
iv. Can psychological factors mediate the relationship between psychosocial work factors and MSS?
v. What are the elements and facilitators that should be included in an effective PE intervention program?
vi. Is the developed PE intervention effective in reducing the prevalence of MSS and level of musculoskeletal pain?

vii. Is the developed PE intervention effective in reducing the level of mental stress, emotional states and psychosocial work factors?
viii. Is there any effect of pretest (pretest sensitization) on PE intervention?

1.3 Significance of Study

The findings of this study will redound to the benefit of the company considering that healthy workforce with good physical and psychosocial health will boost and drive organizational health as well as business performance. Studies on the economic evaluation of PE intervention suggested that PE intervention can be cost beneficial from the company perspective with regards to first aid incidents, modified duty episodes, casual absences, long term sickness absences and product quality and efficiency (Tompa et al., 2013; 2009). Cost benefit analysis justifies the need for effective PE intervention program.

In management perspective, PE intervention demonstrated its commitment towards safety and health of workers, besides improving risk communication between employee and employer. Due to these reasons, it has been suggested that PE could not only have benefits beyond physical or health outcomes, but to improve psychosocial factors, subsequently lead to continual improvement in the safety and health standard of an organization. Companies that apply the PE intervention program derived from the results of this study will be able to improve the work environment, thus improving musculoskeletal health and psychosocial factors of their workers.

As for the workers who joined the PE intervention program in this study, they will be guided and trained with the knowledge and ability to identify risk factors and hazards at their workplace, together with potential improvements that can be done to modify current workstation or work method using local good examples from all the companies. PE is a noted implementation strategy to develop ergonomic measures using bottom up approach (Haines et al., 2004). As the ergonomics measures were developed by workers themselves, the acceptance to use the ergonomic measures might become more widespread among themselves (Driessen et al., 2011).

For researchers, the study will uncover the feasibility and practicability of PE intervention program in the context of manufacturing industry in Malaysia that was not explore by other researchers before. A PE intervention program considering potential barriers and facilitators suitable with the work nature and culture of local manufacturing industry will be formulated. Participation of companies from various manufacturing entities and products greatly increased the generalizability of ergonomics training developed in this study as the training materials were collected from local examples of these companies. Inclusion of psychosocial factors in this study will help the researchers to discover other potential effects of PE intervention and the associations with MSS that many researchers were not able to explore. As Solomon four-group design were used in this study, the findings of this study will help the researchers to detect potential effect of pretest sensitization on PE intervention that was not been done by any researcher before.

1.4 Objectives

1.4.1 Aim

To develop, implement and evaluate the effectiveness of PE intervention to improve musculoskeletal health and psychosocial factors among manufacturing industry workers using Solomon four-group design.

1.4.2 Specific Objectives

i. To determine the prevalence of MSS, level of musculoskeletal pain and psychosocial factors.
ii. To compare the prevalence of MSS and levels of psychosocial factors across sociodemographic, health and work characteristics.
iii. To determine the associations between levels of mental stress, emotional states and psychosocial work factors.
iv. To determine the reciprocal associations between psychosocial factors and MSS.
v. To determine the role of psychological factors as the mediators between psychosocial work factors and MSS.
vi. To develop and implement PE intervention program.
vii. To evaluate the effects of PE intervention on the prevalence of MSS and levels of musculoskeletal pain.
viii. To evaluate the effects of PE intervention on the levels of mental stress, emotional states and psychosocial work factors.

1.5 Research Hypothesis

i. There are no significant differences in the prevalence of MSS and levels of psychosocial factors across sociodemographic, health and work characteristics.
ii. There are no significant associations between levels of mental stress, emotional states and psychosocial work factors.
iii. There are no significant reciprocal associations between psychosocial factors and MSS.
iv. Psychological factors do not significantly mediate the relationship between psychosocial work factors and MSS.
v. There are no significant effects of PE intervention on the prevalence of MSS and levels of musculoskeletal pain.
vi. There are no significant effects of PE intervention on the levels of mental stress, emotional states and psychosocial work factors.

1.6 Definition of Variables

1.6.1 Conceptual Definitions

i. **Musculoskeletal symptoms (MSS)**
MSS were defined as the self-reported musculoskeletal pain, discomfort and complaint perceived by an individual on bones, muscles, ligaments, tendons, and nerves (Widanarko et al., 2011; Burton et al., 2008)

ii. **Psychosocial factors**
Psychosocial factors could be defined as the interaction between social condition (environment) and psychological factors (individual) (Theorell, 2007). Psychosocial factors encompass two categories of variables: the first consists of psychological factors such as mental stress, depression and anxiety while the second variable is psychosocial work factors (Singh-Manoux, 2003).

   a. **Psychological factors (mental stress and negative emotional states)**
   Psychological factors refer to mental health or emotional distress problem of an individual which may adversely affect an individual's cognitive or social functioning (Vargas-Prada & Coggon, 2015).

   b. **Psychosocial work factors**
   Psychosocial work factor may be defined as a measurement that potentially relates psychological phenomena to the social environment and pathophysiological changes (Rick et al., 2001). Psychosocial work factors (stressors) are conditions of the work environment which potentially affect the well-being of employees. Psychosocial work factors are most frequently referred to Karasek's demand-control model (Karasek & Theorell, 1990; Karasek, 1979). According to this model, the risk of adverse health effects, in particular job strain will increase if high job demands are combined with low job control.

iii. **Participatory ergonomics (PE)**
PE has been defined as the involvement of people in planning and controlling a significant amount of their own work activities, with sufficient knowledge and power to influence both processes and outcomes in order to achieve desirable goals (Wilson and Haines, 1997).

1.6.2 Operational Definitions

i. **Musculoskeletal symptoms (MSS)**
Data concerning MSS was measured using modified Nordic Questionnaire (Kuorinka et al., 1987) on 9 anatomical sites: neck, shoulders, upper back, lower back, elbows, hands, thighs, knees and foot, with level of musculoskeletal pain at each site was measured using 10cm visual analogue scale (VAS). Multi-site pain (MSP) was identified as the presence of MSS on more than 3 anatomical sites.

ii. **Psychosocial factors**

   a. **Psychological factors (mental stress and negative emotional states)**
   Data on mental stress was measured using 2 scales, namely Perceived Stress Screening Scale (PSS-10) (Cohen et al., 1983) and chronic stress screening scale (CSSS) (Schulz et al., 2011). The PSS-10 measures the degree to which

situations in one's life are appraised as stressful in the context of perceived stress event and one`s coping ability (Cohen & Williamson, 1988) while CSSS measures different types of chronic stress experience in the context of environmental demands and resources to cope with demands (Schulz et al., 2004). Negative emotional states of depression and anxiety were measured using Depression, Anxiety and Stress Scale (DASS-21) (Lovibond & Lovibond, 1995). The Depression scale assesses dysphoria, hopelessness, devaluation of life, self-deprecation, and lack of interest/involvement, anhedonia, and inertia, while the Anxiety scale assesses autonomic arousal, skeletal muscle effects, situational anxiety, and subjective experience of anxious affect.

b. Psychosocial work factors

Psychosocial work factors were measured using Job Content Questionnaire (JCQ) (Karasek et al., 1998), which includes psychological job demand, skill discretion and decision-making authority. Job control was indicated by decision latitude, which is a combination of job skill discretion and job decision-making authority. High strain job is characterized by high job demand and low job control.

iii. **Participatory ergonomics (PE)**

The PE intervention program was designed based on the Participatory Ergonomics Framework (PEF) by Haines et al. (2002; 1998), which could be divided into 3 phases. The whole intervention process took about 8 months for a company.

Phase 1: Preliminary walkthrough survey at the workplace and development of PE training module

Phase 2: Tailor-made PE training and implementation of workplace improvement

Phase 3: Follow-up and mid-course workshops

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