BINDURA UNIVERSITY OF SCIENCE EDUCATION

WORK-RELATED MUSCULO-SKELETAL DISORDERS AMONG INFORMAL METAL FABRICATION WORKERS IN SMALL URBAN CENTRES OF ZIMBABWE

BY

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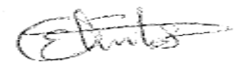
DECLARATION

I, the undersigned, hereby declare that the work contained in this thesis is my own and was conducted under the supervision of Doctor F. Ncube, and Doctor P. Erick. I also declare that this thesis is original and has not been submitted elsewhere for a degree. Assistance towards the production of this thesis and other scholars’ works referred to here have been duly acknowledged and referenced in the respective sections.

Signature 

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ABSTRACT

The use of awkward working postures and repetitive movements in metal fabrication may elevate the risk of developing work-related musculoskeletal disorders (WRMDs). The objectives of the study were to (i) assess the potential ergonomic risk factors for WRMDs among metal fabrication workers, (ii) assess the prevalence, severity and risk factors for WRMDs, and (iii) determine the effects of ergonomic training on postural risk and the effects of combined ergonomic training and stretch exercises on pain severity reported by metal fabrication workers in the informal sector of Zimbabwe. The Preferred Reporting Item for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were used to identify and screen the articles. A pre-designed criterion was used for evidence synthesis. The Modified Cornell Musculoskeletal Questionnaire (MCMQ) was used to assess prevalence, severity and risk factors for WRMDs, and the Quick Exposure Check (QEC) and the Rapid Entire Body Assessment (REBA) were used to conduct postural risk assessment. Two hundred sixty metal fabrication workers were purposively selected and randomly assigned to four groups. Supervised training and exercise sessions were conducted for a period of 11 weeks. A total of 189 metal fabrication workers finished the intervention programme. Potential ergonomic risk factors for WRMDs among metal fabrication workers data were analysed a pre-designed criterion. Prevalence, severity and risk factors were analysed using binary logistics regression, multinomial logistics regression and the paired t-test was used to assess the effects of ergonomic training and stretch exercise. All analyses were conducted in the Statistical Package for Social Science (SPSS) version 25.0. Prolonged working hours using awkward postures were consistently reported to contribute to the development of WRMDs. A high prevalence of pain in the lower back (78%), right shoulder (66%), left hand wrist (62%) and right-hand wrist (61%) was reported. With regards to the severity of lower back pain, 4% reported low pain, 24% mild pain and 48% severe pain. Elevated grand REBA scores were significantly associated with self-reported pain at the lower back (OR = 1.48, 95% CI 1.13 - 1.94), right shoulder (OR = 1.48, 95 CI 1.14 - 1.92) and left shoulder (OR = 1.28, 95 CI 1.04 - 1.57). The multinomial regression analyses showed that smoking, prolonged working hours and not engaging in physical activities were significant predictors for pain. High job satisfaction and taking adequate work-rest breaks were key protective factors for WRMDs ($p < 0.05$). The risk for developing WRMDs on several body regions (shoulder/arm, hand/wrist and neck) significantly reduced after the administration of an ergonomic training program ($p = 0.001$). In the combined ergonomic training and stretch exercise group, there was a significant reduction of reported pain in most body regions ($p = 0.001$). In conclusion the study showed that (i) there is a high prevalence of WRMDs among metal fabrication workers due to individual and work-related risk factors, (ii) interventions such as ergonomics education are required to address the risk factors for and progression of WRMDs among metal fabrication workers, (iii) that there is need for improved study designs that implement and evaluate interventions to reduce the risk, prevalence and severity of WRMDs among metal fabrication workers, and (iv) there is need for ergonomics education, ergonomically designed workstations, and stretch exercises, to reduce the severity of pain among metal fabrication workers.

Keywords: Awkward Working Posture; Ergonomic Risks; Metal Fabrication; Work-Related Musculoskeletal Symptoms; WRMDs.

DEDICATION

I dedicate this research project to my family.

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LIST OF ABBREVIATIONS

BMI	Body Mass Index
BUSE	Bindura University of Science Education
CBBMQ	Corlett and Bishop Body Map Questionnaire
CMQ	Cornell Musculoskeletal Questionnaire
HAL	Hand Activity Level
IBM	International Business Machines
ILO	International Labour Organisation
JSI	Job Strain Index
KG	Kilogrammes
LBP	Lower Back Pain
MCMDQ	Modified Cornell Musculoskeletal
MMQ	Maastricht Musculoskeletal Questionnaire
OHS	Occupational Health and Safety
PRISMA	Preferred Reporting Item for Systematic
QEC	Quick Exposure Check
REBA	Rapid Entire Body Assessment
RPGC	Research and Postgraduate Centre
RULA	Rapid Upper Limb Assessment
SMAW	Shield Metal Arc Welding
SPSS	Statistical Package for Social Sciences
WHO	World Health Organisation
WRMDs	Work Related Musculoskeletal Disorders

CONCEPTUAL DEFINITIONS

Awkward postures mean positions of the body that deviate significantly from the neutral position while performing work activities. When an individual is in an awkward posture, muscles operate less efficiently, and more force must be expended to do the task which is a contributing factor for WRMDs.

Ergonomic intervention means adjusting a workers' environment, behaviour and other approaches to treat and prevent further damage due to WRMDs. Ergonomics interventions are a therapeutic approach to treating and ultimately preventing WRMDs with the goal of long-term musculoskeletal pain relief.

Ergonomics training means a process of transferring knowledge and skills on work designs, work practices, risk factors and preventive measures for WRMDs. Ergonomics training must be facilitated by a competent person.

Fabrication involves the evolutionary process of creating a metal product from layout and designing to formation and finishing and it involve tasks such as measuring, grinding and cutting, hammering and joining.

Informal sector means the economic activities that are not taxable by the government in which little or no regulation is enforced.

Manual handling involves any transporting or supporting of any load by one or more employees and includes lifting, putting down, pushing, pulling and carrying.

Metal fabricator means an individual involved in the fabrication whereby two or more parts are fused together by means of heat, pressure or both forming a join when the parts cool.

Prevalence means the proportion of a particular population found to be affected by a medical condition (typically a disease or a risk factor) at a specific time. It is derived by comparing the number of people found to have the condition with the total number of people studied, and is usually expressed as a fraction or a percentage.

Rest break refers to a period where employees take some time off the tasks they are conducting to rest for a specified period before they resume work in a work shift.

Risk factors mean source, situations and exposures that trigger the onset or aggravation of WRMDs. Risk factors for WRMDs can be categorized into individual and job - related.

Severity means the impact a disorder has on an individual or group of workers. This can be measured by different assessment tools like the Cornell Musculoskeletal Questionnaire (CMQ) as slight, moderate and severe.

Stretch exercise means a form of physical exercise in which a muscle or tendon is deliberately flexed or stretched in order to improve the muscle's elasticity. The result is a feeling of increased muscle control, flexibility and range of motion. This is done also to improve muscle function in daily activities by increasing the range of motion and subsequently reduce WRMDs severity.

Urban centre means a built up area for human settlement and business related activities which includes cities, towns, conurbations and suburbs.

Welding involves use of heat to join metals in order to produce the required product.

Work – related musculoskeletal disorders (WRMDs) mean injuries of the muscles, bones, joints, ligaments, tendons and other soft tissues caused or aggravated by work activities.

CHAPTER 1: GENERAL INTRODUCTION

1.1 Background to the Study

Work-related musculoskeletal disorders (WRMDs) are a major health concern in high income and low-income countries. Noteworthy, they can contribute to: (a) worker absenteeism which may in turn decrease work productivity (Roux et al., 2005; Sarkar et al., 2016), (b) preventable medical costs (Davis et al., 2014) and (c) some adverse effects on the welfare of the worker's family (Berberoğlu & Tokuç, 2013; Sarkar et al., 2016). WRMDs are the second highest contributor to global disability (WHO, 2017). In Great Britain, at least 39% of reported work related illnesses were WRMDs for the period 2016 to 2017 (Health and Safety Executive, 2017). In Australia, 60% of all work-related illness claims in the period 2013 to 2014, were due to WRMDs (Safe Work Australia, 2016). In Africa, a high prevalence of WRMDs has been reported in recent literature. A study by Ajayeoba et al. (2016) reported a prevalence of 80% among metal workers in Nigeria whilst Chiwaridzo et al. (2018) reported a prevalence of 82.1% among a sample of Zimbabwean nurses. WRMDs are ranked as the third leading cause of disability in Africa (WHO, 2017). This highlights a need for closer attention into this problem. However, these statistics usually exclude the informal sector (ILO, 2018). The informal sector employs over 60% of the labour force in low-income countries (ILO, 2018). In comparison to the informal small manual industries, most large formal industries' operations are highly mechanized, which may reduce the risk of developing WRMDs among the workers (Watanabe et al., 2018). Further, workers in formalized industries have scheduled working hours, use mechanic al lifting and enjoy scheduled breaks, social security, formalized employment contracts, and access to health services (Uzhenyu, 2016). Empirical evidence on prevalence of WRMDs among workers in the informal sector in Zimbabwe is lacking. Thus, more work is required in relation to the monitoring and assessment of WRMDs in the informal sector of low-income countries such as Zimbabwe.

Some past studies reported that WRMDs are prevalent in small manual industrial sectors (Dianat & Salimi, 2014; Sahu & Sett, 2015) and that the risk factors and control measures are less well understood (Robertson et al., 2009). In comparison to the informal small manual industries, most large formal industries' operations are highly mechanized, which may reduce the risk of developing WRMDs among the workers. Therefore, it is relevant for researchers to place top priority to investigating the risk factors for the development of WRMDs among the manual informal small industrial sectors, so as to suggest possible intervention measures for safeguarding such workers' health.

In several low income countries, the informal sector employs a high percentage of the workforce and is now the main provider of new employment (Dianat & Salimi, 2014; ILO, 2018). In this sector, for example the metal fabrication industry, manual labour with poor work organisation is often used (Qutubuddin et al., 2015) mainly due to capital constraints. Workers in this sector usually do not have job security, insurance, social security and more importantly they lack access to occupational health and safety (OHS) Services (Uzhenyu, 2016). In Zimbabwe, for example, the informal sector employs over 85% of the overall workforce with metal fabrication workers constituting a significant segment of this population (Uzhenyu, 2016). A report by the World Health Organization (2017) estimated that over 85% of workers in the informal sector lacked access to occupational health and safety services. As a result, this group of workers is exposed to various occupational hazards including ergonomic ones. Some ergonomic exposures include awkward working postures, repetitive movements, manual lifting and unsafe force exertion (Dev et al., 2018; Shahriyari et al., 2018; Watanabe et al., 2018; Chiboyiwa et al., 2020).

The manufacture of metal products involves joining metals by heat or pressure using gas or electric arc (Seles at al., 2018). Generally, items such as window and door frames, scotch carts, burglar bars, door screens and different types of gates are manufactured by metal fabrication workers in the informal sector in Zimbabwe (Uzhenyu, 2016). Preliminary observations revealed that workers in this sector either use light industrial areas or backyard spaces to conduct their activities (Dev et al., 2018). Tools used by metal fabrication workers in the informal sector include hammers, chisels, grinding tools, and small manual welding machines. Most of these enterprises use the shield metal arc welding (SMAW) technique (Seles et al., 2018). Workers work extra hours with less time for scheduled breaks to meet production targets (Uzhenyu, 2016). It is important for workers to take health breaks as they ensure there is recovery of muscles after straining encounters (Dev et al., 2018). Unlike the formalized metal fabrication industry, lifting of objects is usually done manually because of lack of mechanization (Shahriyari et al., 2018).

Ergonomic literature is rich with systematic review studies of WRMDs and the associated risk factors. Noteworthy, a study by Vieira and Kumar (2004) noted the relationship between working postures and WRMDs. It is crucial to note that the aforementioned study included studies of workers from different sectors of the economy. However, the timeframe of included articles was short that is 2000-2002. Moreover, from 2002 to date much literature has accumulated. Therefore, it might be crucial for researchers to consider reviewing ergonomic literature that has accumulated over these years to ascertain the strength of evidence of association between ergonomic risks and WRMDs.

Anderson and Oakman (2016) carried out a systematic literature review of WRMDs and risk factors among Allied Health Professionals (physiotherapists, occupational therapists, speech pathologists, prosthetists, orthotists, dieticians, sonographers, social workers, osteopaths, audiologists, radiologists, exercise physiologists, perfusionists and chiropractors) using studies from databases such as CINHAL, Ovid Medline, Cochrane Library and EBSCO EMBASE from 1937 to 2016. Their inclusion criteria appears to be very relevant since it included both observational and experimental studies. Since this review study only looked at studies carried out among Allied Health Professionals, it might be helpful for researchers to broaden their scope to include studies from other sectors of the economy. Systematic reviews of WRMDs and associated ergonomic risks among metal fabrication workers have not yet received closer attention in existing literature. In the current study, the researcher examined the strength of evidence of association between ergonomic risk factors and WRMDs by undertaking a systematic review of studies. The inclusion criteria covered: (a) studies published from January 2000-January 2019, (b) metal fabrication tasks, (c) studies from databases (PubMed, Science Direct, Scopus, Taylor and Francis Online and Risk Abstracts), and (d) studies that used ergonomic risk assessment methods. This is crucial in ascertaining the risk factors associated with the reported prevalence and severity of WRMDs among metal fabrication workers.

The prevalence and severity of WRMDs among metal fabrication workers have been assessed using different methods such as the Nordic Musculoskeletal Questionnaire (NMQ) (Nikpey et al., 2013; Shahriyari et al., 2018) and the NIOSH discomfort survey (Suman et al., 2018a; Suman et al., 2018b). These studies were conducted in middle income countries. It can be concluded from these studies that WRMDs are a health concern among metal fabrication workers and metal fabrication workers. However, empirical evidence on self-reported

WRMDs prevalence and severity among metal fabrication workers in the informal sector in low-income countries like Zimbabwe is suboptimal. It is therefore, critical to assess their prevalence and severity so that intervention measures targeting risk factors such as awkward postures can be implemented to reduce them.

Awkward working postures are the major ergonomic risk factors contributing to WRMDs among metal fabrication workers (Shahriyari et al., 2018; Watanabe et al., 2018). The above-mentioned studies were undertaken in formalized industries which is different from the informal sector. Metal fabrication workers in the informal sector might be exposed to ergonomic risks due to the nature and design of their work-stations (Dev et al., 2018). Some tasks such as cutting, assembling, joining and lifting are carried out in awkward postures during kneeling, squatting or overstretching (Shahriyari et al., 2018). Therefore, it is necessary to conduct an ergonomic risk assessment of the metal fabrication tasks to determine the level of risk associated with each task in the informal sector and to suggest corrective measures.

Studies have reported that the implementation of ergonomics training programs can significantly reduce WRMDs prevalence among workers (Jahangiri et al., 2015; Robertson et al., 2009; Shariat et al., 2017). Other studies have reported a reduction in the severity of WRMDs due to scheduled stretch exercise (Mehrparvar et al., 2014; Shariat et al., 2018). This clearly brings to light the importance of different ergonomic interventions in the quest to reduce WRMDs prevalence and severity. Studies assessing the effects of ergonomics training and stretch exercise interventions among metal fabrication workers in the informal sector of a low-income country like Zimbabwe are scarce.

Therefore, the current study determined the prevalence and severity of self-reported WRMDs and associated risk factors. Also, a randomized control study was carried out to assess the effects of ergonomics training on postural risks and the effects of combined ergonomics training and stretch exercise interventions on the prevalence and severity of self-reported WRMDs among metal fabrication workers in the informal sector of urban centres of a low-income country using Zimbabwe as a case study.

1.2 Statement of the Problem

The informal sector employs more than 60% of the labour force in low income countries (ILO, 2018). However, little attention has been put to address the occupational health concerns of informal metal fabrication workers. Preliminary field visits to the informal light industrial areas by the author showed that metal fabrication workers use awkward working postures and manually lift heavy equipment and materials. Furthermore, some of the workers complained of pain at the back, shoulders and wrists. In addition, few studies have investigated WRMDs and associated risks among metal fabrication workers (Burdorf et al., 1998; Watanabe et al., 2018). The few available studies were predominantly conducted in well-established and formalized fabrication industries (Watanabe et al., 2018; Shahriyari et al., 2018). This shows that more studies are required in relation to ergonomic concerns of metal fabrication workers in the informal sector in low-income countries. Equally important, to date the strength of ergonomics evidence linking ergonomic risk factors and WRMDs among metal fabrication workers is still to be determined. Although it is understood that ergonomics training and stretch exercise interventions can reduce the ergonomic risk levels and the prevalence and severity of WRMDs (Robertson et al., 2009; Mehrparvar et al., 2014; Shariat et al., 2017; Bulduk et al., 2017), there is no empirical evidence on these interventions among metal fabrication workers in the informal sector of Zimbabwe. The lack of such research in resource-constrained economies suggests that the risk factors are yet to be investigated and mitigated. Therefore, the present study was conducted to add to the body of knowledge on the ergonomic factors associated with WRMDs, among metal fabrication workers in the informal sector and to assess the effects of ergonomic training and stretch exercises on risk factors, pain prevalence and pain severity.

1.3 Justification

There is scarcity of empirical studies on WRMDs among metal fabrication workers in the informal sector in Zimbabwe. Findings from this study will add to the body of knowledge on these disorders among the study population under study. The present study is further envisaged to establish the extent of the problem of WRMDs among metal fabrication workers in the informal sector and assess potential intervention strategies that can be implemented to reduce exposure to risk factors, prevalence and severity of these disorders among this vulnerable group of workers. The study will help to raise awareness and the general understanding of the risk factors and effects of WRMDs in the context of informal metal fabrication work. Furthermore, considering the important role the informal sector plays in the economies of low-income countries such as Zimbabwe, this study may lead to OHS policy formulation which covers this sector. Zimbabwe’s OSH laws do not cover the informal sector which necessitated the development of the OSH policy of 2014. Since the principles of the OSH policy of 2014 is now at the OSH Bill stage, results of the current study may assist in informing the policy makers with regards to ergonomic concerns of metal fabrication workers in the informal sector.

Results from the current study may be used by technical institutions for the improvement of their metal fabrication curriculum. Employers may incorporate the findings from the present study as ergonomics principles necessary for the prevention of WRMDs in their respective work stations in the context of the informal sector. The implementation of proposed interventions will assist in finding an effective intervention program or combination of intervention programs that is effective in reducing risk factors and WRMDs prevalence and severity among metal fabrication workers. The implementation of effective intervention programs may in turn improve metal fabrication workers' potential to increase productivity as well as saving income by reducing absenteeism and health associated expenditures caused by WRMDs.

1.4 Aim and Objectives

The following were the aims and objectives of this study:

1.4.1 Aim

- To assess the prevalence, severity and risk factors for WRMDs and to determine the effects of ergonomic training on postural risk and the effects of combined ergonomic training and stretch exercises on pain severity reported by metal fabrication workers in the informal sector of Zimbabwe.

1.4.2 Specific Objectives

1. To determine the screening tools used to assess the prevalence and risk factors for WRMDs among metal fabrication workers.
2. To assess the methodological quality of available literature on WRMDs among metal fabrication workers.
3. To evaluate the strength of evidence of association of selected ergonomic risk factors and WRMDs among metal fabrication workers using predesigned criteria.

4. To assess the prevalence and severity of WRMDs using a Modified Cornell Musculoskeletal Questionnaire (MCMQ).
5. To conduct postural risk assessment using the Quick Exposure Check (QEC) and the Rapid Entire Body Assessment (REBA).
6. To evaluate the association of individual and job – related factors with the prevalence and severity of WRMDs
7. To assess the effects of ergonomic training on postural risk levels using the Quick Exposure Check (QEC) method.
8. To assess the effects of combined ergonomics training and stretch exercise on the prevalence and severity of WRMDs among metal fabrication workers in the informal sector of Zimbabwe.

1.5 Research Questions

1. What are the screening tools used to assess the prevalence and risk factors for WRMDs among metal fabrication workers?
2. To what extent do methodological strengths and shortcomings of available literature on WRMDs among metal fabrication workers exist?
3. How strong is the strength of evidence of association of selected ergonomic risk factors and WRMDs among metal fabrication workers?
4. To what extent does the prevalence and severity of self-reported WRMDs among metal fabrication workers in the informal sector differ with body regions?
5. To what extent do the ergonomic exposures and risk levels associated with metal fabrication in the informal sector differ body regions?
6. How strong is the association between individual and job – related risk factors with WRMDs among metal fabrication workers in the informal sector?
7. Does ergonomics training intervention reduce the ergonomic risk levels for developing WRMDs among metal fabrication workers?
8. Is the prevalence and severity of WRMDs among metal fabrication workers in the informal sector reduced when ergonomics training and stretch exercises are implemented?

1.6 Limitations and Strengths of the Study

The following were some limitations of the present study. Despite the use of a rigorous search strategy in five databases in the review of literature, the study could have missed some relevant material available in non-included databases. Studies that were not published in English were left out which may have introduced language bias and limited the capacity to generalize findings of this study to a wider context. Postural assessment was carried out using observation methods (not immune to observer bias). Due to budgetary limitations only two readily accessible provinces out of a total of 10 provinces in the country were considered in this study. Of the two selected provinces written permission to conduct this study was received from three out of a total of eight urban centres. (Appendix 2 to Appendix 4). Due to these limitations, the study findings may not necessarily reflect general work conditions of metal fabrication workers in other provinces of Zimbabwe. Further, the study did not conduct a comparative analysis of the exposures and outcomes of the selected three urban centres. Therefore, large scale studies are required to document and compare the work conditions of this category of workers in the remaining provinces. Furthermore, fewer metal fabrication workers (< 200, all male) consented and participated to the end of the study. In Zimbabwe the metal fabrication industry is male dominated which explains the lack of female metal fabrication workers in the three studied urban centres. The self-reported nature of the CMQ could be influenced by response and recall bias (Shariat et al., 2016). The frequency of stretch exercise was self-reported, so participants may have overstated their compliance of the prescribed program. The randomised control trial lasted for 11 weeks which is relatively shorter as compared to other longitudinal studies such as cohort studies. In this regard, the study should be repeated with a longer follow-up to confirm the findings and the long term effects.

On the other hand this study has some strength. Methodological triangulation was accomplished by using two methods (REBA and QEC) to assess ergonomic exposures among metal fabrication workers in the informal sector. One of the strengths of the REBA method is that it considers the nature of hand coupling that is associated with the use of hand-held tools (Chiasson et al., 2012). Further, it allows scoring for static, dynamic and rapid changing or unstable postures (Hignett & McAtamney, 2000). Concurrent validity for the CMQ with respect to pain prevalence and severity measurement was assessed through concurrent use of the Corlett and Bishop Body Map Questionnaire (CBBMQ). Randomization was applied when selecting study participants into the four intervention groups which allowed every participant a chance. Uniform assessment methods were applied during the assessment of both postural risks and WRMDs pain severity.

1.7 Delimitations

The study only focused on three urban centres of Zimbabwe (Bindura, Mutoko and Mt Darwin) where permission to conduct the study was granted (Appendix 2 to Appendix 4). The conditions and exposures that affect WRMDs and other risk factors might be different from that of big cities. In this regard, the findings from this study may not be generalised to represent all informal sector metal fabrication workers in Zimbabwe. The study also focused on workers of the informal sector who do not have structured processes of employment and operating procedures. This could affect the findings as this cannot be compared with other metal fabrication workers in formalized industries. The study found out that there were only male metal fabrication workers in the three urban centres where the study was conducted and this indicated that the informal metal fabrication sector is male dominated in these centres.

1.8 Ethical Considerations

The following ethical considerations were observed in this study:

1.8.1 Principle 1: Formal approval

The study commenced after a written consent and approval from the Bindura University of Science Education's Research and Post Graduate Centre (RPGC) was given (Appendix 1). Prior to engaging metal fabrication workers to participate in the current study, permission to collect the data was obtained from responsible local authorities (Appendix 2 to Appendix 4).

1.8.2 ***Principle 2: Informed consent***

The study protocol was explained to all study participants. Written informed consent forms were signed by all study participants.

1.8.3 ***Principle 3: Voluntary participation***

Participation in this study was voluntary and the study participants had the right to withdraw from the study whenever they felt uncomfortable. Since the study involved the use of stretch exercises, whenever participants felt uncomfortable to continue with the study due to health or other reasons, they were allowed to withdraw. Participants who felt that they want to withdraw from the study were allowed to do so without any risk or penalty involved.

1.8.4 ***Principle 4: Privacy and confidentiality***

All the information obtained from study participants was kept private and confidential in order to protect the identity of study participants. Since the study processes involved taking pictures and videos of study participants, faces of study participants were either censured or hidden to protect their identity. Other information obtained from questionnaires was also kept confidential and was used for research purposes only.

1.8.5 ***Principle 5: Anonymity***

All data collection instruments did not capture the names and identifying information of the study participants in order to guarantee their anonymity.

1.9 Thesis Structure

Chapter 1 introduces the research by giving the background to the study, the statement of the problem, study aims and specific objectives, and limitations and delimitations. The background to the study presented in this chapter informed the methodology used in the attainment of all the study aims and objectives presented in chapter 2.

Chapter 2: This chapter presents findings of a review article based on the first aim of this study. This article was published in the International Journal of Human Factors and Ergonomics. This chapter starts by presenting the introduction and then describes the search strategy, data extraction, methodological quality assessment and evidence synthesis. This chapter also presents the results of the systematic review of literature, discusses the findings, concludes and gives recommendations for future studies. Basing on the recommendations presented in this chapter, a cross-sectional study aimed at assessing the prevalence, severity and risk factors for WRMDs among metal fabrication workers in the informal sector in three urban centres of Zimbabwe was undertaken which is presented as a full article in chapter 4.

Chapter 3: This chapter presents findings for the second aim of the study. This article was published in the WORK Journal. This chapter starts by presenting the introduction, describes the study design used, how assessment of prevalence and severity of WRMDs was conducted, task analysis, postural analysis and statistical analysis. This chapter also presents the results of the prevalence and severity of WRMDs, postural risks and the association of individual and job – related factors with prevalence and severity of WRMDs. Lastly, chapter 4 discusses the findings, concludes and gives recommendations for future studies. Basing on the recommendations of the this study, a randomised control trial study aimed at assessing the effect of ergonomics training and stretch exercise interventions on prevalence and severity of WRMDs among metal fabrication workers in the informal sector of three urban centres of Zimbabwe was undertaken which is presented as a full article in chapter 5.

Chapter 4: This chapter presents the full article on the third aim of the study. This article is under review in the International Journal of Industrial and Systems Engineering. This chapter starts by presenting the introduction to the study, describes the methodology used to assess the effects of ergonomics training on postural risk levels and the effects of combined ergonomic training and stretch exercise interventions on the prevalence and severity of WRMDs among metal fabrication workers in the informal sector. This chapter also presents the results of the effects of ergonomics training on postural risk levels and the effects of combined ergonomic training and stretch exercise interventions on the prevalence and severity of WRMDs among metal fabrication workers in the informal sector. Lastly, chapter 4 discusses the findings, concludes and gives recommendations for future studies.

Chapter 5: Conclusions and recommendations

Chapter 5 provides the general conclusions of the study based on the study aims presented in chapter one. The chapter also outlines the recommendations for actioning by different stakeholders.

Chapter 6: Synthesis

Chapter 6 provides a synthesis of the thesis. It explains the link between the thesis chapters. The introduction section provides an overview on research gaps. WRMDs among metal fabrication workers. The chapter summarises research methods and the study findings for this study.

1.10 Conceptual Framework

The informal sector employs a high percentage of the workforce (ILO, 2018). Workers in this sector usually do not have job security, insurance, social security and OHS services (Uzhenyu, 2016). If a healthy worker is exposed to risk factors on a daily basis, they can be affected by work-related ailments (WHO, 2017). Risk factors that lead to the onset and or aggravation of WRMDs are common in the informal sector (Dev et al., 2018; Shahriyari et al., 2018). This can be exacerbated by individual factors such as age and body mass index (Dev et al., 2018). In this framework, there is need to ascertain the strength of evidence of association between risk factors and WRMDs. In this regard, risk factors that significantly contribute to the onset and aggravation of WRMDs are noted. However to increase productivity, reduce absenteeism and health associated costs, there is need to prevent or at least reduce exposure to risk factors by metal fabrication workers. Interventions that have been proven to be useful in other sectors have to be tested so that if they are effective, they can be used to prevent the onset and aggravation of WRMDs thereby ensuring that a healthy worker is always available for work.

CHAPTER 2: ERGONOMIC RISK FACTORS ASSOCIATED WITH WORK-RELATED MUSCULOSKELETAL SYMPTOMS AMONG METAL FABRICATION WORKERS: A SYSTEMATIC REVIEW

Abstract

This study reviewed literature on ergonomic risks for work-related musculoskeletal symptoms (WRMDs) among metal fabrication workers. The preferred reporting item for systematic reviews and meta-analyses (PRISMA) guidelines were used to screen the articles. A pre-designed criterion was used for evidence synthesis. Twenty articles met the inclusion criteria. Most studies were cross-sectional, used small sample sizes, and lacked statistical rigour. Prolonged working hours using awkward posture were consistently reported to contribute to the development of WRMDs. The prevalence rate of WRMDs among workers in the reviewed studies ranged between 60% and 85%. Only 6 out of 20 studies assessed the severity of the reported WRMDs. Studies did not implement interventions to reduce the risk, prevalence rate and severity of WRMDs. There is need for improved study designs that implement and evaluate interventions to reduce the risk, prevalence and severity of WRMDs among metal fabrication workers.

Keywords: Awkward Working Posture; Ergonomic Risks; Metal Fabrication; Work-Related Musculoskeletal Symptoms; WRMDs.

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2.1 Introduction

Musculoskeletal disorders affect soft tissues such as muscles, tendons, ligaments and cartilage (Sarkar et al., 2016). They may result in negative health outcomes such as pain, numbness, tingling, stiff joints, difficulty in moving, muscle loss, poor quality of life and sometimes paralysis (Osborne et al., 2012; Qutubuddin et al., 2015). When these disorders are related to, or aggravated by work, they are termed work-related musculoskeletal disorders (Choobineh et al., 2009; Da Costa and Vieira, 2010; Ncube et al., 2018). Studies have reported that Work-related musculoskeletal symptoms (WRMDS) are multi-factorial (Haynes & Williams, 2008; Da Costa & Vieira, 2010). For example, sustained and/or awkward working posture, prolonged standing and sitting, improper workplace design, age, heavy loads have been associated with development of WRMDs (Haynes & Williams, 2008; Da Costa and Vieira, 2010; Shahriyari et al., 2018), such as pain at the lower back, shoulder and neck (Da Costa & Vieira, 2010; Howarth et al., 2016). Persons with WRMDs such as lower back pain (LBP) for at least three months have a lower probability of recovering (Marin et al., 2017), which highlights the need for preventive measures.

Metal fabrication involves use of heat to join metals in order to produce the required product (Babkin & Gladkov, 2016; Seles et al., 2018). Metal fabrication tasks (measuring, grinding and cutting, hammering and joining) expose workers to risk factors which lead to the development of WRMDs and other health problems (Yusop et al., 2018; Dev et al., 2018). The work environment for this category of workers has been reported to lack adequate ventilation and suitable temperatures to prevent heat stress (Parida & Ray, 2012; Alexander et al., 2016), ergonomically designed tools (Parida & Ray, 2012; Dev et al., 2018), appropriate personal protective equipment (Alexander et al., 2016) and adequate working space (Parida & Ray, 2012; Watanabe et al., 2018; Dev et al., 2018). In such suboptimal work conditions metal fabrication workers commonly bend, stand, twist and squat for prolonged periods whilst performing metal fabrication tasks (Chung et al., 2003; Caceres & Troya, 2012).

Studies examining WRMDs in metal fabrication workers have reported a high prevalence of the neck and back problems (Vieira & Kumar, 2007; Zare et al., 2016), that may be related to ergonomic work exposures such as awkward working postures, repetitive movements and manual handling of heavy loads. Besides these exposures, metal fabrication workers are also subjected to toxic metal fabrication fumes that contain manganese particles, dinitrogen tetroxide, nitrogen dioxide, nitric oxide, ozone, phosphine and phosgene (Hedmer et al., 2014; Koh et al., 2015). Manganese particles have been reported to cause adverse neurotoxic effects (Hedmer et al., 2014). On the other hand, dinitrogen tetroxide, nitrogen dioxide, nitric oxide, ozone, phosphine and phosgene cause systemic effects such as chronic bronchitis and emphysema as well as localised skin and eye health problems (Koh et al., 2015; Alexander et al., 2016). Adverse workplace exposures to such hazards may lead to worker absenteeism and reduced productivity (Da Costa and Vieira, 2010; Hedmer et al., 2014). Improvements in legislation, capacities and international frameworks have been identified as necessary occupational health and safety measures to safeguard workers' health (Mrema et al., 2015; Jacobs & Forst, 2017; Ncube & Kanda, 2018). Research that examines the development and prevention of WRMDs can add to the evidence base to guide such improvements.

An assessment of the exposure of workers to ergonomic risks is essential for the purposes of planning and implementation of required ergonomics programs (Choobineh et al., 2009). Various methods have been used to assess ergonomic exposures in the metal fabrication industry. They include the following: Rapid Upper Limb Assessment (RULA), (Singh & Singhal, 2016; Bhardwaj et al., 2017), Rapid Entire Body Assessment (REBA), (Ajayeoba et al., 2016; Suman et al., 2018), Quick Exposure Check (QEC), (Rahimian et al., 2014), OVAKO working posture analysis system (OWAS), (Nikpey et al., 2013) and inclinometry (Shahriyari et al., 2018). WRMDs manifest in the form of pain in different body regions that include the neck, lower and upper back, shoulder and wrist (Choobineh et al., 2009; Osborne et al., 2012). The screening tools for the assessment of the prevalence and/or severity of such pain include the following:

- Nordic Musculoskeletal Questionnaire (NMQ),
- Dutch Musculoskeletal Questionnaire (DMQ)
- Cornell Musculoskeletal Questionnaire (CMQ),
- Maastricht Musculoskeletal Questionnaire (MMQ) and,
- Corlett and Bishop Body Map Questionnaire (CBBMQ)

To the best of the authors' knowledge, no systematic reviews have synthesised literature pertaining to WRMDs among metal fabrication workers. Findings from this systematic review are essential for informing workers, regulatory authorities and management on high risk exposures where preventive efforts should be targeted.

The purpose of this review was to assess the available evidence of potential ergonomic risk factors for WRMDs in metal fabrication workers. The specific objectives of this study were to: (i) Determine the screening tools used to assess the prevalence and risk factors for WRMDs among metal fabrication workers; (ii) Assess the methodological quality of available literature on metal fabrication workers and; (iii) Evaluate the strength of evidence of association of selected ergonomic risk factors and WRMDs using predesigned criteria.

2.2 Materials and Methods

2.2.1 Search Strategy

Following the PRISMA guidelines (Figure 2.1), a literature search for relevant articles was conducted by the researcher in the period 3 September 2018 to 31 January 2019. Databases that were searched included: Scopus, EBSCO, PubMed, Taylor and Francis Online and Risk Abstracts. A search strategy that combined the Boolean operator "AND" and "OR" and text words representing key concepts of our study: ergonomic risks or postural risks, work related musculoskeletal symptoms and metal fabrication workers was applied (Table 2.1).

Table 2.1 Key Search Terms and Search Strategy

Subject heading	1. ergonomic risk
	2. postural risk
	3. welding posture
Keywords	4. ergonomic risk* or postural risk* or welding posture
Combine	5. 1 or 2 or 3 or 4
Subject heading	6. Musculoskeletal disorder
	7. Musculoskeletal symptom
	8. Musculoskeletal disease
Keywords	9. Work-related musculoskeletal* or musculoskeletal disorder* or musculoskeletal disease* or musculoskeletal symptom
Combine	10. 6 or 7 or 8
Limit	11. English language

* Truncation that allows a literature search to include multiple forms of a word including singular, plural and variable spellings.

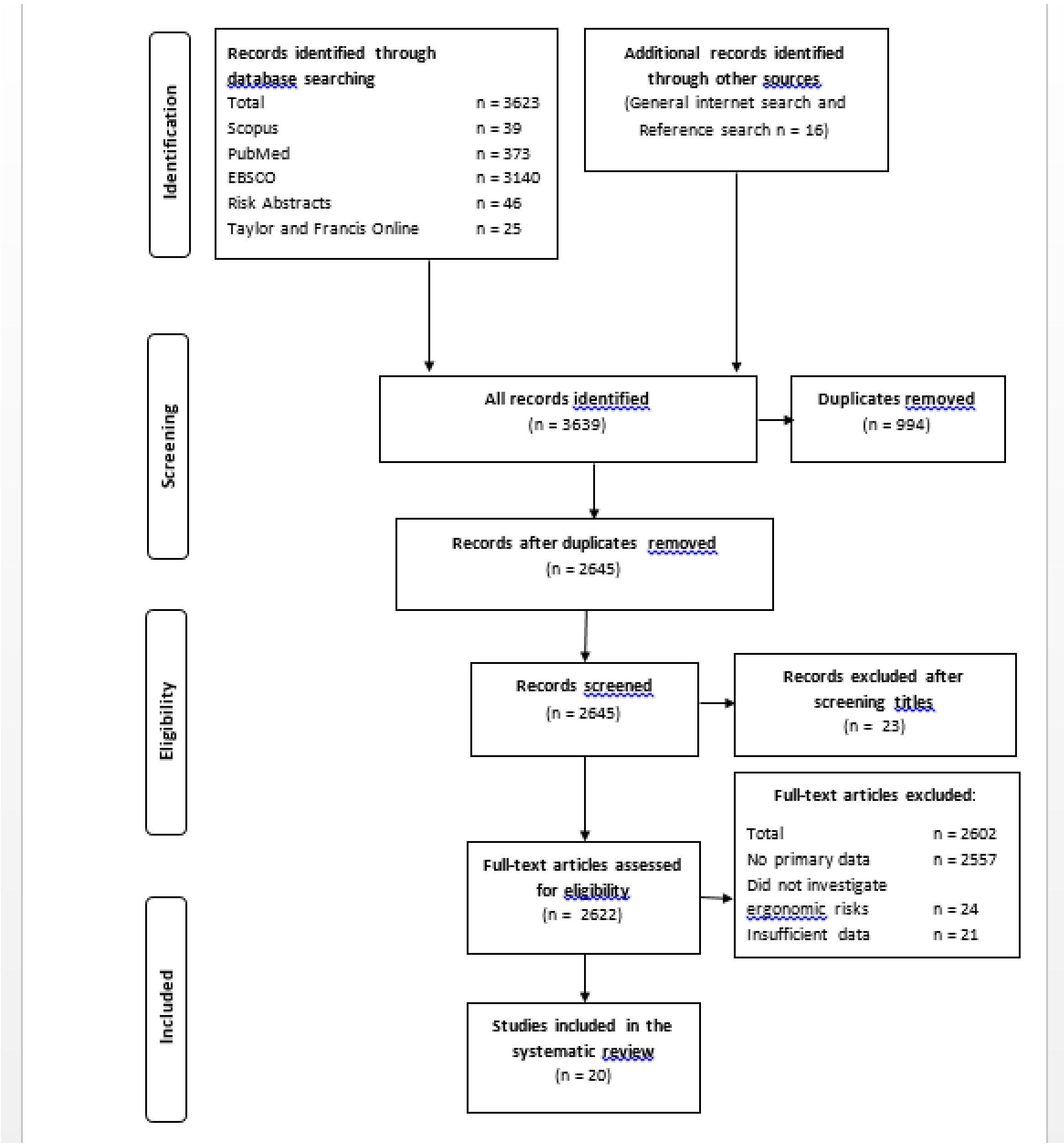

Figure 2.1. Study Selection Process

2.2.2 Inclusion and Exclusion Criteria

The Preferred Reporting Item for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Moher et al., 2009) were used to screen articles for eligibility. This review included peer-reviewed journal articles: (i) published between January 2000 and December 2019, (ii) that investigated ergonomic risks of welding and/or metal fabrication workers, (iii) described the ergonomic risk assessment methods for the development of WRMDs, (iv) written in English, and (v) available in full text. There was no restriction applied on the study design and or study setting (small, medium and large scale manufacturing). Articles excluded were those that did not use primary data, such as review articles, commentaries, editorials and correspondences. The period between 2000 and 2019 was applied as a filter in the search string.

2.2.3 Data Extraction

The screening of articles for eligibility was independently carried out by the first author under the guidance of the project supervisors. A pre-designed form was used for data extraction. The form was used to collect information about articles' author/s, country of study, setting, exposures assessed, outcomes, data collection methods, research design and the main findings. In this study, the outcome refers to WRMDs. Exposures refer to ergonomic risk factors such as: working posture, duration of work task, repetitive movements, manual lifting, force exertion and design of the work environment.

2.2.4 Methodological Quality Assessment

Eligible articles were subjected to Law and colleagues' critical review criteria for quantitative studies (Law et al., 1998). The criterion comprises of sixteen criteria that are described in Table 2. A "yes" response to a given criterion was given a score of one point and denoted by a plus (+). A "no" response was accorded a score of zero denoted by a minus (-). The researcher rated and scored articles included. Differences were resolved through focused discussions to reach a consensus. Quality assessment for each study was rated as sufficient when the study scored ≥ 50% on the quality assessment criteria and inadequate when the study scored < 50%. Only those studies that scored ≥ 50% were considered for subsequent systematic review.

Table 2.2. Methodological Quality of Included Studies (*n* = 20)

Reference	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Final Score
Vieira and Kumar (2007)	+	+	-	+	+	+	-	+	+	+	+	+	+	+	n/a	+	13/16
Shahriyari et al. (2018)	+	+	-	+	+	+	-	+	+	+	+	+	+	+	n/a	+	13/16
Parida and Ray (2012)	+	+	-	+	+	+	-	+	+	+	+	-	+	+	n/a	+	13/16
Domingo et al. (2015)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	n/a	+	15/16
Nikpey et al. (2013)	+	+	-	+	+	+	-	+	+	+	+	+	+	+	n/a	+	14/16
Ismaila et al. (2010)	+	+	-	+	+	+	-	+	+	+	+	-	+	+	n/a	+	12/16
Fethke et al. (2011)	+	+	-	+	+	+	-	+	+	+	+	-	+	+	n/a	+	12/16
Suman et al. (2018)	-	-	-	+	+	+	-	+	+	+	+	-	+	+	n/a	+	10/16
Akter et al. (2015)	+	+	+	+	+	+	-	+	+	+	+	+	+	-	n/a	+	13/16
Qutubuddin et al. (2015)	+	+	-	+	+	+	-	+	+	+	+	-	-	+	n/a	+	11/16
Sing and Singhal (2016)	+	+	-	+	+	-	-	+	+	+	+	-	-	-	n/a	+	9/16
Bhardwaj et al. (2017)	+	+	-	+	+	-	-	+	+	+	+	-	-	+	n/a	+	10/16
Suman et al. (2018)	+	+	-	+	+	-	-	+	+	+	+	-	+	+	n/a	+	11/16
Watanabe et al. (2018)	+	+	-	+	+	+	-	+	+	+	+	+	+	+	n/a	+	13/16
Yusop et al. (2018)	+	-	-	+	-	-	-	+	+	+	+	-	+	+	n/a	+	9/16
Rahimian et al. (2014)	+	+	-	+	+	+	-	+	+	+	+	-	+	+	n/a	+	12/16
Dev et al. (2018)	+	+	-	+	+	+	-	+	+	+	+	+	+	+	n/a	+	13/16
Gbiri et al. (2012)	+	+	-	+	+	+	-	+	+	+	+	-	+	+	n/a	+	12/16
Mahesa et al. (2017)	+	+	-	+	+	+	-	+	+	+	+	+	+	+	n/a	+	13/16
Ajayeoba et al. (2016)	+	+	-	+	+	+	-	+	+	+	+	-	-	-	n/a	+	10/16

+ denotes yes to the criterion; - denotes no to the criterion; n/a denotes not applicable to the criterion. 1, study purpose stated; 2, design outlined; 3, sample biases detected; 4, no measurement biases detected; 5, sample sized stated; 6, sample described; 7, sample size justified; 8, outcomes stated; 9, outcome measurement described; 10, outcome measures reliable; 11, outcome measure valid; 12, statistical significance reported; 13, analysis methods appropriate; 14, clinical importance stated; 15, dropouts reported; 16, conclusions relevant.

Table 2.3. Details of Included Studies (*n* = 20)

Authors and country	Setting	Exposure assessed	Outcome	Sample size (n)	Data collection methods	Research design	Main findings
Vieira and Kumar (2007) Canada	Metal fabrication and computer workers	Working posture, movement, repetition, forces, duration	Lower back pain	64	Borg's scale Visual analogue scale (VAS), Corlett and Bishop 10-Point Body Part Discomfort Index, Questionnaires	Comparative retrospective cohort	Prevalence of WRMDs was 44% and 61% complained of low back pain. The lower back discomfort scores were higher than the scores for the other body parts Postures, repetitions and duration contributed significantly to overall effort needed for a task than the movements and forces.
Shahriyari et al. (2018) Iran	Metal fabrication at a steel industry.	Working posture, duration	Pain on the back, shoulders and neck	15	Inclinometry was used to assess postures and Standardised Nordic Musculoskeletal Questionnaires (NMQ) was used to assess prevalence of WRMDs.	Cross sectional	Reported high prevalence of pain was at the lower back (53.3%), knees (53.3%), neck (46.7%), and upper arm (46.75%). The median neck flexion was significantly related to neck pain. Time spent in flexion >45° was not significantly associated with neck pain. The proportion of time spent in low angular velocity (<5°/s) of the right arm was significantly

							related to pain at the right shoulder in the previous year. The median trunk flexion and the proportion of time spent in trunk flexion (> 20^o) were factors significantly related to low back pain in the previous year.
Akter et al. (2015) Indonesia	Workers at a metal tools manufacturing factories.	Working posture, force, manual handling, repetitive movement, vibration, insufficient ventilation	Pain on the neck, lower and upper back, shoulder, elbow, wrist, thigh, knee and ankle	60	DMQ was used to assess WRMDs Pre-designed checklists were used to assess risk factors.	Cross sectional	There was 85% prevalence of WRMDs among metal fabricators in the past year. A significant association between reported WRMD**s** with awkward postures and repetitive movement was found. A non-significant association between reported WRMDs with force and environmental conditions was found.
Domingo et al. (2015) Philippines	Workers at a construction company	Working posture	Pain on the neck, shoulder, elbow, arm, wrist, thigh, back, hip, knee, leg, ankle and	101	Standardised NMQ was used to assess WRMDs REBA and RULA were used for postural risk assessment	Cross Sectional	Reported musculoskeletal pain in various body regions (neck, elbow, arm, wrist, hand, upper back, lower back, hip, thigh). Average REBA score was 7.5. Average RULA score was 7.

			foot				
Nikpey et al. (2013) Iran	Workers at a manufacturing company	Working posture	Pain on the back, hands, fingers and legs	71	NMQ was used to assess WRMDs. Ovako Working posture Analysis System (OWAS) and RULA was used for postural risk assessment	Cross sectional	Right shoulder pain was significantly related to the tasks. Most prevalent WRMDs were related to assembling and metal fabrication tasks. Highest prevalence was found in the middle back, legs, wrist and lower back. Significant association was found between age and pain in the upper back, left hand and fingers and left legs
Parida and Ray (2012) India	Construction workers	Awkward posture, static posture, prolonged sitting and standing, repetitive work	Back and shoulder pain	259	Questionnaires Past records and direct observation	Cross sectional	Repetitive work, awkward posture, static posture, prolonged sitting and standing were noted among metal fabrication and they significantly contributed to severe back and shoulder pain.
Qutubuddin	Workers at an	Working	WRMDs	38	RULA, REBA	Cross	RULA demonstrated that about

et al. (2015) India	automotive coach manufacturing company in India.	postures			and QEC were used for postural assessment.	sectional	32% of workers were at high risk, about 29% were at medium risk, about 29% were at low risk and about 11% were at negligible risk. REBA demonstrated that 7.90% of workers were at low risk, about 42% were at medium risk, about 24% were at high risk and 26.32% at very high risk. QEC showed that about 11% of workers were at low risk, about 32% were at medium risk, about 24% were at high risk and 34.21% were at very high risk.
Ismaila et al. (2010) Nigeria	Metal fabricators from metal fabrication workplaces	Working postures	WRMDs	50	Questionnaires were used to assess both WRMDs and working postures	Cross sectional	Prevalence of back pain was found to be 43.8%. 38% were absent from work due to pain and 40% could not report for work due to the pain. 70.8% reported that their job requires them to maintain same posture all time, 58.3% claimed they work with arms above shoulders, 50% squat for > 2 two hours during their work, 77.1%

							bend or twist the spine.
Singh and Singhal (2016) India	Metal fabrication at a steel fabrication company.	Working postures	WRMDs	33	RULA was used for postural assessment.	Cross sectional	RULA showed that about 6 % of metal fabricators were at no risk for the development of WRMDs, 24.24% were at low risk, 30.30% were at moderate risk and 39.40% were at high risk.
Bhardwaj et al. (2017) India	Workers in a small manufacturing industry.	Working postures	WRMDs	54	Discomfort Assessment Checklist were used to assess WRMDS and RULA and QEC were used to assess working postures.	Cross sectional	Discomfort frequency in the lower back was 51.85%, upper back was 44.5%, shoulder was 42.59% and neck was 37.03%. Elbow, knees and ankle and feet were found to be least affected areas. RULA scores showed that 16.66% of the workers were at risk level 1, 25.93% were at risk level 2, 33.33% were at risk level 3 and 24.07% were at risk level 4. QEC scores showed that 16.66% of workers were at an acceptable risk, 27.77% were at moderate risk, 31.48% were at high risk and 24.07% were at very high

							risk.
Suman et al. (2018a) India	Workers in small scale welding units.	Working postures	Pain on the lower back, knees and wrists.	20	REBA was used to assess working postures and NIOSH discomfort survey method was used to assess WRMDs.	Cross sectional	Final REBA score showed that workers were at high risk. Reported WRMDs were lower back with 43%, knees 53% and wrist 53%. NIOSH Discomfort Survey showed that the level of discomfort in the first working hour was within acceptable range and in the eighth hour was in the insupportable range. The upper part of the metal fabricators' bodies were highly affected in the last working hour.
Watanabe et al. (2018) Japan	Workers of a ship building company.	Working postures, work environment, manual lifting, frequency.	Pain on the lower and upper back, shoulders, knees and neck	375	Pre-designed questionnaire NMQ was used to assess WRMDs	Cross sectional	Symptoms were reported at the lower and upper back (46.5%), shoulder (11.4%), knees (9.6%) and neck (5.3%). 132 were absent from work due to pain. Pain interfered with work in 46.5% of the workers Back pain was common in subjects who work in lying

							posture. Significant association was reported between back pain and commonly working in a half sitting posture. Sometimes working in a lying posture was a risk factor for absence from work due to back pain but there was no significant association. Working with elevated or extend arms was significantly related to onset of back pain. Working in confined spaces was significantly associated with back pain. Increase in smoking was significantly associated with back pain.
Yusop et al. (2018) Malaysia	Engineering students at a metal fabrication workshop at an university	Working postures	WRMDs	1	RULA, CATIA software were used in combination for postural assessment.	Cross sectional	Overall RULA risk reduced from 6 to 2 by the proposed armrests. Neck, trunk and leg were at very high risk. Wrists and arms were at low risk.

Dev et al. (2018) India	Metal fabricators in unorganised manufacturing units	Working posture, working hours and individual factors	WRMDs	60	NMQ for WRMDs assessment RULA and REBA for ergonomic risk assessment	Cross sectional	Age, Body Mass Index, working hours and work experience were associated with WRMDs RULA and REBA scores reveal that metal fabrication were at moderate to very high risk of developing WRMDs WRMDs were significantly related working hours. Age, BMI and having length of work experience > 10 years was significantly associated with pain in the lower back region.
Mahesa et al. (2017) India	Metal fabricators in small firms in an Engineering Fabrication Cluster	Individual and employment factors (shift)	WRMDs	987	Modified version of the NMQ was used to assess WRMD**s** and risk factors assessment	Cross sectional	Most metal fabricators (81%) experienced up to six WRMDs incidences. About 53% of welders were employed in regular working hours of 8 hours per day WRMD**s** were significantly associated with shift work. WRMDs were significantly associated with the mode of apprenticeship.

Fethke et al. (2011) USA	Metal fabricators at a construction workplace	Working postures	WRMDs	10	Electromyogram	Repeated measures	Mean trunk inclination was reduced from 34.4^{o} when using the conventional method of metal fabrication to 9.7^{o} in the alternate method. Peak trunk inclination was reduced from 81.7^{0} in the conventional method to 34.6^{0} in the alternate system.
Rahimian et al. (2014) Iran	Metal fabricators at a steel manufacturing company	Working posture, manual handling	WRMDs	243	The NMQ was used to assess WRMDs. The QEC was used to assess postural risks	Cross Sectional (Cross sectional)	Highest prevalence of pain symptoms at the lower back, trunk and knees. The QEC results showed 64% of metal fabricators were at high and very high risk.
Suman et al. (2018b) India	Workers working in small firms	Working posture	WRMDs	10	RULA and OWAS were used for postural risk assessment. NIOSH discomfort survey was used to assess WRMDs Questionnaire was used for other work related	Cross sectional	RULA analysis showed that workers were at high risk. Workers were engaging in manual handling tasks. The lower back, wrist and knee reported the highest frequency. WRMDs were significantly associated with metal fabrication type, work time and type of seat.

					aspects.		
Gbiri et al. (2012) Nigeria	Metal fabricators at a rural-urban centre	Working posture, job demand and work environment	WRMDs	177	Modified Maastricht Musculoskeletal Questionnaire	Cross sectional	About 69% of metal fabricators had WRMD**s** in the previous year and 87.5% of WRMDs were related to job activities. 41% were visited physician for treatment of the pain. 34.4% participants could not work due to pain and 54.9% had could not carry out routine work tasks due to the pain. About 18% of metal fabricators worked whilst standing upright, 20% sitting, 18% bending from knee and 44% bending from back.
Ajayeoba et al. (2016) Nigeria	Workers at a metal working micro enterprise.	Working posture, vibrating tools, heavy loads	WRMDs	66	NMQ was used to assess WRMDs prevalence REBA was used for postural risk assessment.	Cross sectional	There was 80% and 60% prevalence in the lower back in the past year and past week respectively. REBA scores showed that 12% of subject were at medium risk, 48% were at high risk and 9% were at very high risk.

2.2.5 Status of Evidence of Association

The systematic review considered studies with a methodological quality score ≥ 50% (Leider et al., 2015). Evidence yielded by the systematic review was rated as: (i) consistent when significant association was reported by ≥ 75% of studies, (ii) moderate when reported by 50 to 74% of the studies and (iii) limited when reported by < 50% of the studies. In circumstances where an ergonomic risk was investigated by ≤ 3 studies of methodological quality ≥ 50%, the significant association reported was considered as yielding limited evidence of association.

Table 2.4 Status of Evidence of Association between Ergonomic Risks and WRMDs

Ergonomic risk factors	Studies with score ≥50% n (%)	Significant association n (%)	Status of evidence
Working posture	19 (95%)	6 (32%)	Limited
Duration	6 (30%)	5 (83%)	Consistent
Repetitive movements	3 (15%)	2 (67%)	Limited
Manual lifting	2 (10%)	1 (50%)	Limited
Force exertion	1 (5%)	0 (0.0%)	Limited
Work environment	3 (15%)	1 (33%)	Limited

Status of evidence association between ergonomic risks and WRMDs: (a) consistent evidence when significant association was reported by ≥ 75% of studies with quality score ≥ 50%, (b) moderate when reported by 50 to 74% of studies with score ≥ 50% and (c) limited when reported by < 50% of studies with score ≥ 50% or when risk factor investigated by ≤ 3 studies with a quality score ≥ 50%.

2.3 Results

2.3.1 Study Selection

Figure 2. 1 presents the results of the study selection process. A total of 3 623 English language articles were identified and retrieved from the Scopus, EBSCO, PubMed, Taylor and Francis Online and Risk Abstracts databases. The general internet search and the reference screening produced 16 additional articles. We removed a total of 994 duplicated articles. Title screening was applied and 23 articles were excluded and the remaining 2 622 full text articles were assessed for eligibility. Most studies (2 602) were excluded during the screening stage. The major reasons for the exclusion were: (i) non-availability of primary data, (ii) study conducted before the year 2000 and (iii) study did not investigate ergonomic

risks. Finally, 20 studies met the inclusion criteria. Of these articles, four were from Scopus, five from PubMed, seven from EBSCO, two from Risk Abstracts, one from Taylor and Francis Online and one from the reference search.

2.3.2 Details of Included Studies

Details of included studies are shown in Table 2.3. All studies were conducted in the period 2007 to 2018. Of the 20 articles that met the inclusion criteria, seventeen were conducted in middle-income and three in high-income countries. Eight studies were carried out in South Asia, four in East Asia and the Pacific, three in Middle East and North Africa, two in North America and three in Sub-Saharan Africa. Eight of the studies were conducted in a manufacturing sector setting, eight in small and medium enterprises, three in the construction sector and one in tertiary institutions of learning. Evidently, this review summarises global evidence from literature covering diverse work settings of metal fabrication workers.

A total of 18 studies (90%) were cross sectional in design, which yielded data on associations and not on cause-effect relationships (Table 2.3). One study (Vieira and Kumar, 2007) used a comparative retrospective cohort study design. Fethke et al. (2011) used a repeated measures design. However, participants were not randomly selected which limited the generalizability of the findings to the larger population of metal fabrication workers. The total population of workers in the 20 included studies was 2 687. The sample sizes ranged from 1 to 987 participants (141.4±52 participants). Most of the studies (90%) used small sample sizes (Table 2.3). Sample sizes < 300 are considered small (Rockwood & Stadynyk, 1994; Loney et al., 1998; Osborne et al., 2012).

2.3.3 Screening Tools

Various screening tools were used to assess the prevalence and risk factors for WRMDs among metal fabrication workers. A total of 15 (75%) studies used either questionnaires or checklists to assess the prevalence of WRMDs among this category of workers (Table 2.3). The commonly used questionnaires or checklists were the NMQ (Nikpey et al., 2013; Rahimian et al., 2014; Domingo et al., 2015; Ajayeoba et al., 2016; Mahesa et al., 2017; Dev et al., 2018; Shahriyari et al., 2018), pre-designed questionnaires or checklists (Parida and Ray, 2012; Bhardwaj et al., 2017; Watanabe et al., 2018), NIOSH discomfort survey (Suman et al., 2018a, Suman et al., 2018b), DMQ (Akter et al., 2015) and the modified MMQ (Gbiri et al., 2012).

The prevalence rate of WRMDs among the workers in the reviewed studies ranged between 60 and 85%. Many of the studies (Vieira and Kumar, 2007; Ismaila et al., 2010; Parida & Ray, 2012; Nikpey et al., 2013; Rahimian et al., 2014; Domingo et al., 2015; Ajayeoba et al., 2016; Bhardwaj et al., 2017; Dev et al., 2018; Shahriyari et al., 2018; Suman et al., 2018b; Watanabe et al., 2018) reported LBP among workers. However, the severity of LBP and other WRMDs was assessed in six out of fifteen studies that investigated the prevalence rate of WRMDs in this occupational group (Table 2.3). The six studies reported severe work-related pain that led to absenteeism from work and difficulties in performing routine tasks. For example, in one study 75.4% (132) of the workers who complained of pain (*n* = 175) could not report to work due to pain and 46.5% had pain-related difficulties when performing their routine work tasks (Watanabe et al., 2018). In another study, 41% of the workers who reported pain (*n* = 122) visited a physician for treatment, 34.4% did not report for work due to pain and 54% could not perform routine work tasks (Gbiri et al., 2012). However, none of the studies reviewed, implemented and evaluated an intervention to reduce the severity or prevalence of the reported pain. The screening tools that were used to assess the severity of the pain were the CBBMQ (Vieira and Kumar, 2007), a pre-designed questionnaire (Ismaila et al., 2010), the modified MMQ (Gbiri et al., 2012), the NIOSH discomfort survey (Suman et al., 2018a, Suman et al., 2018b) and a pre-designed checklist (Watanabe et al., 2018).

The ergonomic risk assessment methods used in the studies reviewed were the RULA (Nikpey et al., 2013; Domingo et al., 2015; Qutubuddin et al., 2015; Singh and Singhal, 2016; Bhardwaj et al., 2017; Dev et al., 2018; Suman et al., 2018b; Yusop et al., 2018), REBA (Domingo et al., 2015; Qutubuddin et al., 2015; Ajayeoba et al., 2016; Dev et al., 2018; Suman et al., 2018a), QEC (Rahimian et al., 2014; Qutubuddin et al., 2015; Bhardwaj et al., 2017) and OWAS (Nikpey et al., 2013). The QEC method assesses ergonomic and psychosocial factors (stress and work pace) to yield an overall risk score (Chiasson et al., 2012). In this regard, the high QEC scores (Rahimian et al., 2014; Qutubuddin et al., 2015; Bhardwaj et al., 2017) denote workers' exposure to ergonomic and psychological factors. Although a fairly wide range of ergonomics assessment methods were used, none of the studies used the Ergonomic Workplace Analysis method, Job Strain Index (JSI) and Hand Activity Level (HAL).

The ergonomic risks investigated by the studies (*n* = 20) were working postures (95%), task duration (30%), work environment (15%), repetitive movements (15%), manual lifting

(10%), and vibration and force exertions (5%). Clearly, studies seem to predominantly focus on working postures than other ergonomic exposures. A shift of focus to the neglected risk factors could widen coverage of the available body of literature and enrich practice in the metal fabrication industry. Future studies should investigate the role of other ergonomic risk factors such as psycho-social and individual factors, in causing or aggravating WRMDs.

2.3.4 Methodological Quality Assessment

The methodological quality of studies (Table 2.2) that met the inclusion criteria (n = 20) was assessed using guidelines proposed by Law et al. (1998). Studies that scored ≥ 8 (50%) were considered to be of sufficient methodological quality. Studies were of sufficient quality as the scores ranged from 56.3 to 93.8%. Studies scored well stated (i) the purpose of the study, (ii) the study design used, (iii) measurement biases, (iv) sample sizes and (v) outcome measures. The major methodological limitations pertained to sample biases, lack of justification of sample sizes used and lack of description of results in terms of statistical significance.

2.3.5 Evidence of Association between Ergonomic Risks and WRMDs

Table 2.4 shows results of the systematic review of associations between ergonomic risk factors and WRMDs. In terms of our review criteria, there is limited evidence that poor working postures significantly contribute to WRMDs. Only 32% of the nineteen (19) studies of sufficient quality that investigated the contribution of working postures to WRMDs reported a significant association between: (a) median trunk flexion and back pain and (b) median neck flexion and neck pain, in the previous year (Parida & Ray, 2012; Nikpey et al., 2013; Akter et al., 2015; Shahriyari et al., 2018; Suman et al., 2018b). A study by Watanabe et al. (2018), indicated that back pain was common among subjects who work in a lying and half sitting posture and also among those who work with their trunks flexed. Two studies (Akter et al., 2015; Suman et al., 2018b) reported a significant association between awkward working postures and WRMDs. Awkward postures significantly contributed to back and shoulder pain among metal fabrication workers (Parida & Ray, 2012; Nikpey et al., 2013).

Consistent evidence indicated that prolonged working hours were associated with an elevated risk and prevalence of WRMDs among metal fabrication workers. About 83% of reviewed studies of sufficient methodological quality found a significant association between prolonged work in an awkward posture and WRMDs (Table 2.4). Shahriyari et al. (2018), reported that the time spent (16.82% of the working hours) with low angular velocity of the right arm contributes to shoulder pain and the duration of trunk flexion (23.71% of the working hours) was significantly associated with LBP. In one study more metal fabrication workers who worked at least 6 hours per day reported WRMDs than those who worked less hours (Dev et al., 2018). In the same study no metal fabricator had a low or negligible postural risk level which indicates a need for corrective measures to reduce the elevated risk scores. Suman et al. (2018b), reported that WRMDs were significantly high in the eighth hour of performing metal fabrication work. Evidently, there appears to be no consensus in literature that more daily working hours are a risk factor for WRMDs, but reviewed studies did not use a uniform exposure time in the ergonomic assessments.

On the other hand Mahesa et al. (2017), found that the incidence of WRMDs was significantly related to shift work. In this case, workers engaged in shift work were more likely to get WRMDs than those who were not. Parida & Ray (2012), reported that prolonged standing and sitting (8-11 hours in a day) significantly contributed to WRMDs among workers.

In terms of the present study's review criteria the evidence of association was classified as limited if ≤ 3 studies investigated a risk factor and reported significant association. With regards to repetitive movements two (2) out of three (3) studies reported a significant association. Consequently the evidence was considered to be insufficient. However, there were slight differences in use of the term repetitive movements. For example, Akter et al. (2015), referred to repetitive movements as motions that are repeated more than four times per minute whilst Parida & Ray (2012) defined repetitive movements as activities with similar motion patterns that last more than 50% of the work cycles.

One out of three studies that investigated the association between the work environment and WRMD**s** reported a significant association (Gbiri et al., 2012; Akter et al., 2015; Watanabe et al., 2018). Consequently this review classified the evidence of association as limited. Watanabe et al. (2018), in particular reported that working in a confined space and manual lifting were significantly related to back pain.

Lastly, some studies reported personal factors that can significantly contribute to the development of WRMD**s** among metal fabrication workers. Such factors include body mass index, age, length of work experience and smoking (Nikpey et al., 2013; Dev et al., 2018; Watanabe et al., 2018). For example, Dev et al. (2018) found out that, (a) overweight metal fabrication workers reported pain more frequently in comparison to the normal and underweight metal fabrication workers, (b) more metal fabrication workers aged ≥ 35 had WRMD**s** than those < 35 years, and (d) metal fabrication with a length of work experience > 10 years reported LBP and pain at the hips or thigh more than those with ≤ 10years.

2.4 Discussion

This review is the first to systematically evaluate literature pertaining to the association between ergonomic risk factors and WRMD**s** among metal fabrication workers. The review showed that consistent evidence exists regarding the contribution of prolonged working hours to the prevalence of WRMD**s**. Studies conducted among carpet weavers (Nazari et al., 2012), farmers (Jain et al., 2018) and sewing machine operators (Dianat et al., 2015) also reinforce the notion that prolonged working hours are a significant risk factor for the development of WRMD**s**. However, in light of the variability and lack of uniformity on the length of daily working hours considered to be prolonged working hours, we propose that future ergonomic studies consider > 8 daily working hours as prolonged working hours.

Based on the findings of other studies (Nazari et al., 2012; Dianat et al., 2015; Upasana & Vinay, 2017; Jain et al., 2018) and the present study, more focus must be placed on the need to reduce overall exposure to ergonomic risks. One way to do this is by reducing the daily working hours of metal fabrication workers. Some studies showed that planned regular work-rest schedules reduced the prevalence of WRMD**s** such as pain at the lower back, neck and shoulder (McLean et al., 2001) and allowed the worker's heart rate to return to a normal resting level (Luttman et al., 1992).

This review revealed that there is some evidence concerning the influence of awkward working postures to the development of WRMD**s**. About 32% of studies that assessed the relationship between awkward working postures and the risk of developing WRMD**s**, reported a statistically significant association (Parida and Ray, 2012; Nikpey et al., 2013; Akter et al., 2015; Shahriyari et al., 2018; Watanabe et al., 2018; Suman et al., 2018b). This may be a consequence of the nature of metal fabrication tasks such as cutting, grinding, drilling and frame fitting (Bhardwaj et al., 2017; Yusop et al., 2018). These tasks commonly require the metal fabricator to perform them whilst in a sitting, kneeling, squatting and or stooping postures. Such postures exert physical strain on the tendons, muscles and ligaments of the lower back (Caceres and Troya, 2012), which can contribute to LBP. Several previous studies have shown that: (a) ergonomics training of workers (Robertson et al., 2009; Laal et al., 2016; Bulduk et al., 2017), (b) ergonomics modifications (Robertson et al., 2009), (c) exercise training (Shariat et al., 2018), (d) combined exercise and ergonomics modifications (Shariat et al., 2018), significantly reduce use of inappropriate working postures. In light of the above documented interventions applied to relieve WRMD**s**, further studies are required to determine which interventions or combination of interventions are more effective in reducing the prevalence and severity of WRMD**s** among workers and associated risk factors. It has been reported that psychosocial factors can influence the development of WRMD**s** in construction workers (Sobeih et al., 2006). In light of this, more studies that evaluate the contribution of psychosocial factors in the development of WRMD**s** among metal fabrication workers are required.

Few studies (≤ 3) investigated the association of repetitive movements, manual lifting and force exertion with WRMD**s** among metal fabrication workers and metal fabrication workers. As a result, this review reports that evidence of association is limited. In light of the limited strength of evidence, the study makes cautious suggestions pertaining to improvements in repetitive movements, manual lifting methods, force exertion and work organisation (Jain et al., 2018), to promote a reduction in the prevalence of WRMD**s** among this occupational group. This implies that more research is required concerning the role of such ergonomic risk factors in the development of WRMD**s** in metal fabrication workers. Given the lack of consensus on what constitutes repetitive movements we propose harmonisation of the available definitions in order to improve the comparability of the findings.

Most studies used judgement-based postural observational methods. Such methods are not only user-friendly but inexpensive (David, 2005). Some of the methods, for example RULA, are validated and reliable tools (McAtamney & Corlett, 1993). As depicted in Table 2.3, most of the postural risk assessment methods yielded useful evidence that showed an elevated risk for developing WRMD**s** among workers that used awkward postures. Such evidence underlines a need for ergonomics practitioners, employers, and safety and health officers to carry out further investigations and implement applicable changes to promote the musculoskeletal health of workers. On the other hand, this review reported that only 6 out of 20 studies assessed the severity of the reported WRMD**s** and none of the reviewed studies implemented an intervention to address the reported pain. In addition, most studies did not implement interventions to reduce the elevated risk for developing WRMD**s** (Table 2.3).

Therefore, there is need for more studies that implement and evaluate interventions to reduce the risk, prevalence and severity of WRMD**s** among metal fabrication workers.

There are some potential biases in the research synthesised in this review that may account for differences in the study findings. Firstly, the heterogeneity of postural risk assessment methods used makes it very difficult to draw comparable findings. Chiasson et al. (2012) demonstrated that various postural risk assessment methods yield different findings with regards to the analyses of the same workstation. The Quick Exposure Check method was shown to be less stringent than RULA in assessing overall risk for developing WRMD**s** (Chiasson et al., 2012). It classified 35% of workstations as high risk for WRMD**s** compared to RULA (76%). Furthermore, REBA and RULA methods were observed as being unable to identify any workstations that posed low risk for the development of WRMD**s** (Chiasson et al., 2012). On the other hand, REBA and RUIA classified workstations as high risk at 70% and 76%, respectively (Chiasson et al., 2012).

Secondly, the postural risk assessment methods used by researches reviewed in this study lacked guidance regarding the strategy or strategies employed by raters when selecting the posture to assess. In all the studies, details of what the raters were instructed to do are not provided. Therefore, without predefined criteria for the selection of postures to rate, the studies are prone to yield less reliable postural risk assessment results.

Thirdly, some studies did not indicate whether the reported WRMD**s** were experienced in the past 6 months or in the previous year and so on. Such variability across reviewed studies makes comparison of findings difficult. It appears that there is currently no universal standard of reporting the period that is required to document the prevalence of self-reported WRMD**s**. As shown in Table 2.3 some studies did not specify the regions of the body affected by the WRMD**s**. In addition, none of the studies (Table 2.3), investigated disabilities related to WRMD**s**. These issues require attention in future ergonomics studies of metal fabrication workers. It is essential to note that most pain described in the reviewed studies was self-reported (questionnaires) rather physician-evaluated. The prevalence and incidence of self-reported pain should be interpreted with caution because of the associated response bias (Prins et al., 2008).

Finally, most studies (90%) used small sample sizes but did not justify the use of these small sample sizes (Table 2.2). According to literature (Rockwood & Stadnyk, 1994; Loney et al., 1998; Osborne et al., 2012) a sample size of ≤ 300 study participants is considered small and may affect the validity of the findings. Furthermore, Sobeih et al. (2006), reported that among other issues, the lack of sample size calculation was a major shortcoming of literature on WRMD**s** in the construction industry. Consequently, future studies should improve on methodological rigour in order to yield more credible findings. In particular, the statistical rigour of the studies was low and most studies were not immune to sampling biases. Statistical rigour is useful since it shows the extent of the association between the dependent and independent variables (Filho et al., 2013). About 90% of the studies were cross-sectional in design (Table 2.3). This means that reviewed studies had no capacity to demonstrate temporality. Furthermore, research utilising improved study designs are required. In summary, we proposed the following improvements:

i. Implementation and evaluation of interventions to reduce the: (a) prevalence rate of WRMD**s**, (b) severity of the pain and (c) elevated risk for developing WRMD**s**. This recommendation is based on the notion that since most studies were cross-sectional they could not demonstrate temporality.
ii. Use of larger sample sizes (≥ 300) or use of a specific formula to determine the minimum sample size required for each study.
iii. Improving on statistical rigour with regards to assessing the association between reported risk factors and WRMD**s**.
iv. Studies should also describe the method used to test the validity and reliability of the data collection instruments.
v. Use of uniform definitions of ergonomic exposures (prolonged duration and repetitive movements).

2.5 Strengths and Limitations of this Study

The present study has some strengths and limitations. A uniform criterion was applied to evaluate the methodological quality of studies that met the inclusion criteria, which strengthens the credibility of the study findings. Despite the use of a rigorous search strategy in five databases, the study could have missed some relevant material available in non-included databases. Studies that were not published in English were left out which may have introduced language bias and limited the capacity to generalise findings of this study to a wider context.

2.6 Conclusion

This study systematically reviewed literature that examined ergonomic risk factors associated with WRMD**s** among metal fabrication workers. Based on the findings of this review, prolonged working hours substantially contributed to the development of WRMD**s**. Most studies were cross-sectional, used small sample sizes, and lacked statistical rigour. Prolonged working hours in awkward posture positions were consistently reported to contribute to the development of WRMD**s**. However, there is need to harmonise and use a uniform definition of the term prolonged working hours. The prevalence rate of WRMD**s** ranged between 60 and 85%. Only 6 out of 20 studies assessed the severity of the reported WRMD**s**. However, they did not implement interventions to reduce the risk, prevalence and severity of WRMD**s.**

CHAPTER 3: RISK FACTORS FOR WORK-RELATED MUSCULOSKELETAL DISORDERS AMONG METAL FABRICATION WORKERS IN THE INFORMAL SECTOR UNDER RESOURCE - CONSTRAINED SETTINGS

Abstract

Metal fabrication tasks involve use of awkward working postures and repetitive movements therefore posing a risk for developing work-related musculoskeletal disorders (WRMDs). This study aimed at assessing the prevalence, severity and risk factors for WRMDs among metal fabrication workers in the informal sector. A total of 128 metal fabrication workers (33±10.5 years) were purposively selected from three urban centres in Zimbabwe. WRMDs were assessed using a Modified Cornell Musculoskeletal Questionnaire (MCMQ). The Quick Exposure Check (QEC) and the Rapid Entire Body Assessment (REBA) were used for postural risk analysis. $P < 0.05$ was considered significant. Analyses showed a high prevalence of pain in the lower back (78%), right shoulder (66%), left hand wrist (62%) and right hand wrist (61%). With regards to the severity of lower back pain, 4% reported low pain, 24% mild pain and 48% were severe cases of pain. Elevated grand REBA scores were significantly associated with self-reported pain at the lower back (OR = 1.48, 95% CI 1.13 - 1.94), right shoulder (OR = 1.48, 95 CI 1.14 - 1.92) and left shoulder (OR = 1.28, 95 CI 1.04 - 1.57). Multinomial regression analyses showed that smoking, prolonged working hours and not engaging in physical activities were significant predictors for pain. High job satisfaction and taking adequate work - rest breaks were key protective factors for WRMDs ($p < 0.05$). There is a high prevalence of WRMDs among metal fabrication workers due to individual and work - related risk factors. Interventions such as ergonomics education are required to address the risk factors for and progression of WRMDs among metal fabrication workers.

Keywords: Informal Sector, QEC, REBA, Metal Fabrication Workers, Work - Related Musculoskeletal Disorders.

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3.1 Introduction

A report by the International Labour Organisation (ILO) reported that the informal sector is a major source of livelihoods and employment in many nations, particularly low-income countries such as Zimbabwe (ILO, 2018). Given its importance in providing employment, emphasis has been put on the need to improve work conditions of workers in this sector (ILO, 2018; Ncube & Kanda, 2018). Occupational health and safety (OHS) services are excluded in this sector. This suggests that workers may be more vulnerable to OHS hazards than in the formal sector (Ncube & Kanda, 2018), such as work-related musculoskeletal disorders (WRMDs) (Dev et al., 2018).

Metal fabrication falls within the manufacturing sub-sector (Sangwan et al., 2016). The informal metal fabrication sector produces construction, mining and domestic materials and equipment. Metal fabrication comprises several manual and physically demanding tasks such as measuring, grinding and cutting, hammering and joining that may expose metal fabrication workers to risk factors for WRMDs (Yusop et al., 2018). Measuring is done using measuring tapes and angle squares to accurately take dimensions of required products. Grinding and cutting tasks on the other hand are done using an angle grinder. The equipment uses an abrasive rotating grinding disk to smoothen the pieces or surfaces of steel that require joining or that have been joined. Other equipment used include different sizes of hammers which are used to mould metal into required shape. Shield metal arc welding method is used to join metals to make finished products. A portable welding machine connected to a power source supplies energy to a burning mild-steel welding rod that melts and fuses two metal parts (Seles et al., 2018). Metal fabrication tasks are executed on a work bench or on a level ground, often using non - neutral postures that may contribute to WRMDs (Shahriyari et al., 2018).

Previous research carried out among manual workers such as orange harvesting (Ncube et al., 2018), sugar manufacturing (Choobineh et al., 2009), and hand - sewn shoe making (Dianat and Salimi 2014), have reported an elevated risk of developing WRMDs among these workers. Physical risk factors such as awkward posture, repetitive movements, manual handling, and force exertion have been associated with WRMDs among manual workers (Ncube et al., 2018; Choobineh et al., 2009; Dianat et al., 2014). Individual factors such as age, body mass index (BMI) (Dev et al., 2018; Piranveyseh et al., 2016) and smoking (Vieira et al., 2008) have also been significantly associated ($p < 0.05$) with reporting of WRMDs.

This suggests that WRMDs are multi-factorial and physical, job-related and individual factors playing a substantial role in the aetiology of these conditions.

To the authors' best knowledge, limited research has assessed factors contributing to WRMDs among metal fabrication workers in the informal sector. Choobineh et al. (2009) suggests that assessment of risk factors for musculoskeletal disorders among workers may yield valuable information for the purposes of planning and implementing sound ergonomics intervention programs. Therefore, this study was conducted to assess the prevalence, severity and the association between WRMDs and individual and job-related risk factors among metal fabrication workers in the informal sector under resource - constrained settings.

3.2 Methodology

3.2.1 Study Design

A cross-sectional study to assess the prevalence, severity and associated individual and work - related factors for the development of WRMDs was carried out between February and May 2019. The study was conducted in three urban centres of Zimbabwe where permission was granted (Bindura 17° 18' 4.7016S and 31° 11' 4564"E, Mutoko 17° 24' 20.19"S and 32° 13' 16.03"E and Mt Darwin, 16° 46′ 21″ S and 31° 35′ 01″ E). Of the 182 metal fabrication workers that were invited to participate 144 consented and were enrolled in the study. Six metal fabrication workers were excluded from the study because they declared that they had diseases and or had been involved in accidents affecting the musculoskeletal system (Choobineh et al., 2009). A total of ten metal fabrication workers were excluded because they had not more than one year metal fabrication experience. Therefore, 128 completed the study as shown in Figure 2.3. The study protocol was approved by Bindura University of Science Education Institutional Review Board. Procedures and objectives of the study were explained to all metal fabrication workers. All gave written consent to participate in this study.

3.2.2 Assessment of Prevalence and Severity of WRMDs

Data on prevalence and severity of WRMDs were assessed using the Cornell Musculoskeletal Questionnaire (CMQ). It is a valid and reliable instrument for assessing the prevalence and severity of WRMDs (Shariat et al., 2016). The prevalence of WRMDs was assessed by asking how often a metal fabricator experienced pain, ache or discomfort in the past seven days. The severity of WRMDs was assessed by asking metal fabrication workers how uncomfortable the pain was in the past seven days. A body map diagram to indicate symptom sites (neck, shoulders, upper back, upper arm, lower back, forearm, wrist, hips/buttocks, thigh, knees and lower legs) was provided to aid respondents complete the questionnaire.

In the current study, the CMQ was slightly modified to include individual information (age, gender, height and weight which was to be used to calculate body mass index (BMI), educational level, marital status and habits) and job-related factors (work experience, daily and weekly working hours, break frequency per day, perceived pressure due to targets and job satisfaction). The information was translated to the local language (*ChiShona*). Concurrent validity for the CMQ with respect to pain prevalence and severity measurement was assessed through concurrent use of the Corlett and Bishop Body Map Questionnaire (Appendix 1). In this regard, concurrent validity was considered satisfactory when findings yielded by both instruments were at least 90% in agreement with respect to pain severity and 100% in agreement with the prevalence of pain per body region. For internal consistency, a Cronbach's alpha statistic of $\alpha \geq 0.70$ for the CMQ was considered satisfactory (Shariat et al., 2016).

3.2.3 Task Analysis

Five visits were conducted to metal fabrication workers' workstations to identify and get used to the metal fabrication operations and tasks (measuring, grinding and cutting, hammering and joining) were identified. The different tasks of metal fabrication in the informal sector are as shown on Figure 4.1. Measuring was done using measuring tapes and angle squares to accurately take dimensions of required products (Figure 3.1 a). Grinding and cutting tasks on the other hand are done using an angle grinder (Figure 3.1b). The equipment uses an abrasive rotating grinding disk to smoothen the pieces or surfaces of steel that require joining or that have been joined. Other equipment used include different sizes of hammers which are used to mould metal into required shape (Figure 3.1 c). The shield metal arc welding method was used to join metals to make finished products. A portable welding machine was used (Figure 3.1 d).

Figure 3.1 Metal Fabrication Tasks

3.2.4 Postural Analysis

Postural analysis was carried out using the REBA and the QEC methods. One of the strengths of the REBA method is that it considers the nature of hand coupling that is associated with the use of hand-held tools (Chiasson et al., 2012). Further, it allows scoring for static, dynamic and rapid changing or unstable postures (Hignett & McAtamney 2000). The REBA method was used by selecting an activity and scoring the body part alignment using the REBA diagrams (Hignett & McAtamney, 2000). Photographs of metal fabrication workers were taken to assist in scoring but without showing facial identity of the metal fabricator. Scoring of different body parts alignment was done by two assessors. The REBA worksheet has two categories of scores namely group A (neck, trunk and leg) and Group B scores (upper arm, lower arm and wrist). Group A has a total of 60 posture combinations for the trunk, neck and legs. The posture scores for the trunk, neck and legs and the load/force score were combined to come up with score A. Group B has a total of 36 posture combinations for the upper arms, lower arms and wrists. The posture scores for the upper arms, lower arms and wrist scores were summed with the coupling score to obtain score B. The group A and group B scores were combined in Table C to get the Table C score. An activity score was added to give the final REBA score. The final REBA score for each worker were interpreted as described by Hignett & McAtamney (2000), Table 3.1.

Table 3.1 Rapid Entire Body Assessment Action Levels

Action level	REBA Score	Risk level	Action (including further assessment)
0	1	Negligible	Not necessary
1	2-3	Low	Maybe necessary
2	4-7	Medium	Necessary
3	8-10	High	Necessary soon
4	11-15	Very high	Necessary now

The Quick Exposure Check (QEC) method was also used to assess ergonomic risks associated with metal fabrication tasks (Li & Buckle, 1998). This method has been used to assess ergonomic risks in occupations such as sugar manufacturing (Choobineh et al., 2009) and brick and well ring manufacturing (Bidiawati & Suryani, 2015). The QEC method is useful when assessing psychosocial factors such as work pace and stress (Chiasson et al., 2012) which can be predictive variables for WRMDs development. In addition, it combines both the observer's and the worker's assessments (Chiasson et al., 2012). Such combination reduces bias which can be introduced by the observer's subjective assessment (Bidiawati & Suryani, 2015). The QEC score sheet is divided into two sections namely observer assessment and worker assessment. The first section is the observer assessment. It assesses the back, shoulder/arm, wrist/hand and neck with regards to posture and movements. This section of the assessment worksheet was completed by the authors. The second section was completed by study participants. In this section, the participant gave information on maximum weight handled, time spent on a task, level of hand force, visual demands, driving, use of vibration tools, difficulty sustaining work pace and work stress. The ratings were weighted into scores for different body parts.

The QEC final score was obtained by dividing the maximum possible score for manual handling task (176) and other tasks (162) by the obtained score as shown in the formula:

$E(\%) = \frac{X}{Xmax} \times 100\%$ (Li & Buckle, 1998).

Where E = exposure, X = total score obtained, Xmax = maximum possible score for the task. A final QEC score of ≤ 40 indicates low risk, 41 - 50 indicates moderate risk and further investigation is needed and changes may be required. A score of 51 - 70 indicate high risk and timely investigation and changes are required soon. Finally a score of > 70% indicates very high risk that urgent investigation and changes are required.

3.2.5 Statistical Analysis

The binary logistic regression was used to determine the OR of factors causing pain in different body regions among metal fabrication workers. The response (yes/no) to a question about pain in a specific part of the body was taken to be the dependent variable. There were 12 independent factors: age, qualification (primary, secondary, tertiary), BMI, smoking (yes/no), physical activities (yes/no), work experience in years, hours worked per day, hours worked per week, weight lifted in kg, breaks from work (one or less, more than one), work pressure (low, moderate or high), job satisfaction (low, moderate or high), metal fabrication QEC and metal fabrication REBA scores. Non-significant variables ($p > 0.05$) were eliminated using chi-square to remain with a minimum adequate model. Significant factors in logistic regression model were further assessed for specific categories using a multinomial logistic regression. Model fit was tested using the Hosmer & Lemeshow goodness-of-fit test. Results for all models showed good fit ($p > 0.05$). In all cases over 70% of the variation was explained by the models using the Nagelkerke pseudo R Square. OR and their confidence intervals (CIs) were calculated while factors were tested for significance at $p < 0.05$ using a Wald Chi-square. All analyses were conducted in IBM SPSS version 21 at 95% level of significance.

3.3 Results

3.3.1 Metal Fabrication Tools

Various tools were manually used on either a work bench platform or a level ground by the metal fabrication workers in the current study. Tape measures and angle squares were used to measure dimensions of products to be manufactured. Grinding was performed using portable angle grinders. The weight of the grinders ranged from 11.0 to 11.9 kg (11.4±0.4 kg) for 10 randomly collected samples. The variation in weight was due to different diameter sizes of disks used (diameter ranged from 115 to 230 mm). The length ranged from 17.0 to 17.8 cm (17.2±0.3 cm). The angle grinder rotates at 6500rpm which produces vibration that can be a risk factor for WRMDs (Charles et al., 2018). A hammer was used to flatten or bend metal objects. The weight ranged from of 0.9 to 7.2 kg (2.84±2.23 kg) for 10 randomly collected samples. The use of a hammer commonly involves repeated raising of the arms above shoulder level which can strain upper and lower arm muscles tissues.

3.3.2 Weather Conditions

Table 3.2 presents the weather patterns in the period November 2018 to May 2019. The working weather conditions were hourly recorded by a university weather station (Bindura University of Science Education, Zimbabwe). The mean monthly temperature was 29.6±10.3ºC (ranging from 5.2 to 34.6ºC) measured by a glass bulb thermometer (GH Zeal, UK). The temperature was considered relatively high for manual tasks. Exposure to extreme temperatures has been reported to be associated with detrimental health effects such as hypothermia and frostbites (Rodahl, 2003). The air humidity ranged from 50 to 99 % (72.0±7.2 %). Airflow velocity ranged from 0.3 to 34.8 $m\text{-}s^{-1}$ (8.9±1.6 $m\text{-}s^{-1}$).

Table 3.2 Weather conditions during the period (November 2018 to May 2019)

	November 2018		December 2018		January 2019		February 2019		March 2019		April 2019		May 2019	
Variables	M±SD	Range	M±SD	Range	M±SD	Range	M±SD	Range	M±SD	Range	M±SD	Range	M±SD	Range
Air Temperature (^{0}C)	30.3±3.1	16.1 - 34.6	31.6±4.7	17.1 - 32.6	30.6±4.5	18.0 - 32.9	29.7±2.4	14.1 - 33.7	30±1.9	25.6 - 34.1	28.6±0.3	10.0 - 32.1	26.9±1.4	5.2 - 29.5
Relative Humidity (%)	79.2±9.5	66.9-98.7	82.0±12.3	64.9 - 97.1	81.9±11.6	75.0 - 99.0	73.0±8.7	61.0 - 96.0	70±7.4	58.0 - 88.0	73.3±5.9	62.0 - 92.0	65±4.8	50.0 - 72.0
Air flow (m.s^{-1})	7.6±7.7	0.7 - 31.9	6.9±4.8	0.6 - 28.5	6.3±2.2	0.5 - 34.8	8.9±8.2	0.5 - 33.0	1.7±0.7	0.9 - 3.9	1.3±0.3	0.5 - 1.9	1.18±0.3	0.3 - 1.9

3.3.3 Individual and Work-Related Details of Study Participants (N = 128)

The individual and work characteristics of the metal fabrication workers are presented in Table 3.3. Their age ranged between 19 and 67 years (33± 10.5 years) and about three quarters (73%) of them were married. The BMI ranged from 16.32 to 41.02 kg/m^2 (23.6± 9.3). Few metal fabrication workers (20.3%) did not proceed beyond the primary level of education. Most metal fabrication workers (68.8%) were smokers and about half (52.3%) were not involved in physical activities. The length of working experience ranged between 1 and 26 years (10±6.5 years). The metal fabrication workers worked between 6 to 12 (9.3±1.0 hours). Nearly half of all participants (46.1%) reported a moderate job satisfaction. About half (50.8%) of the metal fabrication workers reported having breaks at most twice a day. About 54% of the metal fabrication workers reportedly felt moderate pressure due to work. The postural risk assessment results for the study group (*n* = 128 metal fabrication workers) are shown in Table 3.3. The REBA and QEC methods classified about 41% of metal fabrication workers in the high risk category. This indicated a good level of agreement between the two methods. In addition, the working postures of metal fabrication workers were unsafe and required further investigation and corrective measures to reduce their risk for developing WRMDs. The QEC method classified more metal fabrication workers (28.9 %) into the very high risk category than the REBA method (15.6%).

Table 3.3 Individual and Work-Related Details of Metal Fabrication Workers (*n* = 128)

Variables		**Variables**	
Age (yrs.)		Daily working hours	
Mean (SD)	33 (10.5)	Mean (SD)	9.3 (1.0)
Range	19 – 67	Range	6 – 12
Marital status (n (%))		Weekly working hours	
Single	35 (27.3)	Mean (SD)	57.6 (8.7)
Married	93 (72.7)	Range	36 – 84
Body Mass Index (kg/m^2)		Job satisfaction (n (%))	
Mean (SD)	23.6 (3.8)	Low	22 (17.2)
Range	16.4 - 41.0	Moderate	49 (46.1)
		High	47 (36.7)
Educational level (n (%))		Breaks per day (n (%))	
Primary	26 (20.3)	≤One break	56 (43.7)
Secondary	60 (46.9)	>One break	72 (56.3)
Tertiary	42 (32.8)		
Regular physical activity (n (%))		Feeling pressure due to work (n (%))	
Yes	61 (47.7)	Low	22 (17.2)
No	67 (52.3)	Moderate	69 (53.9)
		High	37 (28.9)
Smoking (n (%))		REBA scores (n (%))	
Yes	40 (31.3)	High risk	52 (40.6)
No	88 (68.8)	Very high risk	20 (15.6)
No of yrs. as a metal fabricator		QEC scores (n (%))	
Mean (SD)	10 (6.5)	High risk	53 (41.4)
Range	1 – 26	Very high risk	37 (28.9)

3.3.4 Prevalence and Severity of WRMDs amongst Metal Fabrication Workers (n =128)

Table 3.4 shows the prevalence and severity of pain in different body regions in the previous seven days. About 78% of the metal fabrication workers reported pain in the lower back region in the previous seven days (preceding data collection). Over 60% of the metal fabrication workers complained of wrist pain. About half (53%) of the metal fabrication workers reported pain in the neck region. More metal fabrication workers (66%) complained of pain on the right shoulder. Almost two-fifths of metal fabrication workers (38%) reported pain in the upper back region. Pain was reported to be more severe at the trunk (lower and upper back), wrists and neck region.

Table 3.4 Prevalence and Severity of Pain in Different Body Regions among Metal Fabrication Workers (*N* = 128)

Body region	**Prevalence** n (%)	**Severity** Low n (%)	Moderate n (%)	High n (%)
Neck	68 (53)	12 (18)	35 (51)	21 (31)
Right shoulder	85 (66)	11 (13)	67 (79)	7 (8)
Left shoulder	53 (41)	13 (25)	36 (68)	4 (7)
Upper back	48 (38)	8 (17)	15 (31)	25 (52)
Right upper arm	68 (53)	18 (26)	42 (62)	8 (12)
Left upper arm	46 (36)	10 (21)	32 (70)	4 (9)
Lower back	100 (78)	7 (9)	31 (31)	62 (62)
Right forearm	48 (38)	12 (25)	29 (60)	7 (15)
Left forearm	38 (30)	12 (31)	21 (55)	5 (14)
Right hand/wrist	78 (61)	7 (10)	41 (52)	30 (38)
Left hand/wrist	79 (62)	9 (11)	38 (48)	32 (41)
Hip/buttock	56 (44)	13 (23)	27 (48)	16 (29)
Right thigh	78 (61)	16 (21)	37 (47)	25 (32)
Left thigh	75 (59)	16 (22)	36 (48)	23 (30)
Right knee	67 (52)	14 (21)	34 (51)	19 (28)
Left knee	62 (48)	13 (21)	31 (50)	18 (29)
Right lower leg	59 (46)	9 (15)	34 (58)	16 (27)
Left lower leg	57 (45)	9 (16)	32 (56)	16 (28)

Severity: low = slightly uncomfortable, moderate = moderately uncomfortable, high = very uncomfortable

3.3.5 Risk Factors for WRMDs

3.3.5.1 Individual Risk Factors

Table 3.5 shows the results of binary logistic regression analyses. Ageing was significantly associated with neck (OR = 1.21, 95% CI 1.09, 1.34), right shoulder (OR = 1.09, 95% CI 1.02, 1.17), and left forearm (OR = 1.06, 95% CI 1.00, 1.11) pain. Less educated (primary education) metal fabrication workers were more likely to report neck (OR = 1.41, 95% CI 10.74, 184.5), upper back (OR = 1.85, 95% CI 1.45, 7.64) and left shoulder (OR = 20.72, 95% CI 2.73, 1.57.4) pain when compared to more educated ones (tertiary education). BMI was significantly associated with neck pain (OR = 1.28, 95% CI 1.00, 1.62) and pain at the right forearm (OR = 1.26, 95% CI 1.04, 1.53). Current smokers were more likely to report pain at the right wrists (OR = 1.21, 95% CI 1.07, 1.60), left wrists (OR = 1.11, 95% CI 1.03, 1.44) and hip/buttock (OR = 3.19, 95% CI 1.07, 9.50) when compared to non - smokers. Engaging in physical activities such as sports was a protective factor against neck pain (OR = 0.01, 95% CI 0.01, 0.53), left thigh pain (OR = 0.21, 95% CI 0.06, 0.67) and left lower legs (0.33, 95% CI 0.11, 0.98).

3.3.5.2 Work-Related Risk Factors

This study also showed that prolonged daily working hours were significantly associated with pain in several body regions ($p < 0.05$) as shown on Table 3.5. Moderate and high work pressure was significantly associated with left upper arm (OR = 20.34, 95% CI 3.03, 36.7), left forearm (OR = 2.97, 95% CI 1.00, 8.88), hip/buttock region (OR = 6.52, 95% CI 1.21, 35.27), and right thigh (OR = 6.61, 95% CI 1.19, 36.79) pain compared to low work pressure. The high grand QEC and REBA scores were significantly associated with pain in several body regions ($p < 0.05$) which clearly indicate that working postures and other ergonomic risks contributed significantly to pain in various body regions.

The results of multinomial regression analyses of factors associated with self-reported pain in different body regions are presented in Table 3.6. Smoking significantly contributed to pain reported on the hand and wrists. Being less educated (primary education) influenced the prevalence of pain at the neck and shoulders pain. Job-related factors such as fewer or no work-rest schedules were independent risk factors for the pain reported at several body regions (shoulders, hand/wrists, forearms, knees and lower legs). Prolonged daily working hours were a risk factor for shoulder pain. Metal fabrication workers who work under more pressure were at risk of developing work-related pain at the forearms. Not engaging in physical activities such as sport contributed to pain at the thighs and legs.

3.3.5.3 Protective Factors against WRMDs.

Results of binomial regression analysis showed some protective factors against pain in different body regions (Table 3.5). Metal fabrication workers who took more than one break during their daily working time were significantly less likely to experience pain in the lower body region than those who took one or no break. A high job satisfaction was a significant protective factor against pain on the left shoulder (OR = 0.18, 95% CI 0.04, 0.84), right forearm (OR = 0.09, 95% CI 0.42, 1.89) and left knee (OR = 0.20, 95% CI 0.05, 0.73).

Table 3.5 Binomial Regression of Factors Associated with WRMDs in Different Body Regions among Metal Fabrication Workers *(N = 128)*

	Neck (n=78)		Upper back (n = 56)		Lower back (n = 100)		Right shoulder (n = 86)		Left shoulder (n = 82)		Right hand/wrist (n = 78)	
Factor	**%[a]**	**OR[95%CI]**	**%[a]**	**OR[95%CI]**	**%[a]**	**OR[95%CI]**	**%[a]**	**OR[95%CI]**	**%[a]**	**OR[95%CI]**	**%[a]**	**OR[95%CI]**
Age	100	1.21[1.09,1.34]*	–	–	–	–	100	1.09[1.02,1.17]*	–	–	–	–
Qualification												
Primary	60.8	141.78[10.74,184.5]*	26.8	1.85[1.45,7.64] *	–	–	–	–	24.6	20.72[2.73,157.4]*	–	–
Secondary	15.3	0.14[0.01,1.91]	58.9	0.28[0.05,1.68]	–	–	–	–	45.9	0.88[0.02,2.28]	–	–
Tertiary[b]	23.9	1.00–	14.3	1.00–	–	–	–	–	29.5	1.00–	–	–
BMI	100	1.28[1.00,1.62]*	–	–	–	–	–	–	–	–	–	–
Smoking												
Yes	–	–	–	–	–	–	–	–	–	–	26.9	1.21[1.07,1.60] *
No[b]	–	–	–	–	–	–	–	–	–	–	73.12	1.00–
Physical activities												
Yes	44.3	0.08[0.01,0.53]*	–	–	–	–	–	–	–	–	–	–
No[b]	55.7	1.00 –	–	–	–	–	–	–	–	–	–	–
Hours/day	–	–	–	–	–	–	100	1.19[0.15,2.68]*	–	–	–	–
Hours/week	100	1.21[1.06,1.37]*	100	1.08[1.02,1.15]*	–	–	100	1.17[1.01,1.35]*	–	–	–	–
Breaks involved												
≤1 Break[b]	–	–	–	–	–	–	43.4	1.00–	41.7	1.00–	–	–
>I Break	–	–	–	–	–	–	56.6	0.12[0.02,1.35]	58.3	0.14[0.03,1.86]	–	–
Job satisfaction												
Low[b]	–	–	–	–	–	–	–	–	8.23	1.00–	–	–
Moderate	–	–	–	–	–	–	–	–	6.1	1.12 [0.40,3.20]	–	–
High	–	–	–	–	–	–	–	–	55.7	0.18 [0.04,0.84]*	–	–
Metal fabrication QEC	100	1.09[1.04,1.15]*	100	1.08[1.04,1.12]*	100	1.08[1.03,1.13]*	100	1.11[1.06,1.17]*	100	1.07[1.03,1.11]*	100	1.09[1.05,1.12]
Metal fabrication REBA	–	–	–	–	100	1.48[1.13,1.94]*	100	1.48[1.14,1.92]*	100	1.28[1.04,1.57]*	100	1.24[1.02,1.50]

OR = Odds ratio; CI = Confidence interval; * significant at $p < 0.05$; a-calculated with respect to the dependent variable in that column; b-referent group

	Right thigh (n = 78)		Left thigh (n = 75)		Right knee (n = 67)		Left knee (n = 62)		Right lower leg (n = 59)		Left lower leg (n = 57)	
Factor	**%[a]**	**OR[95%CI]**	**%[a]**	**OR[95%CI]**	**%[a]**	**OR[95%CI]**	**%[a]**	**OR[95%CI]**	**%[a]**	**OR[95%CI]**	**%[a]**	**OR[95%CI]**
Age	—	—	100	1.07[1.02,1.12]	—	—	—	—	—	—	—	—
Physical activities												
Yes	—	—	41.3	0.21[0.06,0.67]*	—	—	—	—	—	—	40.4	0.33[0.11,0.98]*
No[b]	—	—	58.7	1.00—	—	—	—	—	—	—	59.6	1.00—
Hours/day	—	—	—	—	100	2.24[1.27,3.94]*	100	2.34[1.32,4.23]*	—	—	—	—
Hours/week	—	—	—	—	—	—	—	—	100	1.15 [1.03,1.28]*	—	—
Weight lifted	—	—	—	—	—	—	—	—	100	1.15[1.04,1.28]*	—	—
Breaks involved												
≤1 Break[b]	—	—	37.3	1.00—	41.6	1.00—	44.6	1.00—	28.3	1.00—	25.6	1.00—
>1 Break	—	—	62.7	0.63[0.40,0.94]*	58.4	0.54[0.41,0.58]*	55.4	0.23[0.05,0.23]*	71.7	0.17[0.03,0.37]*	74.4	0.43[0.12,1.21]
Work pressure												
Low[b]	23.1	1.00—	—	—	—	—	—	—	—	—	—	—
Moderate	50.0	6.61[1.19,36.79]*	—	—	—	—	—	—	—	—	—	—
High	26.9	1.53[0.50,4.67]	—	—	—	—	—	—	—	—	—	—
Job satisfaction												
Low[b]	12.8	1.00–	—	—	—	—	9.7	1.00–	—	—	—	—
Moderate	34.6	1.31[0.44,3.90]	—	—	—	—	40.3	1.71[0.26,1.94]	—	—	—	—
High	52.6	0.21[0.05,0.88]*	—	—	—	—	50.0	0.20[0.05,0.73]*	—	—	—	—
Metal fabrication QEC	100	1.08[1.04,1.12]*	100	1.05[1.01,1.09]*	100	1.09[1.05,1.13]*	100	1.08[1.05,1.12]	—	—	—	—
Metal fabrication REBA	100	1.29[1.05,1.59]*	100	1.33[1.09,1.63]*	—	—	—	—	100	1.10[1.05,1.15]*	100	1.08[1.03,1.13]*

OR = Odds ratio; CI = Confidence interval; * significant at p<0.05; a-calculated with respect to the dependent variable in that column; b-referent group

Table 3.6 Parameter Estimates from a Multinomial Logistic Regression Model of Factors Related to Pain in Different Body Regions *(n = 128)*

Body region	Factor	OR	95%CI	P
Neck	Age	0.83	[0.76,0.91]	0.001*
	Hours/week	0.90	[0.82,0.98]	0.02*
	Metal fabrication QEC	0.93	[0.89,0.97]	0.001*
	Academic Qualification: primary (referent “tertiary”)	3.02	[1.02,5.16]	0.001*
	Physical activity: no (referent “yes”)	6.32	[1.39,12.68]	0.02*
Upper back	Hours/week	0.90	[0.82,0.99]	0.04*
	Metal fabrication QEC	0.95	[0.93,0.98]	0.002*
	Academic Qualification: secondary (referent “tertiary”)	0.45	[0.11,1.92]	0.03*
Lower back	Metal fabrication REBA	0.50	[0.38,0.65]	0.001*
Right shoulder	Age	0.93	[0.88,0.99]	0.03*
	Hours/day	1.47	[0.89,2.43]	0.03*
	Metal fabrication QEC	0.89	[0.85,0.93]	0.001*
Left shoulder	Metal fabrication QEC	0.93	[0.90,0.96]	0.001*
	Academic Qualification: primary (referent “tertiary”)	1.10	[0.02,5.54]	0.008*
	:secondary (referent “tertiary”)	0.17	[0.03,0.88]	0.04*
	Breaks per day : one or less (referent “more than one”)	8.89	[1.09,17.36]	0.04*
Right wrist	Metal fabrication QEC	0.91	[0.88,0.94]	0.001*
	Academic Qualification: secondary (referent “tertiary”)	0.23	[0.04,1.39]	0.04*
	Smoking: yes (referent “no smoking”)	4.32	[1.45,12.83]	0.008*
	Work pressure: low (referent “high”)	0.57	[0.14,12.83]	0.04*
Left wrist	Metal fabrication QEC	0.89	[0.85,0.93]	0.001*
	Smoking: yes (referent “no smoking”)	5.28	[1.65,16.93]	0.005*
	Work pressure: moderate (referent “high”)	0.43	[0.12,1.53]	0.02*
	Breaks per day: one or less (referent “more than one”)	7.52	[0.86,16.60]	0.04*
Right Upper arm	Weight lifted	0.94	[0.89,0.99]	0.01*
	Age	0.95	[0.91,0.99]	0.02*
	Hours per day	0.94	[0.89,0.99]	0.03*
Left Upper Arm	Age	0.95	[0.91,0.99]	0.02*
	Work pressure: low(referent “high”)	0.16	[0.04,0.59]	0.01*
	Hours per week	0.89	[0.84,0.94]	0.001*
Right forearm	Weight lifted	0.92	[0.87,0.97]	0.004*
	Age	0.95	[0.90,0.99]	0.02*
	Job satisfaction: low (referent “high”)	0.16	[0.03,0.77]	0.02*
	Job satisfaction: moderate (referent “high”)	0.14	[0.04,0.48]	0.002*
	Breaks per day: one or less (referent “more than one”)	15.6	[1.59,153.13]	0.02*
	Work pressure: moderate (referent “high”)	5.30	[1.22,22.92]	0.03*
	BMI	0.87	[0.76,0.99]	0.04*
	Hours per week	0.92	[0.85,0.98]	0.02*

Left forearm	Weight lifted	0.93	[0.89,0.97]	0.001*
	Age	0.93	[0.90,0.97]	0.001*
Hip buttock	Weight lifted	0.91	[0.86,0.96]	0.001*
	Job satisfaction: moderate (referent “high”)	0.30	[0.10,0.89]	0.03*
	Smoking: yes (referent “no”)	0.31	[0.11,0.88]	0.03*
	Academic qualification: primary (referent “tertiary”)	11.70	[1.86,73.58]	0.01*
	Work pressure: low (referent “high”)	0.19	[0.05,0.84]	0.03*
Right thigh	Age	0.94	[0.91,0.98]	0.003*
Left thigh	Hours per day	0.46	[0.26,0.80]	0.01*
	Age	0.94	[0.90,0.98]	0.01*
	Breaks per day: one or less (referent “more than one”)	24.94	[1.92,324.85]	0.01*
	Physical activity: no (referent “yes”)	3.10	[1.16,8.29]	0.02*
	Work pressure: low (referent “high”)	0.16	[0.03,0.82]	0.03*
Right knee	Hours per day	0.47	[0.29,0.78]	0.003*
	Breaks per day: one or less (referent “more than one”)	12.76	[1.52,106.89]	0.02*
Left knee	Hours per day	0.41	[0.24,0.68]	0.001*
	Breaks per day: one or less (referent “more than one”)	16.87	[1.92,148.69]	0.01*
Right lower leg	Weight lifted	0.96	[0.92,0.99]	0.02*
	Age	0.96	[0.92,1.00]	0.03*
Left lower leg	Age	0.94	[0.90,0.98]	0.003*
	Breaks per day: one or less (referent “more than one”)	15.33	[2.00,117.46]	0.01*
	Physical activity: no (referent “yes”)	2.94	[1.21,7.13]	0.02*

OR = Odds ratio; CI = Confidence interval; * significant at $p < 0.05$; a- calculated with respect to the dependent variable in that column; b-referent group

3.4 Discussion

This study assessed the prevalence and risk factors of WRMDs among metal fabrication workers in the informal sector in Zimbabwe. The prevalence of WRMDs among this category of workers was consistent with similar studies elsewhere (Dev et al., 2018; Mahesa et al., 2017) and studies conducted in other manufacturing sectors (Abaraogu et al., 2016). This demonstrates that WRMDs are common among manual occupations and require urgent intervention measures to safeguard workers' musculoskeletal health. In the current study, the grand QEC and REBA scores were significantly associated with pain in several body regions ($p < 0.05$). This indicated that awkward working postures increased the risk for developing WRMDs. The metal fabrication workers commonly used awkward working postures and complained of pain at the lower and upper back, wrists, shoulders and neck. The use of awkward working postures may contribute to the development of WRMDs when carrying out different metal fabrication tasks (Dev et al., 2018; Shahriyari et al., 2018, Chiboyiwa et al., 2020). Metal fabrication workers lack awareness of unsafe working postures that can contribute to WRMDS (Dev et al., 2018). Kruger et al. (2015) demonstrated that a tailor-made strength training program for metal fabrication workers resulted in a significant reduction of the relative muscle load employed during metal fabrication. Therefore, health training programs for metal fabrication workers must contain emphasis on recommended working postures in order to reduce the risk of WRMDs among this occupational group.

With regards to pain severity the most affected body region was the lower back. This is consistent with previous studies (Shahriyari et al., 2018; Vieira et al., 2008). In the current study, elevated grand REBA scores were significantly associated with a higher risk of developing lower back pain. The REBA method captures awkward posture such as squatting, sitting, lumbar flexion > 90 ^{o} and torso twisting (Chiasson et al., 2012). Awkward working postures are a common phenomenon among metal fabrication workers in the informal sector due to lack of proper workplace designs, confined spaces, overreaching and manual lifting of materials and tools. Use of adjustable work benches appears necessary to alleviate extreme bending and twisting common among various metal fabrication tasks. A study by Fethke et al. (2011) reported that prolonged trunk flexion (> 20^{o}) was common when carrying out metal fabrication tasks due to the poor design of metal fabrication work stations. Such flexion strains the upper and lower back muscles and causes back pain (Ncube et al., 2018; Howarth et al., 2016). In addition, metal fabrication tasks involve adduction and abduction of shoulders for prolonged periods, which is a risk factor for the development of WRMDs (Shahriyari et al., 2018). Postural education coupled with worksite restructuring and modifications can reduce the use of unsafe working postures (Abaraogu et al., 2016).

In this study, metal fabrication workers who took more than one work-rest breaks were less likely to experience pain in the shoulders, forearm and in the lower body regions. This indicated that work-rest schedules were a protective factor against WRMDs. Previous studies also reported a higher prevalence rate of shoulder and neck pain among workers who did not take adequate work rest schedules (Dev et al., 2018; Jain et al., 2018). Due to pressure to meet targets, metal fabrication workers are reluctant to take regular rest breaks even when fatigued. Rest breaks are required to alleviate prolonged exposure and also aid recovery from unhealthy postures (Dianat et al., 2015). In addition, stretch exercises may assist in alleviating pain at the neck, shoulders and lower back (Shariat et al., 2016).

Findings of the current study showed a significant association between increase in age and the prevalence of neck pain among our sample of metal workers. Studies conducted elsewhere also reported association between age and WRMDs (Dev et al., 2018; Jain et al., 2018). Studies report that some degenerative changes of muscles, tendons and ligaments attributed to aging can potentially increase susceptibility of tissues to physical loads (Cassou et al., 2002). In addition, it appears older metal fabrication workers had a longer length of metal fabrication work experience that entailed use of unsafe work postures described earlier on in this article.

This study showed that having low working pressure is a protective factor against WRMDs. Wrist pain was associated with increased pressure to meet production demands. Metal fabrication workers reported that they worked under pressure to meet targets from customers and resultantly make more profit. Metal fabrication workers manually held heavy grinders and hammers and lifted heavy materials and products. Such work reportedly strained wrist muscles and increased vulnerability to wrist pain. It has been reported that increased work pressure is significantly associated with a high prevalence of upper back symptoms (Dianat et al., 2015). To alleviate working under pressure, we recommend that metal fabrication workers should employ more assistants, properly plan and schedule their work.

A significant proportion of less educated metal fabrication workers reported neck, upper back and left shoulder pain in the last seven days. It has been reported that less educated workers may have difficulties with regards to understanding the sources of occupational hazards and required control measures (Yusop et al., 2018; Magidi & Mahiya, 2020). Workers in the informal sector hardly receive any form of technical training to equip them with knowledge related to their health and safety (Uzhenyu 2016; Dev et al., 2018). In addition, it has been reported that workers in the informal sector hardly received any form of technical training to equip them with knowledge related to their health and safety (Uzhenyu 2016; Dev et al., 2018), which increase their vulnerability to WRMDs risks. Jain et al., (2018) also reported that WRMDs were common among less educated farmers. However, results from the current study are in disagreement with those of Kumar et al. (2016) who reported that WRMDs were not significantly associated with education levels of sampled pineapple peeling workers in India.

Findings from our sample of metal fabrication workers indicated that wrist pain was significantly common among smokers. According to Abate et al., (2013) smoking cigarettes can have deleterious effects on the musculoskeletal system including the loss of bone mineral content. This may eventually favour or aggravate the onset of WRMDs. A study among metal fabrication workers and nurses reported that smoking was one of the factors associated with lower back disorders (Vieira et al., 2008). On the contrary, Dianat et al. (2015) reported no association between smoking and prevalence of WRMDs among workers. In light of the inconclusive evidence on the contribution of smoking to WRMDs, more research is required in this regard.

In this study, more metal fabrication workers who reported high job satisfaction did not experience work-related pain at the shoulders and arms. This indicated that being satisfied with one’s work was a significant protective factor against body region pain. In addition, this finding is consistent with a study on farmers India that reported a significant association between low job satisfaction and WRMDs.

Engaging in physical activities such as sport and exercises was a protective factor against neck pain and thigh pain. This implies that metal fabrication workers who engage in sport and exercises enhance relief of tissue pain (muscles, bones, tendons and ligaments). Onsite and offsite exercises have been shown to reduce WRMDs among office and construction workers (Shariat et al., 2018; Ludewig et al., 2003). A study by Nyawose & Naidoo (2021) among teachers reported that a tailor-made physical training exercise targeting shoulders had beneficial effects such as reducing pain and strengthening shoulder muscles. In this regard, we propose that metal fabrication workers should engage in physical activities (e.g. home exercises) to reduce musculoskeletal pain in various body regions.

Lastly, the current study presented the ergonomic risks and WRMDs of metal fabrication workers in the informal sector of resource constrained settings. The use of awkward postures due to lack of ergonomically designed work stations was highlighted as a major factor that elevated the risk for developing WRMDs among informal metal fabrication workers. Jadhav et al. (2020) also demonstrated that workers in the informal sector commonly use unsafe working postures because their workplaces were not properly designed. This highlights a need for ergonomic modifications of the work environment and facilities in the informal sector to reduce the risk for developing WRMDs.

3.5 Limitations of the Study

Findings of the present study should be considered in the context of the following limitations. First, due to budgetary limitations only two readily accessible provinces out of a total of 10 provinces in the country were considered in this study. Of the two selected provinces written permission was granted by only three relatively small urban centres. In this regard, our results may not necessarily reflect work conditions of metal fabrication workers in other provinces of Zimbabwe. Further large scale studies are required to document the work conditions of this category of workers in the remaining provinces. Second, out of the 224 metal fabrication workers that were identified as potential participants in this study, only 128 male metal fabrication workers consented and participated in this study. In Zimbabwe the metal fabrication industry is male dominated which explains the lack of female metal fabrication workers in the three studied urban centres. Thirdly, a cross sectional design was used. In this regard, the current study cannot demonstrate a temporal relationship between exposure and investigated outcomes. Fourthly, postural assessment was carried out using observation methods (not immune to observer bias). It is proposed that future studies use other real time methods such as inclinometry and electromyography. The self-reported nature of the MCMQ can be influenced by response and recall bias.

3.6 Conclusion

There is a high prevalence of WRMDs among metal fabrication workers due to individual (age, BMI and smoking habits) and work-related risk factors (working postures, inadequate rest breaks, prolonged working time and pressure due to work). This study showed that taking more work rest breaks, having a high job satisfaction and attaining a high level of education, were protective factors for the development of WRMDs. Ergonomics education and improvements are required to address the risk factors for and progression of WRMDs among metal fabrication workers.

3.7 Competing Interests

The authors declare that no competing interest exists.

CHAPTER 4: IMPLEMENTATION AND EVALUATION OF AN ERGONOMIC TRAINING PROGRAM AND STRETCH EXERCISES AMONG METAL FABRICATION WORKERS IN THE INFORMAL SECTOR IN THREE URBAN CENTRES IN ZIMBABWE

Abstract

This study assessed the effects of ergonomic training on postural risk and the effects of combined ergonomic training and stretch exercises on pain severity reported by metal fabrication workers in the informal sector of Zimbabwe. Supervised training and exercise sessions were conducted for a period of 11 weeks. Out of total of 260 metal fabrication workers that were purposively selected and randomly assigned to four groups, 189 finished the intervention program. There was significant reduction of risk in the shoulder/arm, hand/wrist and neck ($p = 0.001$) after the administration of ergonomic training. Non-significant reduction of risk was observed in the back ($p = 0.061$). In the combined ergonomic training and stretch exercise group, there was a significant reduction in the severity of the reported pain in most body regions ($p = 0.001$). There is need to implement a combination of intervention measures in order to substantially reduce the severity of pain among metal fabrication workers.

Keywords: Administration, Ergonomic, Informal Sector, Intervention, Pain Severity, Postural Risk, Program, Training, Stretch Exercises, Metal Fabrication Workers.

4.1 Introduction

The informal sector is a significant employment provider in developing economies (ILO, 2018). In Zimbabwe, the informal sector employs over 85% of the overall workforce with metal fabrication workers constituting a significant segment of this population (Uzhenyu 2016). A report by the World Health Organisation (WHO, 2017) indicated that more than 85% of workers in the informal sector lack access to occupational health and safety (OHS) services (WHO, 2017). This exposes this group of workers to ergonomic risk factors that include awkward working postures, repetitive movements, manual lifting, and unsafe force exertion (Dev et al., 2018; Shahriyari et al., 2018; Watanabe et al., 2018). Ergonomic risk factors account for a substantial part of the burden of overall chronic musculoskeletal disorders with 37% of all back pain attributed to occupational exposures (WHO, 2017).

Musculoskeletal disorders attributed to occupational exposures are termed work–related musculoskeletal disorders (WRMDs) (Sarkar et al., 2016). WRMDs are a major problem faced by metal fabrication workers (Dev et al., 2018), and more pain has been reported in the neck, shoulder, back and wrist regions (Mahesa et al., 2017; Shahriyari et al., 2018). This may be related to the physical nature of the tasks metal fabrication workers engage in when manufacturing and repairing different products. Informal metal fabrication tasks include grinding, welding, measuring and hammering (Yusop et al., 2018). When conducting these tasks, metal fabrication workers in the informal sector are exposed to a plethora of risk factors described earlier in the current study. Such exposure is caused by lack of knowledge on (i) proper workplace designs (Watanabe et al., 2018), (ii) effects of prolonged periods of exposure (Mahesa et al., 2017) and (iii) the contribution of awkward postures to the onset and progression of WRMDs (Dev et al., 2018, Chiboyiwa et al., 2020). There is need to find proper intervention programs to prevent the onset and progression of WRMDs as they have personal and socio-economic consequences (Bulduk et al., 2017). They may, for example, reduce productivity at the workplace, increase health associated costs and ultimately affect the worker and his/her family (Coggon et al., 2013; Sarkar et al., 2016).

Research has shown that workplace health and safety intervention programs may help to reduce sick leave absenteeism by 27% and health care costs by 26% (WHO, 2017). Watanabe et al., (2018) reiterated the need to provide appropriate training to minimize the risk factors for pain among shipyard workers. Vieira and Kumar (2007) proposed a wide variety of workplace intervention programs such as training, stretching, adjustable tables and crane use among others for metal fabrication workers.

Previous studies have highlighted the positive contribution of workplace intervention programs such as ergonomic training in reducing ergonomic risks in physically demanding workplaces. A study by Bulduk et al. (2017) showed that ergonomic training programs significantly reduced exposure to risk factors to the lower back ($p < 0.001$), shoulder/arm ($p < 0.005$), neck ($p < 0.005$) and wrist/hand ($p < 0.001$) among sewing machine operators. In addition, Denadai et al. (2021) found out that WRMDs pain complaints were reduced in the neck, back and wrist ($p < 0.05$) whilst pain intensity was significantly reduced only in the wrist [OR = 1.0, 95% CI (0.3 – 1.7)] after implementing an ergonomic training program among Brazilian poultry workers. In their study on WRMDs among school teachers Erick and Smith (2015) recommended that ergonomic training specific to WRMDs risk factors and prevention should form part of the training curriculum.

Stretch exercises have also been significantly associated with reduced WRMDs of different body areas. For example, Shariat et al. (2017) found that stretch exercises significantly reduced neck, shoulder and lower back pain among office workers. In a randomized control study among metalworkers, Rasotto et al. (2014) found out that a tailored exercises program significantly reduced pain in the neck ($p = 0.0164$), shoulder ($p = 0.0224$) and wrist ($p = 0.0007$). From these findings, it can be concluded that both risk factors and WRMDs symptoms may be reduced after successful implementation of individual intervention programs. However, the above mentioned study did not find a significant reduction of pain intensity in the elbows ($p = 0.3429$). Moreover, Gram et al. (2012) reported that there was a non-significant reduction of pain intensity in the neck ($p = 0.96$), right shoulder ($p = 0.11$), left shoulder ($p = 0.37$), dominant shoulder ($p = 0.31$), upper back ($p = 0.92$), lower back ($p = 0.73$), hip ($p = 0.74$) and knee ($p = 0.70$) among a sample of construction workers after implementing a tailored stretch exercise program. This points to the fact that in some occupational settings, stretch exercise programs alone may not produce the required results in significantly reducing pain severity.

Other studies have highlighted the need for a combination of two or more intervention programs in reducing ergonomic risks and WRMDs in different sectors. Robertson et al.

(2009) found out that ergonomics training coupled with stretch exercises and adjustable chairs significantly reduced WRMDs risks in the experimental group compared to the control group of sampled office workers. It is therefore important for high-risk occupations such as informal metal fabrication to be subjected to a combination of interventions (Dev et al., 2018). A combination of ergonomic training and stretch exercises might be useful in reducing ergonomic risk and the severity of WRMDs symptoms among metal fabrication workers in the informal sector. Considering the important role the informal sector plays in resource constrained economies, such intervention programs may assist in reducing health associated costs, increasing productivity, boosting incomes and increasing the welfare of workers.

To date, few studies have assessed the effects of ergonomic interventions on WRMDs and risk factors among metal fabrication workers (Kruger et al., 2015) and none conducted in the informal sector of resource constrained settings of low income countries such as Zimbabwe. Although there are safety standards and laws in developing economies, it seems they are not implemented in the informal sector (Moyo et al., 2015; WHO, 2017; Ncube & Kanda, 2018). This indicates a need for training and stretch exercise interventions in high-risk occupations such as metal fabrication (Dev et al., 2018). Therefore, the specific objectives of this study were to assess the effect of ergonomic training intervention on ergonomic risk levels and to assess the effect of combined ergonomic training and stretch exercise intervention programs on pain severity of WRMDs among metal fabrication workers in the informal sector of Zimbabwe.

4.2 Materials and Methods

4.2.1 Study Participants

In this randomized control trial, a total of 260 metal fabrication workers from three urban centres of Zimbabwe operating in the informal sector were invited to participate in the current study. A total of 40 metal fabrication workers were excluded due to chronic conditions such as cardio vascular, psychiatric and pathological ailments that could affect the metal fabricator during and or after the study were excluded (Shariat et al., 2017) and for other reasons. A total of 220 participants were randomly assigned to (a) ergonomic training group, (b) stretch exercise group, (c) combined ergonomic training and stretch exercise group and (d) control group (Figure 4.1). Randomisation was performed by the researcher blindly selecting one of the four slips of paper indicating group assignments (Ludewig & Borstad, 2003). A total of 31 metal fabrication workers were lost during the follow up period (4 in the ergonomics training group, 12 in the stretch exercise group, 15 in the combined ergonomics training and stretch exercise group and 0 in the control group). The study was conducted following the latest version of Helsinki Ethical Declaration. The study protocol was approved by the Bindura University of Science Education Institutional Review Board. The specific objectives and procedures of the study were explained to all study participants prior to data collection. All participants signed an informed consent form. A pilot study was conducted with ten randomly selected metal fabrication workers (Holzgreve et al., 2018).

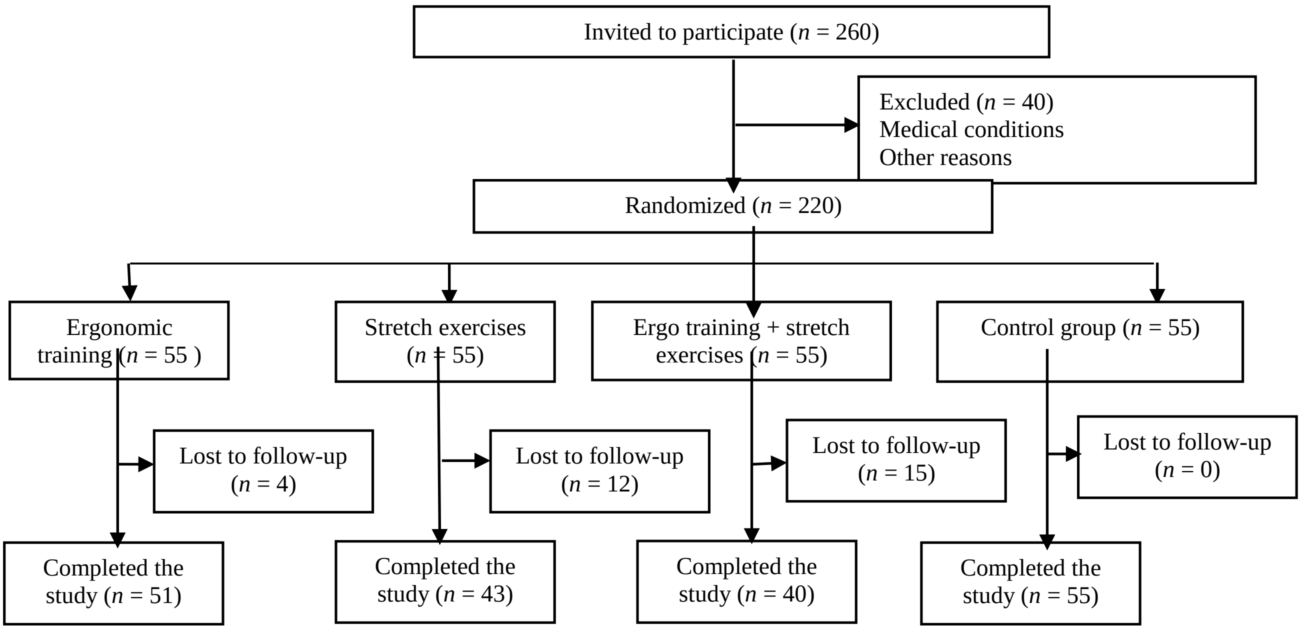

Figure 4.1 Study Participants

4.2.2 Interventions

4.2.2.1 Ergonomic Training

The ergonomic training was facilitated by the first author and was conducted following strict WHO guidelines to prevent the spread of corona virus. A recording of the training presentations was done and covered all elements of the ergonomic training described in literature (Habibi & Soury, 2015; Bulduk et al., 2017). The video recording was sent to the ergonomic training group and the combined ergonomic training and stretch exercise group. The video recording was compressed and put in a format that can be played on a computer or smart device such as a smart phone. This way, the participants followed the training sessions at their appropriate time and was regularly supervised. Each participant received a training brochure with (a) information on ergonomic risk factors, (b) WRMDs, and (c) the importance of aspects such as regular rest schedules, exercises, and safe work techniques, equipment and facilities. WhatsApp groups were created for regular feedback. The researcher conducted weekly follow ups for the purpose of clarification of any issues raised by study participants.

4.2.2.2 Stretch Exercises

The stretch exercises were performed for 11 consecutive weeks and consisted of the exercise protocol proposed by Shariat et al. (2017). The stretch exercises were conducted three times a week for 11 consecutive weeks with each session lasting approximately 20 minutes. The sessions were conducted at home. A video of the exercise regimes was recorded on an electronic device and distributed among metal fabrication workers. The researcher gave a demonstration of how the stretch exercise training was supposed to be conducted to all the study participants. The exercises protocol involved gradual application of tension to each muscle until a point of mild discomfort has been reached (Shariat et al., 2017). The stretch exercises were slightly modified to targeted body regions with moderate to severe pain. Participants spent the first week learning and familiarizing with the exercises. A WhatsApp group was created for all study participants in this cohort for regular feedback and clarifications of any issues that might arise during the training. Regular support visits were conducted to assess adherence to the training.

4.2.2.3 Combined Ergonomic Training and Stretch Exercise

The third group received both ergonomic training and stretch exercises as described above. The stretch exercises were conducted after the ergonomic training on each of the selected three days of the week.

4.2.2.4 Control Group

The metal fabrication workers in the control group were randomly selected from the three urban centres. The control group was requested not to alter any of their work activities and schedules during the intervention period. The control group did not record any drop out during the intervention period.

4.2.3 Assessment of WRMDs Severity

The severity of WRMDs was assessed using the Cornell Musculoskeletal Questionnaire (CMQ) and the Corlett and Bishop Body Map Questionnaire (CBBMQ). This assessment was conducted in the first week to get the baseline information and then after 11 weeks to assess the effect of the exercise interventions on pain severity. In the current study, the CMQ was slightly modified to include individual information (age, gender, BMI calculated using height and weight, educational level, marital status and habits) and job-related factors (work experience, daily and weekly working hours, break frequency per day, perceived pressure due to targets and job satisfaction). The information was translated to the local language (*ChiShona*). Concurrent validity for the CMQ with respect to prevalence of pain and severity measurement was assessed through concurrent use of the Corlett and Bishop Body Map Questionnaire. In this regard, concurrent validity was considered satisfactory when findings yielded by both instruments were at least 90% in agreement with respect to pain severity and 100% in agreement with the prevalence of pain per body region (Shariat et al., 2016).

4.2.4 Postural Risk Assessment

The Quick Exposure Check (QEC) method was used to assess ergonomic risks associated with metal fabrication tasks. This method has been used to assess ergonomic risks in occupations such as sugar manufacturing (Choobineh et al., 2009) and brick and well ring manufacturing (Bidiawati & Suryani, 2015). The QEC method is useful when assessing psychosocial factors such as work pace and stress (Chiasson et al., 2012) which may be predictive variables for WRMDs development. In addition, it combines both the observer's and the worker's assessments (Chiasson et al., 2012). Such combination reduces bias which may be introduced by the observer's subjective assessment (Bidiawati & Suryani, 2015). The tool was selected since it allows the user to assess the job before and after an intervention (Li & Buckle, 1998). The QEC score sheet is divided into two sections namely observer assessment and worker assessment. The first section assesses the back, shoulder/arm, wrist/hand and neck with regards to posture and movements. This section of the assessment worksheet was completed by the author. The second section was completed by study participants. In this section, the participant gave information on maximum weight handled, time spent on a task, level of hand force, visual demands, driving, use of vibration tools and difficulty in sustaining work and work stress. The ratings were weighted into scores for different body parts.

The QEC final score was obtained by dividing the maximum possible score for manual handling task (176) and other tasks (162) by the obtained score as shown in the formula.

$E(\%) = \frac{X}{Xmax} \times 100\%$ (Li & Buckle, 1998),

Where E = exposure, X = total score obtained, Xmax = maximum possible score for the task.

A final QEC score of ≤ 40 indicates low risk, 41 – 50 indicates moderate risk and further investigation is needed and changes may be required. A score of 51 – 70 indicates high risk and timely investigation and changes are required soon. Finally, a score of >70% indicates very high risk and that urgent investigation and changes are required.

4.2.5 Statistical Analysis

All analyses were conducted in IBM SPSS version 25 at 95% level of significance. All data were subjected to normality test using the Shapiro–Wilk test. Data on individual and work – related details of metal fabrication workers were presented as mean, frequencies and percentages. The paired-samples *t*-test was conducted to establish the effect of ergonomic training on QEC scores, risk levels, and pain severity scores before and after ergonomic training and stretch exercise interventions.

4.3 Results

***4.3.1 Individual and Work-Related Details of Metal Fabrication Workers* (n = 189)**

A total of 71 participants dropped out of the study during the intervention period with 189 remaining until the end of the study period. In the ergonomic training group, the mean age was 33±11.15 years (range 19 - 67 years). The majority (74.5%) of the metal fabrication workers in this group were married with mean Body Mass Index (BMI) of 22.9±3.66 kg/m^2 (range 16.3 - 36.6 kg/m^2). In the stretch exercise group, the mean BMI was 23.4±3.02 kg/m^2 (range 16.6 - 29.3 kg/m^2) with average working experience being 9.76±5.65 years (range 2 - 22 years). More metal fabrication workers (41.9%) attained at most a secondary education in this group in the stretch exercise group. Individual and work-related details of metal fabrication workers in the combined ergonomics training and stretch exercise group and the control group are presented in Table 4.1.

Table 4.1 Individual and Work-Related Details of Metal Fabrication Workers (*n* = 189).

Variables	Ergonomic training group *(n = 51)*	Stretch exercises group *(n = 43)*	Ergonomic training & stretch exercises group *(n = 40)*	Control group *(n = 55)*
Age (yrs.)				
Mean (SD)	33±11.15	32±9.47	34.8±10.6	31.8±10.15
Range	19 – 67	19 – 50	19 – 55	19 – 50
Marital status (n (%))				
Married	38 (74.5)	28 (65.1)	29 (72.5)	40 (72.7)
Single	13 (25.5)	15 (34.9)	11 (27.5)	15 (27.3)
Body Mass Index (kg/m^2)				
Mean (SD)				
Range	22.9±3.66	23.4±3.02	23.1±2.93	23.3±3.06
	16.3 – 36. 6	16.6 – 29.3	16.3 – 28.7	16.6 – 29.3
No. of yrs. as a metal				
fabricator	10.0±7.77	9.76±5.65	9.9±6.9	10.2±5.53
Mean (SD)	2 – 26	2 – 22	2 – 26	2 – 20
Range				
Educational level (n (%))				
Primary				
Secondary	11 (21.6)	12 (27.9	7 (17.5)	11 (20.0)
Tertiary	24 (47.1)	18 (41.9)	17 (42.5)	21 (38.2)
	16 (31.4)	13 (30.2)	16 (40.0)	23 (41.8)

4.3.2 QEC Scores and Risk Levels before and after Ergonomics Training

The QEC scores and risk levels in different body regions among metal fabrication workers before and after the ergonomic training intervention are presented in Table 4.2. The study found out that before the administration of ergonomic training, the mean risk scores for the back was 36.1±8.6 (very high), shoulder/arm 24.4±6.9 (moderate), wrist/hand 24.8±5.1 (moderate) and neck 12.7±3.4 (high). After the administration of training, the mean risk scores for the back was 35.5±8.2 (very high), shoulder/arm 20.6±6.8 (low), wrist/hand 19.8±4.9 (low) and neck 10.1±2.6 (moderate). According to the current study, there was a significant reduction of risk levels in the shoulder/arm (p = 0.001), hand/wrist (p = 0.001) and neck (p = 0.001) after the administration of training. Furthermore, the risk levels significantly reduced for vibration (p = 0.001), work pace (p = 0.001) and work stress (p = 0.001) from 5.8±3.2 to 5.0±3.4, 3.8±3.1 to 1.0±0.00 and 6.4±6.1 to 1.0±0.00 respectively as shown in Table 4.2. Conversely, there was a non-significant reduction of risk score of the back (p = 0.061). There was a non-significant reduction of risk level for driving before and after the ergonomic training (p = 0.826).

Table 4.2. QEC Scores and Risk Levels before and after Ergonomic Training (n = 51)

Body region	Before training (mean±SD)	After training (mean±SD)	t-value	*P*
Back (dynamic)	36.1±8.6	35.5±8.2	1.833	0.068
Exposure level	*Very high*	*Very high*		
Shoulder/arm	24.4±6.9	20.6±6.8	6.608	**0.001**
Exposure level	*Moderate*	*Low*		
Wrist/hand	24.8±5.1	19.8±4.9	11.044	**0.001**
Exposure level	*Moderate*	*Low*		
Neck	12.7±3.4	10.1±2.6	8.409	**0.001**
Exposure level	*High*	*Moderate*		
Driving	1.03±0.3	1.04±06	-2.20	0.826
Exposure level	*Low*	*Low*		
Vibration	5.8±3.2	5.0±3.4	3.375	**0.001**
Exposure level	*Moderate*	*Moderate*		
Work pace	3.8±3.1	1.0±0.00	12.309	**0.001**
Exposure level	*Moderate*	*Low*		
Work stress	6.4±6.1	1.0±0.00	12.177	**0.001**
Exposure level	*Moderate*	*Low*		
Grand QEC Score	59.5±14.4	53.4±7.3	6.445	**0.001**
Exposure level	*High risk*	*High risk*		
QEC score ranges	2.88	2.67	3.609	**0.001**
Exposure level	*High risk*	*High risk*		

Bolded are statistically significant differences ($p < 0.05$).

4.3.3 Prevalence of Musculoskeletal Pain in Different Body Regions among Metal Fabrication Workers before and after Interventions (n = 189)

Table 4.3 shows the prevalence of musculoskeletal pain among different groups of metal fabrication workers. Results indicated a significant reduction in the prevalence of pain in the neck (p = 0.004), upper back (p = 0.002), lower back (p = 0.041) and right forearm (p = 0.049) regions in the training group. Non-significant reduction of prevalence was recorded in the right shoulder (p = 0.078), left shoulder (p = 0.068), right upper arm(p = 0.089), left upper arm (p = 0.066), left forearm (p = 0.078), right hand/wrist (p = 0.066), left hand/wrist (p = 0.110), hip/buttock (p = 0.064), right thigh (p = 0.081), left thigh (p = 0.058), right knee (p = 0.061), left knee (p = 0.078), right lower leg (p = 0.066) and left lower leg (p = 0.079). In the stretch exercise group, results show a significant reduction of pain in most of the body regions except for the right shoulder (p = 0.498), right forearm (p = 0.061), left forearm (p = 0.062), left knee (p = 0.880), right lower leg (p = 0.059) and left lower leg (p = 0.067). In the combined ergonomic training and stretch exercise group, there was a significant reduction of prevalence of pain in all the body regions assessed. In the control group, prevalence of the lower back pain significantly increased from 31% to 33% ($p = 0.044$) after the intervention period. In all the other body regions, no significant changes to prevalence of pain were reported in this group as shown in Table 4.3.

Table 4.3. Prevalence of Musculoskeletal Pain in Different Body Regions before and after Interventions (N = 189)

	Ergonomic training group *(n = 51)*			Stretch exercises group *(n = 43)*			Ergonomic training & stretch exercises group *(n = 40)*			Control group *(n = 55)*		
Body region	Before n (%)	After n (%)	*P*	Before n (%)	After n (%)	*P*	Before n (%)	After n (%)	*P*	Before n (%)	After n (%)	*P*
Neck	23 (45.1)	18 (35.3)	**0.004**	22 (51.2)	17 (39.5)	**0.003**	24 (60.0)	18 (45.0)	**0.003**	23 (41.8)	24 (43.6)	0.344
Right shoulder	39 (76.5)	39 (76.5)	0.078	17 (39.5)	16 (37.2)	0.498	15 (37.5)	12 (30.0)	**0.033**	23 (41.8)	23 (41.8)	0.112
Left shoulder	22 (43.1)	22 (43.1)	0.063	20 (46.5)	16 (37.2)	**0.006**	14 (35.0)	12 (30.0)	**0.008**	31 (56.4)	34 (61.8)	0.056
Upper back	18 (35.3)	15 (29.4)	**0.002**	33 (76.5)	30 (69.3)	**0.044**	30 (75.0)	26 (65.0)	**0.001**	42 (76.4)	42 (76.4)	0.651
Right upper arm	34 (66.7)	34 (66.7)	0.089	11 (25.6)	10 (23.3)	0.061	8 (20.0)	7 (17.5)	**0.044**	17 (30.9)	16 (29.1)	0.710
Left upper arm	16 (31.4)	16 (31.4)	0.066	22 (51.2)	20 (46.5)	0.062	22 (55.0)	20 (50.0)	**0.024**	34 (61.8)	34 (61.8)	0.111
Lower back	41 (80.4)	36 (70.6)	**0.041**	26 (60.5)	22 (51.2)	**0.001**	18 (45.0)	12 (30.0)	**0.001**	31 (56.4)	33 (60.0)	**0.044**
Right forearm	23 (45.1)	19 (37.3)	**0.049**	22 (51.2)	20 (46.5)	**0.044**	17 (42.5)	15 (37.5)	**0.041**	28 (50.9)	28 (50.9)	0.572
Left forearm	19 (37.3)	19 (37.3)	0.078	20 (46.5)	14 (32.6)	**0.001**	15 (37.5)	12 (30.0)	**0.003**	27 (49.1)	27 (49.1)	0.091
Right hand/wrist	36 (70.6)	36 (70.6)	0.066	29 (67.4)	25 (58.1)	**0.009**	27 (67.5)	20 (50.0)	**0.001**	40 (72.7)	40 (72.7)	0.324
Left hand/wrist	38 (74.5)	39 (76.5)	0.110	31 (72.1)	27 (62.8)	**0.039**	29 (72.5)	23 (57.5)	**0.008**	39 (70.9)	39 (70.9)	0.723
Hip/buttock	27 (52.9)	27 (52.9)	0.064	23 (53.5)	20 (46.5)	**0.009**	21 (52.5)	19 (47.5)	**0.007**	27 (49.1)	29 (52.7)	0.078
Right thigh	34 (66.7)	34 (66.7)	0.081	21 (48.8)	26 (60.5)	**0.011**	24 (60.0)	18 (45.0)	**0.024**	36 (65.5)	34 (61.8)	0.045
Left thigh	31 (60.80	31 (60.8)	0.058	20 (46.5)	24 (55.8)	**0.042**	21 (52.5)	16 (40.5)	**0.022**	31 (56.4)	31 (56.4)	0.066
Right knee	29 (56.9)	29 (56.9)	0.061	23 (53.5)	24 (55.8)	**0.043**	20 (50.0)	17 (42.5)	**0.039**	32 (58.2)	32 (58.2)	0.111
Left knee	26 (51.0)	26 (51.0)	0.078	21 (48.8)	21 (48.8)	0.880	18 (45.0)	17 (42.5)	**0.042**	28 (50.9)	28 (50.9)	0.653
Right lower leg	26 (51.0)	26 (51.0)	0.066	22 (51.2)	21 (48.8)	0.059	20 (50.0)	17 (42.5)	**0.008**	26 (47.3)	26 (47.3)	0.054
Left lower leg	24 (47.1)	24 (47.1)	0.079	20 (46.5)	19 (44.2)	0.067	18 (45.0)	14 (35.0)	**0.001**	26 (47.3)	26 (47.3)	0.172

Bolded are statistically significant differences ($p < 0.05$).

4.3.4 Mean Pain Severity Scores before and after Interventions

Comparative mean pain severity scores before and after interventions among metal fabrication workers in the informal sector in different groups are presented in Table 4.4. In the ergonomic training group, mean pain severity was significantly reduced in the lower back (p = 0.049), right forearm (p = 0.044), left forearm (p = 0.006), right wrist (p = 0.003), left wrist (p = 0.001), right knee (p = 0.044) and right lower leg (p = 0.044). In the stretch exercise group, significant reduction of pain was recorded in the majority of body regions except the right shoulder (p = 0.078), left forearm (p = 0.256), right hand/wrist (p = 1.000), right knee (p = 0.183) and right lower leg (p = 0.183) (Table 4.4). No effect was recorded in the right hand/wrist as pain severity after the intervention period. In the combined ergonomic training and stretch exercise group, there was a significant pain severity reduction in all body regions except the left shoulder (p = 0.103) and the right upper arm (p = 0.323). Significant reduction of pain severity after the intervention periods was recorded in the left shoulder (p = 0.002) and right hand/wrist (p = 0.013) in the control group. The mean pain severity scores significantly increased in the neck (p = 0.001), left knee (p = 0.001) and left lower leg (p = 0.002) after the intervention period in the control group. No statistically significant differences were found for pain reduction in all other body regions as reflected in Table 4.4.

Table 4.4. Mean Pain Severity Scores before and after Interventions *(N = 189)*

	Ergonomic training group *(n = 43)*				Stretch exercise group *(n = 51)*				Stretch exercises & ergonomic training group *(n = 40)*				Control group *(n = 55)*			
Body region	Before	After	t-value	*P*	Before	After	t-value	*P*	Before	After	t-value	*P*	Before	After	t-value	*P*
Neck	0.71±0.14	0.60±0.12	1.697	0.096	102±0.17	0.90±0.15	2.351	**0.024**	1.38±0.20	0.70±0.10	4.970	**0.001**	1.04±0.14	1.45±0.16	-3.727	**0.001**
Right shoulder	1.25±0.13	1.15±0.12	1.940	0.058	0.91±0.18	0.91±0.18	-1.807	0.078	1.03±0.21	0.50±0.11	4.069	**0.001**	0.87±0.14	1.00±0.15	-1.628	0.109
Left shoulder	0.69±0.13	0.68±0.13	1.429	0.159	1.12±0.19	0.83±0.16	2.906	**0.006**	0.75±0.17	0.65±0.16	1.669	0.103	1.56±0.06	0.98±0.13	3.281	**0.002**
Upper back	0.49±0.11	0.45±0.10	1.429	0.159	1.33±0.14	1.20±0.13	2.351	**0.024**	1.70±0.18	1.30±0.16	3.252	**0.002**	1.35±0.13	1.49±0.13	-1.184	0.242
Right upper arm	1.22±0.15	1.17±0.14	1.000	0.322	0.56±0.16	0.39±0.11	2.203	**0.033**	0.43±0.14	0.37±0.13	1.000	0.323	0.45±0.11	0.49±0.09	0.531	0.598
Left upper arm	0.57±0.13	0.54±0.12	-2.018	**0.049**	1.09±0.18	0.97±0.16	2.351	**0.024**	1.18±0.17	0.82±0.13	3.557	**0.001**	0.85±0.12	0.92±0.12	-1.427	0.159
Lower back	2.24±0.16	1.90±0.24	3.125	**0.003**	1.49±0.19	0.88±0.13	4.832	**0.001**	1.00±0.19	0.47±0.08	4.235	**0.001**	1.25±0.17	1.18±0.16	.704	0.485
Right forearm	0.73±0.13	0.52±0.09	2.063	**0.044**	1.07±0.17	0.74±0.12	3.774	**0.001**	0.78±0.16	0.47±0.10	3.122	**0.003**	0.85±0.13	0.96±0.15	-1.097	0.277
Left forearm	1.62±0.06	0.59±0.12	2.848	**0.006**	0.91±0.16	0.79±0.14	1.151	0.256	0.70±0.16	0.52±0.12	2.211	**0.033**	1.50±0.06	0.72±0.11	.000	1.000
Right hand/wrist	1.61±0.17	1.39±0.16	2.445	**0.018**	1.51±0.18	1.51±0.18	.000	1.000	1.55±0.19	1.22±0.17	2.816	**0.008**	1.71±0.16	1.48±0.15	2.574	**0.013**
Left hand/wrist	1.63±0.15	1.49±0.14	3.449	**0.001**	1.72±0.18	1.18±0.13	4.574	**0.001**	1.70±0.19	0.90±0.10	5.731	**0.001**	1.65±0.15	1.52±0.14	1.357	0.180
Hip/buttock	0.67±0.10	0.66±0.10	1.429	0.159	0.65±0.10	0.65±0.10	2.746	**0.009**	0.65±0.11	0.55±0.08	2.082	**0.044**	0.62±0.09	0.63±0.10	-1.000	0.322
Right thigh	1.41±0.17	1.13±0.17	1.000	0.322	1.30±0.18	1.02±0.15	3.597	**0.001**	1.28±0.19	0.90±0.10	3.553	**0.001**	1.36±0.16	1.32±0.16	0.814	0.419
Left thigh	1.39±0.17	1.31±0.17	1.768	0.083	1.28±0.19	0.86±0.14	2.235	**0.031**	1.28±0.21	0.67±0.11	4.878	**0.001**	1.29±0.17	1.29±0.17	-1.427	0.159
Right knee	1.00±0.14	0.94±0.13	2.063	**0.044**	1.05±0.17	0.86±0.14	1.355	0.183	0.98±0.17	0.62±0.11	3.557	**0.001**	0.98±0.13	1.00±0.13	-.574	0.568
Left knee	0.76±0.13	0.70±0.12	-.444	0.659	0.65±0.12	0.58±0.10	2.203	**0.033**	0.63±0.13	0.45±0.07	2.211	**0.033**	0.78±0.12	0.81±0.13	-3.727	**0.001**
Right lower leg	0.84±0.13	0.76±0.12	2.063	**0.044**	0.81±0.14	0.65±0.10	1.775	0.083	0.83±0.15	0.52±0.07	3.122	**0.003**	0.78±0.12	0.78±012	-1.628	0.109
Left lower leg	0.90±0.15	0.92±0.14	-.444	0.659	0.81±0.15	0.74±0.14	2.351	**0.024**	0.80±0.16	0.60±0.11	2.243	**0.031**	0.87±014	0.89±0.14	3.281	**0.002**

Bolded are statistically significant differences ($p < 0.05$).

4.4 Discussion

The current study was conducted to evaluate the effect of ergonomic training on exposure to ergonomic risk factors for WRMDs among metal fabrication workers in the informal sector using the QEC. The QEC assessment method is appropriate for ergonomic assessments before and after administration of interventions (David et al., 2008). The study also applied a stretch exercise intervention protocol proposed by Shariat et al. (2017) and assessed the effects to WRMDs pain severity after an 11 week period. According to the current study, significant reduction of QEC scores were recorded in the shoulder/arm, wrist/hand and neck. These results are consistent with those of Bulduk et al. (2017) who found a significant reduction of QEC scores and risk levels after the implementation of ergonomic training among sewing machine operators. Our findings are commendable especially in trying to reduce the prevalence and progression of WRMDs in this study population as previous studies have found that these body regions are commonly affected by WRMDs among metal fabrication workers (Shahriyari et al., 2018; Dev et al., 2018; Mahesa et al., 2017). The reduction in the QEC scores and risk levels might be due to the changes in working postures metal fabrication workers adopted after receiving ergonomic training. The training intervention targeted unsafe postures metal fabrication workers engaged in, when conducting their daily tasks. Metal fabrication workers got information and practical demonstrations on how to adopt recommended safe work postures during the intervention period. This has proved to be helpful in reducing the risk level in the upper extremities of the body. It is therefore suggested that all metal fabrication workers be given ergonomic training in order to reduce risk levels and protect their musculoskeletal health.

On the other hand, we found a non-significant reduction of QEC scores and risk levels in the back region. This may be due to a lack of ergonomically designed workstations and improved workstation setup and space informal metal fabrication workers use when conducting their tasks (Dev et al., 2018) which required trunk flexion for prolonged periods (Parida & Ray 2015; Shahriyari et al., 2018). This is not surprising since informal metal fabrication workers lack capital required to install engineering controls. A study by Fethke et al. (2011) reported that prolonged trunk flexion (> 20^{o}) was common when carrying out metal fabrication tasks due to the poor design of metal fabrication workstations. Risk factors for musculoskeletal disorders could be reduced after the implementation of engineering controls (Zare et al.,

2020) such as ergonomic designed work stations. There is need for more investments in workplace designs in the informal metal fabrication sector in order to reduce WRMDs risk factors especially for the back region. Installation and proper use of adjustable work benches is recommended to reduce extreme flexion, extension and twisting of the back which is common among metal fabrication workers in the informal sector. It is also suggested that fabrication workers acquire and properly use lifting equipment to reduce risk associated with manual handling of heavy loads. Risk scores for other factors such as vibration, work pace and work stress were significantly reduced after the administration of ergonomic training which is in agreement with a previous study by Bulduk et al. (2017) who found a significant reduction in risk level after ergonomic education among sewing machine operators. The ergonomic training that metal fabrication workers received encompassed elements of how to reduce work pace and subsequently work stress. In that regard, fabrication workers were able to utilise information gained during the intervention period.

Participants in the training group reported reduced prevalence rates of WRMDs in the upper back, lower back, right forearm and neck regions. This is in agreement with the results observed by Choobineh et al. (2011) who reported that prevalence rate of the reported symptoms in upper back, lower back and feet/ankles regions reduced significantly after the ergonomic training intervention. From this assessment, it is evident that WRMDs pain prevalence of the upper extremities can be reduced if workers are given appropriate training targeting preventive measures. Furthermore, the current results are similar to those reported among Brazilian poultry processing industry workers who reported less musculoskeletal complaints in the neck, wrist and thoracic and lumbar spine after ergonomic training (Denadai et al., 2021). Ergonomics training targeting preventive strategies to the upper body regions are required in manual workers.

Prevalence of pain was significantly reduced in the most of the body regions except the right shoulder, both arms, left knee and both legs among fabrication workers in the stretch exercise group. There is need for further assessments to get conclusive evidence regarding the effects of stretch exercises on shoulders, arms, knees and legs. The combined ergonomic training and stretch exercise group reported significant WRMDs prevalence reduction in all the body regions assessed which suggest that it is the most effective way of reducing prevalence of pain among manual workers such as metal fabrication workers. Results from this assessment concur with those of Choobineh et al. (2011) who reported no change before and after intervention among workers in the control group of sampled office workers. Significant increase of prevalence of pain in the lower back region among workers in the control group can be attributed to continuous working in un-ergonomic designed work stations which enabled metal fabrication workers to squat, kneel, twist and bend for prolonged periods which is a risk factor for the development of WRMDs (Dev et al., 2018; Shahriyari et al., 2018). It is therefore suggested that metal fabrication workers in the informal sector with high prevalence be subjected to a combination of interventions to reduce prevalence of pain.

The current study shows that stretch exercises significantly reduced pain severity in the majority of body regions. This is similar to results of Tunwattanapong et al. (2015) who found out that stretch exercises targeting neck and shoulder significantly reduced pain intensity after stretch exercise intervention among office workers. Rasotto et al. (2014) have also suggested that performing a tailored physical activity program is beneficial to reduce pain and disability on upper-limb WRMDs among metalworkers in Italy. Based on the results of our study and these studies, it is evident that stretch exercises are important in musculoskeletal pain reduction. It is therefore proposed that stretch exercises be conducted among both sedentary and manual workers to reduce musculoskeletal pain severity. The results also indicated that pain severity was not significantly reduced in the right shoulder, left forearm, right hand/wrist, right knee and right lower leg. This requires further assessment to assess the effect of stretch exercises on different body sides (left and right side) as well as to assess the side which is negatively impacted on by these exercises so that improvements may be made. In this way conclusive evidence may be deduced.

In the combined ergonomic training and stretch exercise group, there was a significant pain severity reduction ($p < 0.05$) in the majority of body regions. The results support both the hypotheses that a series of stretching and resistance training exercises, performed in a particular sequence, could significantly reduce neck, shoulders and lower back pains (Shariat et al., 2017). This clearly indicates that a combination of intervention measures is needed to reduce pain severity among both office workers and manual workers such as metal fabrication workers. When pain severity in significantly reduced, workers' productivity can be enhanced thereby increasing their incomes. In the majority of body regions assessed, there was a non-significant reduction of pain in the control group. Results of the current study and those of Ludewig & Bostard (2003) and Rasotto et al. (2014) are in agreement in that the control group remained unchanged after the intervention period among construction workers.

However, in a few body regions, mean pain severity scores significantly increased in the current study. This might be due to increased demand of products at work which in return require workers to spend more time thereby increasing chances of pain severity. This was necessitated by the relaxation of COVID-19 lockdown by the government allowing the informal traders to fully operate. Since metal fabrication workers are paid basing on the number of items finished, the increase in demand tend to force them to ignore and bypass some of the important WRMDs pain preventive measures. For example, metal fabrication workers may adopt unsafe work postures that pose a threat to their musculoskeletal health due to increased pressure to finish a client's product. Some of them may work for prolonged periods without taking rest breaks (Dev et al., 2018). Regular rest breaks are recommended among metal fabrication workers in the informal sector in order to aid muscle recovery after prolonged exposure to unsafe work postures. More planning and scheduling of work is required for metal fabrication workers to reduce chances of working under intense pressure which can force them to adopt unsafe work postures and procedures.

4.5 Strengths and Limitations of this Study

The current study has its strengths and limitations. Randomisation was applied when selecting study participants into the four study groups which allowed every participant a chance. Uniform assessment methods were applied during the assessment of both postural risks and WRMDs pain severity. Due to budgetary limitations only two readily accessible provinces out of a total of 10 provinces in the country were considered in this study. Of the two selected provinces written permission was granted by only three relatively small urban centres (Appendix 2 to Appendix 4) out of the eight randomly selected. Due to this, results cannot be generalized to represent all metal fabrication workers in the informal sector in Zimbabwe. It is therefore suggested that future studies be conducted covering more urban centres in Zimbabwe. The study found out that there were only male metal fabrication workers in the three urban centres where the study was conducted which indicated that the informal metal fabrication sector is male dominated in these centres. Therefore, further studies incorporating female metal fabrication workers are required. Postural assessment was carried out using observation method (not immune to observer bias). It is proposed that future studies use other real time methods such as inclinometry and electromyography. Further, self-reported nature of the CMQ may be influenced by response and recall bias. The frequency of exercise was self-reported, so participants may have overstated their compliance of the prescribed program. The study should be repeated with a longer follow-up to confirm the findings and the long term effects.

4.6 Conclusion

Ergonomic training significantly reduced postural risks in the neck, shoulder and hand/wrists. Combined ergonomic training and stretch exercises are more effective in reducing pain severity in comparison to training alone.

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This chapter is organised into two sections. Section 6.2 presents the general conclusion of the study based on the study aims and objectives highlighted in chapter 1. Section 6.3 details the recommendations of this study based on the study findings and conclusion.

5.2 General conclusion

Based on the findings of this review, this study concluded that (a) prolonged working hours substantially contributed to the development of WRMDs, (b) there is a lack of studies implemented interventions to reduce the risk, prevalence rate and severity of WRMDs, and (c) the key methodological shortcomings of reviewed studies included the use of cross-sectional designs which makes it difficult to demonstrate temporality, use of small sample sizes, and a lack of statistical rigour.

Analyses showed a high prevalence and severity of pain in several body regions that included the lower back, right shoulder, left hand wrist and right hand wrist. The study showed that elevated grand REBA scores were significantly associated with self-reported pain in various body regions. The multinomial regression analyses showed that smoking, prolonged working hours and not engaging in physical activities were significant predictors for pain. High job satisfaction and taking adequate work - rest breaks were key protective factors for WRMDs. Conclusively, this study showed that there is a high prevalence of WRMDs among metal fabrication workers due to individual and work-related risk factors.

The study findings showed that an ergonomic training program was an effective intervention for reducing the risk for developing WRMDs among informal metal fabrication workers. Also the study demonstrated that stretch exercises combined ergonomic training significantly reduced the severity of the reported pain in most body regions.

5.3 Recommendations

Based on the study findings and conclusion, described in chapters three to six, the following are the recommendations of this study:

i. There is need for improved study designs that implement and evaluate interventions to reduce the risk, prevalence and severity of WRMD**s** among metal fabrication workers.
ii. Employers of metal fabrication workers should implement ergonomics education and ergonomic improvements to address the risk factors for and progression of WRMDs among metal fabrication workers. Engineering interventions such as installation of ergonomically designed workstations coupled with proper use could be helpful in reducing risk scores for the back region.
iii. Metal fabrication workers should engage in stretch exercises to reduce the prevalence and severity of WRMDs.
iv. Studies incorporating female participants are lacking which should be the focus of future research in other urban centres of Zimbabwe to ensure ergonomic concerns of female metal fabrication workers are taken care of.

CHAPTER 6: SYNTHESIS

6.1 Introduction

The informal sector employs more than 60% of low income's labour force (ILO, 2018). In Zimbabwe, for example the informal sector employs over 85% of the overall workforce with metal fabrication workers constituting a significant segment of this population (Uzhenyu, 2016). The informal metal fabrication sector produces construction, mining and domestic materials and equipment which makes it a critical industry in the Zimbabwe's labour market. Despite this importance, little attention has been put to address the occupational health concerns of informal metal fabrication workers which exposes them to occupational risk factors including those that cause or aggravate WRMDs.

To give light to WRMDs and ergonomic concerns of informal metal fabrication workers, a systematic review of literature to assess available evidence of potential ergonomic risk factors for WRMDs among metal fabrication workers was conducted. This was done to understand the global outlook of the problem and to see areas, settings, tools that have been used and the gaps for future studies. Five databases namely PubMed, EBSCO, Scopus, Taylor and Francis Online and Risk Abstracts were used to search for the eligible articles using the PRISMA guidelines (Moher et al., 2009). Methodological quality assessment and evidence synthesis was done using the 16 point Law et al. (1998) criteria. Basing on the findings of the literature review, a study to collect primary data on WRMDs and associated risk factors among informal sector metal fabrication workers in a low income setting was conducted. To assess the prevalence and severity of WRMDs among metal fabrication workers, the CMQ was used which is a widely used tool for assessing prevalence and severity of WRMDs in different settings. The CMQ was slightly modified to include individual and job-related factors. The REBA and QEC methods were used to assess postural and other ergonomic risk factors for WRMDs among metal fabrication workers. Since most published studies did not implement and assess interventions to reduce ergonomic risk factors and WRMDs prevalence and severity, a randomised control trial was conducted to assess the effects of ergonomics training on postural risk levels and the effects of combined ergonomic training and stretch exercise interventions on the prevalence and severity of WRMDs among metal fabrication workers in the informal sector. This was conducted to determine an intervention or combination of interventions that are effective in reducing WRMDs prevalence, severity and risk factors.

6.2 Ergonomics and WRMDs Status of Informal Metal Fabrication Workers in Zimbabwe

A study by Uzhenyu (2016) on the labour conditions of informal workers including metal fabrication workers in Zimbabwe highlighted that more than 85% lack OHS services. These services include training, inspection and enforcement of regulations and standards. Lack of the above mentioned services allows for the exposure of workers to a myriad of OHS risk factors. The situation is further worsened by lack of specific regulatory framework that cover the informal sector. The Zimbabwe's Occupational Health and Safety Policy (2014) states in its objectives that it endeavours to promote and maintain the highest possible level of occupational health and safety among workers in all the sectors of the economy. This policy has been subjected to the law making process and is now at the Bill stage. Provisions of the Bill cannot be enforced since it is not yet an Act. This means that informal sector workers will continue to be exposed to a myriad of OHS risk factors for as long as the Bill has not been enacted into law. Further, the main OHS law in Zimbabwe, the Factories and Works Act Chapter 14:08 does not recognise a premise with less than five employees as a factory. Most informal sector work stations have less than five workers which makes it difficult to enforce the regulations to premises which do not fit the definition of a factory under law. Results from the current study may assist policy makers with information necessary in the OHS law making process so that the ergonomic concerns of metal fabrication workers are taken into account thereby preventing the onset and aggravation of WRMDs. Studies assessing WRMDs and ergonomic risk factors have been conducted in India (Dev et al., 2018), Nigeria (Ajayeoba et al., 2016) and Japan, (Watanabe et al., 2018). Results indicate that WRMDs are prevalent and that workers are exposed to a plethora of ergonomic risk factors. No study has assessed the WRMDs and ergonomic concerns of metal fabrication workers in Zimbabwe.

6.3 Literature on Ergonomic Risks and WRMDs among Metal Fabrication Workers

Chapter 3 of the current study presents the findings of a review article based on the first aim of this study which has been published in the International Journal of Human Factors and Ergonomics. The results indicate that there is strong evidence of association between prolonged working hours and WRMDs. However inconclusive evidence was found on the contribution of awkward postures and other job-related factors with WRMDs. The study also found out that included studies did not assess or find the association between individual risk factors and WRMDs. Most of the included studies were conducted in formalised industries in middle and high income countries which show that risk factors and WRMDs are yet to be identified and mitigated in the informal sectors of low income countries such as Zimbabwe. Studies included in the literature review did not implement and assess the effects of interventions necessary for the prevention on WRMDs among metal fabrication workers which is a research gap that needs to be filled. Basing on these findings and recommendations presented in this chapter, a cross-sectional study aimed at assessing the prevalence, severity and risk factors for WRMDs among metal fabrication workers in the informal sector in three urban centres of Zimbabwe was undertaken which is presented as a full article in the Chapter 4 of the thesis. Further, since reviewed studies did not implement and assess the effects of interventions, Chapter 5 explored the effects of ergonomics training and stretch exercise interventions on WRMDs prevalence, severity and risk factors.

6.4 Prevalence, Severity and Risk Factors for WRMDs among Metal Fabrication Workers in Zimbabwe

The study was conducted in a resource constrained setting of Zimbabwe. Metal fabrication workers conducting their activities in the informal sector were selected as study participants. The study assessed the association of individual and job-related factors with WRMDs in different body regions. Results indicate a high prevalence and severity of pain in various body regions such as upper back, lower back, shoulders and wrists. The study found out that age, less education and smoking were individual factors significantly associated with WRMDs. Awkward working postures, prolonged working hours without breaks and high work pressure were job-related factors associated with WRMDs. Intervention studies to assess the effects of ergonomics training and stretch exercise intervention that have been assessed elsewhere were recommended (Shariat et al., 2017). Basing on the recommendations of this study, a randomised control trial study aimed at assessing the effect of ergonomics training and stretch exercise interventions on prevalence severity and risk factors for WRMDs among metal fabrication workers in the informal sector of three urban centres of Zimbabwe was undertaken which is presented as a full article in Chapter 5.

6.5 The Role of Interventions on WRMDs Prevalence, Severity and Risk Factors

Results indicate that ergonomics training significantly reduced ergonomic risks in the shoulder/arm, hand/wrist and arm. However there was a non-significant reduction of risk in the back region. Pain prevalence in the upper extremities was significantly reduced after training while pain prevalence was significantly reduced in most of the body regions in the stretch exercise group. Pain severity was significantly reduced in all the body regions in the combined ergonomics training and stretch exercise group. Conclusively, ergonomics training is required to reduce ergonomic risks and combined ergonomics training and stretch exercises are required to reduce WRMDs prevalence and severity among metal fabrication workers.

6.6 Direction for Future Research

Future studies should concentrate on

i. conducting long term studies such as cohort studies to assess the association between exposure (risk factors) and outcomes (WRMDs) among metal fabrication workers,
ii. assessing WRMDs among other informal sector workers such as carpenters, panel beaters and spray painters and mechanics,
iii. assessing the effects of ergonomic modifications such as adjustable work benches on WRMDs risk factors among metal fabrication workers,
iv. assessing risk factors using real time methods such as electromyography and WRMDs using doctor diagnosed information to prevent information and recall bias,
v. assessing WRMDs, risk factors and effects of interventions in bigger urban settings such Harare and Bulawayo.

6.7 Conclusion

Results on literature on WRMDs and ergonomics risk factors were explored as well as the gaps discovered in literature that need to be filled. Results on the primary data collected and analysed on WRMDs and associated risk factors are explained with recommendations for future research given. The chapter also presents the results of effects of interventions on risk factors and WRMDs among metal fabrication workers and lastly it gives direction for future research.

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APPENDICES

Appendix 1: Bindura University of Science Education Study Approval Letter

HDR/5

BINDURA UNIVERSITY OF SCIENCE EDUCATION

RESEARCH AND POSTGRADUATE CENTRE

APPLICATION FOR PROVISIONAL REGISTRATION

MASTER OF PHILOSOPHY/DOCTOR OF PHILOSOPHY STUDIES

Candidate	Mr. Elvis Chiboyiwa
Qualification:	• Bachelor of Environmental Science Honours Degree in Safety, Health and Environmental Management obtained from Bindura University of Science Education with a First Class Degree.
Degree Programme	Master of Philosophy in Occupational Health and Safety
Department / Faculty	Environmental Science, FAES
Proposed Research Topic	Occupational musculoskeletal disorders among informal welders in selected small towns of Zimbabwe.
Field of Study	Occupational Health and Safety
Proposed Supervisors	Principal Supervisor – Dr. France Ncube **(BUSE)** Co-Supervisor – Dr. Patience Erick **(University of Botswana)**
Mode of Study/Duration Commencement Year	Part-time /4 years /2018
RPGC Consideration	Recommended/ ~~Not Recommended~~ Signature......[signature]......Date 14/05/18
SENEX CHAIRMAN-VICE CHANCELLOR'S APPROVAL	Approved / ~~Not Approved~~ Signature......[signature]......Date 20/05/18

Appendix 2: Study Approval Letter from Bindura Municipality

MUNICIPALITY OF BINDURA

All Communications To
Be Addressed To The
TOWN CLERK
P O Box 15,
BINDURA

565 Thurlows Avenue
Bindura, Zimbabwe
Phone: 6430/9453/7591-5

Our ref: A1/0051
Your ref:

19 April 2018

Mr. E. Chiboyiwa

Bindura University of Science Education
P. Bag 1020
Bindura

Dear Madam

<u>RE: REQUEST FOR PERMISSION TO CARRY OUT A RESERCH PROJECT IN BINDURA URBAN TOWN</u>

Your application on the above dated 13 April 2018 refers.

We advise that permission has been granted for you to carry out occupational musculoskeletal disorders among informal welders.

Yours Faithfully

N. Machingauta
Chamber Secretary
For Town Clerk

Appendix 3: Study Approval Letter from Mutoko Rural District Council

DEPARTMENT OF ENVIRONMENTAL SCIENCE
P. Bag 1020 **BINDURA**, Zimbabwe

Tel: 263 - 71 – 6505
Cell :0772 773 560

Email : alzkanda@gmail.com

BINDURA UNIVERSITY OF SCIENCE EDUCATION

13 April 2018

District Administrator
Mutoko Rural Council
MUTOKO

Dear Sir/Madam

REQUEST FOR PERMISSION TO COLLECT DATA FOR ACADEMIC RESEARCH PROJECT

PROJECT TITLE*: PROJECT TITLE: OCCUPATIONAL MUSCULOSKELETAL DISORDERS AMONG INFORMANT WELDERS IN SELECTED SMALL TOWNS OF ZIMBABWE*

ACADEMIC SUPERVISORS: MR F. NCUBE AND DR. P. ERIC

This letter serves to inform you that **Chiboyiwa Elvis (Reg No. B1232698)** is an MPhil student at Bindura University of Science Education, in the Department of Environmental Science. During his study period he is supposed to do a research project in his area of specialisation.

Please assist in any possible way. Data collected will be used for academic purposes only and will not be published without your prior consent.

Thank you for your assistance.

Yours faithfully.

MUTOKO RURAL DISTRICT COUNCIL
CHIEF EXECUTIVE OFFICER
19 APR 2018
P. BAG 509, MUTOKO
TEL ... 592 888

CHAIRPERSON
Department Of Environmental Science
Faculty Of Agriculture And Environmental Science
Bindura University Of Science Education
P. BAG 1020 BINDURA
ZIMBABWE
OFFICIAL

DISTRICT ADMINISTRATOR
MUTOKO
19 APR 2018
P. O. BOX 61, MUTOKO
ZIMBABWE, TEL: 2874

…………….
Mr A. Kanda
CHAIRPERSON – DEPARTMENT OF ENVIRONMENTAL SCIENCE

Mr Chiboyiwa Elvis has been cleared to carry out the proposed research. May you assist him in every possible way

Appendix 4: Study Approval Letter from Mt Darwin Rural District Council

Corporate Vision
Be the best run and well managed local authority in Zimbabwe

PFURA RURAL DISTRICT COUNCIL

P.O Box 277
Mt Darwin

OFFICES:
Head Office
Stand No 1
Dotito Growth Point
MT DARWIN

All correspondences to be addressed to the Chief Executive Officer.
C.E.O: +263772700912
Hot line: +263773617250
Website: www.pfurardc.org
Email:pfurardc1@gmail.com
Email: info@pfurardc.org
Facebook: Pfura Rural District Council
Twitter: @PfuraRDC
Instagram: Pfura Rural District Council

OUR REF: XC/155/BLD7

06 /06/2018

MR CHIBOYIWA ELVIS

RE: AUTHORITY TO CARRY OUT A STUDY IN PFURA RURAL DISTRICT COUNCIL.

Your letter dated 29 March 2018 refers,

You are being granted authority to carry out the study as requested. We will be grateful if you give us a copy of your research study. We wish you the best in your research study.

pp! [signature]

Yours faithfully

L. JAKATA
FOR CHIEF EXECUTIVE OFFICER

PFURA RURAL DISTRICT COUNCIL
-6 JUN 2018
Re: -6 JUN 2018
Ref:xc/iss/.........class code.........
P.O. BOX 277, MT. DARWIN

SUB – OFFICES

No 1
Mt Darwin Urban
Mt Darwin

No. 5 Kamutsenzere Business Centre
Kamutsenzere
Lower Mt Darwin

No. 1 Mukumbura Business Centre
Mukumbura
Lower Mt Darwin

Appendix 5: Attendance Register: Bindura Ergonomics Training Workshop

Name	Gender	Stand No.
Mainoti D	M	38
Mainoti C	M	38
Choruma P	M	4
Mukandi T	M	30
Kaseke K	M	30
Karumazondo P	M	30
Jonasi M	M	30
Karima E	M	29
John M	M	16
Murambiwa P	M	16
Chitabura L	M	17
Chitabura D	M	17
Muredzi c	M	18
Mutekedzi C	M	17
Machocho R	M	28A
Pfidza G	M	43
Musandivirire G	M	54
Nyamanzi M	M	45
Mukonowenda A	M	53
Katembaringa S	M	52
Chitabura N	M	51
Chinguku Z	M	49
Gwenzi P	M	64
Kasango M	M	57
Chivero C	M	59
Mabheka P	M	10
Murombo G	M	9
Makovare F	M	8
Masunda E	M	66
Kanyemba P	M	67
Muropa L	M	4
Namulela M	M	4
Dula S	M	69
Dique E	M	76
Muchemwa S	M	5
Mafunga M	M	70
Kajawo M	M	2
Takaendesa S	M	76
Chochera C	M	76
Mpango J	M	77
Ticha T	M	2
Musarurwa A	M	2
Dodo T	M	3
Elias T	M	43
Jabulani M	M	6A
Mafunga G	M	4

Muchemwa P	M	5A
Mubaiwa C	M	5B
Sakupwanya D	M	19
Murombo P	M	12
Kandiero Z	M	13
Musona W	M	16
Musona V	M	16
Mashingaodze W	M	12
Chichiri S	M	13
Chimedza N	M	18
Mudonhi B	M	6B
Muchenje C	M	6B
Murerwa O	M	21A
Bamusi E	M	20
Tandi C	M	30
Murandu Z	M	40
Murandu C	M	40
Shivambu S	M	40
Mnatsa R	M	42

Appendix 6: Attendance Register: Mt Darwin Ergonomics Training Workshop

Name	Gender	Stand No.
Jaji P	M	2
Chiswiti M	M	4A
Chinyani L	M	4B
Makamba O	M	8
Mashanda B	M	6
Pasimupindu A	M	7A
Dandamera B	M	8
Mutasa L	M	9
Munyuki C	M	10
Munyuki C	M	10
Munyuki C	M	10
Muradzikwa C	M	23
Bandera K	M	19
Munyongani M	M	20A
Musekiwa L	M	20A
Sanderson T	M	29
Gumbeze K	M	30
Marimira S	M	11A
Marimira S	M	11A
Marimira S	M	11A
Munaki C	M	15
Kazembe H	M	21
John B	M	22
Banda Z	M	28
Marinda T	M	29
Phiri L	M	16
Phiri G	M	16
Phiri A	M	16
Kamudyariwa E	M	19A
Machinga W	M	21
Muza F	M	18
Mudzengerere C	M	6
Mudzengerere D	M	6
Madamombe N	M	7
Knight A	M	6
Chigwerewe M	M	18
Chibanda P	M	19A
Nyamanzi R	M	8
Nyamanzi C	M	8
Mukurugado N	M	7
Chari S	M	4
Yemurai C	M	28
Zvoradza N	M	28
Maeresera P	M	25

Appendix 7: Rapid Entire Body Assessment (REBA) Worksheet

ERGONOMICS PLUS

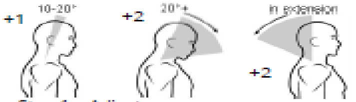
REBA Employee Assessment Worksheet

Task Name:

Date:

A. Neck, Trunk and Leg Analysis

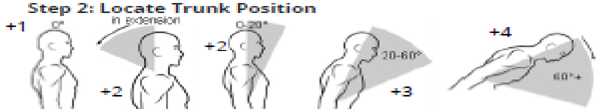
Step 1: Locate Neck Position



Neck Score

Step 1a: Adjust…
If neck is twisted: +1
If neck is side bending: +1

Step 2: Locate Trunk Position



Step 2a: Adjust…
If trunk is twisted: +1
If trunk is side bending: +1

Trunk Score

Step 3: Legs

Leg Score

Step 4: Look-up Posture Score in Table A
Using values from steps 1-3 above,
Locate score in Table A

Posture Score A

+

Step 5: Add Force/Load Score
If load < 11 lbs. : +0
If load 11 to 22 lbs. : +1
If load > 22 lbs.: +2
Adjust: If shock or rapid build up of force: add +1

Force / Load Score

=

Step 6: Score A, Find Row in Table C
Add values from steps 4 & 5 to obtain Score A.
Find Row in **Table C**.

Score A

Scoring
1 = Negligible Risk
2-3 = Low Risk. Change may be needed.
4-7 = Medium Risk. Further Investigate. Change Soon.
8-10 = High Risk. Investigate and Implement Change
11+ = Very High Risk. Implement Change

Scores

Table A		Neck 1				Neck 2				Neck 3			
	Legs	1	2	3	4	1	2	3	4	1	2	3	4
Trunk Posture Score	1	1	2	3	4	1	2	3	4	3	3	5	6
	2	2	3	4	5	3	4	5	6	4	5	6	7
	3	2	4	5	6	4	5	6	7	5	6	7	8
	4	3	5	6	7	5	6	7	8	6	7	8	9
	5	4	6	7	8	6	7	8	9	7	8	9	9

Table B		Lower Arm 1			Lower Arm 2		
	Wrist	1	2	3	1	2	3
Upper Arm Score	1	1	2	2	1	2	3
	2	1	2	3	2	3	4
	3	3	4	5	4	5	5
	4	4	5	5	5	6	7
	5	6	7	8	7	8	8
	6	7	8	8	8	9	9

Table C

Score A	Score B 1	2	3	4	5	6	7	8	9	10	11	12
1	1	1	1	2	3	3	4	5	6	7	7	7
2	1	2	2	3	4	4	5	6	6	7	7	8
3	2	3	3	3	4	5	6	7	7	8	8	8
4	3	4	4	4	5	6	7	8	8	9	9	9
5	4	4	4	5	6	7	8	8	9	9	9	9
6	6	6	6	7	8	8	9	9	10	10	10	10
7	7	7	7	8	9	9	9	10	10	11	11	11
8	8	8	8	9	10	10	10	10	10	11	11	11
9	9	9	9	10	10	10	11	11	11	12	12	12
10	10	10	10	11	11	11	11	12	12	12	12	12
11	11	11	11	11	12	12	12	12	12	12	12	12
12	12	12	12	12	12	12	12	12	12	12	12	12

Table C Score + Activity Score = REBA Score

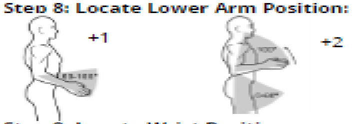
B. Arm and Wrist Analysis

Step 7: Locate Upper Arm Position:

Step 7a: Adjust…
If shoulder is raised: +1
If upper arm is abducted: +1
If arm is supported or person is leaning: -1

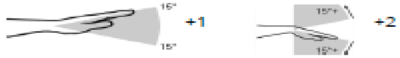
Upper Arm Score

Step 8: Locate Lower Arm Position:



Lower Arm Score

Step 9: Locate Wrist Position:



Wrist Score

Step 9a: Adjust…
If wrist is bent from midline or twisted : Add +1

Step 10: Look-up Posture Score in Table B
Using values from steps 7-9 above, locate score in Table B

Posture Score B

+

Step 11: Add Coupling Score
Well fitting Handle and mid rang power grip, ***good: +0***
Acceptable but not ideal hand hold or coupling acceptable with another body part, ***fair: +1***
Hand hold not acceptable but possible, ***poor: +2***
No handles, awkward, unsafe with any body part, ***Unacceptable: +3***

Coupling Score

=

Step 12: Score B, Find Column in Table C
Add values from steps 10 &11 to obtain Score B. Find column in **Table C** and match with Score A in row from step 6 to obtain Table C Score.

Score B

Step 13: Activity Score
+1 1 or more body parts are held for longer than 1 minute (static)
+1 Repeated small range actions (more than 4x per minute)
+1 Action causes rapid large range changes in postures or unstable base

Original Worksheet Developed by Dr. Alan Hedge. Based on Technical note: Rapid Entire Body Assessment (REBA), Hignett, McAtamney, Applied Ergonomics 31 (2000) 201-205

Appendix 8: Quick Exposure Check (Qec) Worksheet

Worker's name ____________________ Date ____________

Observer's Assessment

Back

A When performing the task, is the back
(select worse case situation)

- A1 Almost neutral?
- A2 Moderately flexed or twisted or side bent?
- A3 Excessively flexed or twisted or side bent?

B Select ONLY ONE of the two following task options:

EITHER

For seated or standing stationary tasks. Does the back remain in a static position most of the time?

- B1 No
- B2 Yes

OR

For lifting, pushing/pulling and carrying tasks (i.e. moving a load). Is the movement of the back

- B3 Infrequent (around 3 times per minute or less)?
- B4 Frequent (around 8 times per minute)?
- B5 Very frequent (around 12 times per minute or more)?

Shoulder/Arm

C When the task is performed, are the hands
(select worse case situation)

- C1 At or below waist height?
- C2 At about chest height?
- C3 At or above shoulder height?

D Is the shoulder/arm movement

- D1 Infrequent (some intermittent movement)?
- D2 Frequent (regular movement with some pauses)?
- D3 Very frequent (almost continuous movement)?

Wrist/Hand

E Is the task performed with
(select worse case situation)

- E1 An almost straight wrist?
- E2 A deviated or bent wrist?

F Are similar motion patterns repeated

- F1 10 times per minute or less?
- F2 11 to 20 times per minute?
- F3 More than 20 times per minute?

Neck

G When performing the task, is the head/neck bent or twisted?

- G1 No
- G2 Yes, occasionally
- G3 Yes, continuously

Worker's Assessment

Workers

H Is the maximum weight handled MANUALLY BY YOU in this task?

- H1 Light (5 kg or less)
- H2 Moderate (6 to 10 kg)
- H3 Heavy (11 to 20kg)
- H4 Very heavy (more than 20 kg)

J On average, how much time do you spend per day on this task?

- J1 Less than 2 hours
- J2 2 to 4 hours
- J3 More than 4 hours

K When performing this task, is the maximum force level exerted by one hand?

- K1 Low (e.g. less than 1 kg)
- K2 Medium (e.g. 1 to 4 kg)
- K3 High (e.g. more than 4 kg)

L Is the visual demand of this task

- L1 Low (almost no need to view fine details)?
- *L2 High (need to view some fine details)?

* *If High, please give details in the box below*

M At work do you drive a vehicle for

- M1 Less than one hour per day or Never?
- M2 Between 1 and 4 hours per day?
- M3 More than 4 hours per day?

N At work do you use vibrating tools for

- N1 Less than one hour per day or Never?
- N2 Between 1 and 4 hours per day?
- N3 More than 4 hours per day?

P Do you have difficulty keeping up with this work?

- P1 Never
- P2 Sometimes
- *P3 Often

* *If Often, please give details in the box below*

Q In general, how do you find this job

- Q1 Not at all stressful?
- Q2 Mildly stressful?
- *Q3 Moderately stressful?
- *Q4 Very stressful?

* *If Moderately or Very, please give details in the box below*

* *Additional details for L, P and Q if appropriate*

* **L**

* **P**

* **Q**

Exposure Scores Worker's name ______________________ Date ____________

Back

Back Posture (A) **& Weight** (H)

	A1	A2	A3
H1	2	4	6
H2	4	6	8
H3	6	8	10
H4	8	10	12

☐ Score 1

Back Posture (A) **& Duration** (J)

	A1	A2	A3
J1	2	4	6
J2	4	6	8
J3	6	8	10

☐ Score 2

Duration (J) **& Weight** (H)

	J1	J2	J3
H1	2	4	6
H2	4	6	8
H3	6	8	10
H4	8	10	12

☐ Score 3

Now do **ONLY** 4 if static
OR 5 and 6 if manual handling

Static Posture (B) **& Duration** (J)

	B1	B2
J1	2	4
J2	4	6
J3	6	8

☐ Score 4

Frequency (B) **& Weight** (H)

	B3	B4	B5
H1	2	4	6
H2	4	6	8
H3	6	8	10
H4	8	10	12

☐ Score5

Frequency (B) **& Duration** (J)

	B3	B4	B5
J1			6
J2			8
J3			10

☐ Score 6

Total score for Back
Sum of scores 1 to 4 **OR**
Scores 1 to 3 plus 5 and 6 ______

Shoulder/Arm

Height (C) **& Weight** (H)

	C1	C2	C3
H1	2	4	6
H2	4	6	8
H3	6	8	10
H4	8	10	12

☐ Score 1

Height (C) **& Duration** (J)

	C1	C2	C3
J1	2	4	6
J2	4	6	8
J3	6	8	10

☐ Score 2

Duration (J) **& Weight** (H)

	J1	J2	J3
H1	2	4	6
H2	4	6	8
H3	6	8	10
H4	8	10	12

☐ Score 3

Frequency (D) **& Weight** (H)

	D1	D2	D3
H1	2	4	6
H2	4	6	8
H3	6	8	10
H4	8	10	12

☐ Score 4

Frequency (D) **& Duration** (J)

	D1	D2	D3
J1	2	4	6
J2	4	6	8
J3	6	8	10

☐ Score 5

Total score for Shoulder/Arm
Sum of Scores 1 to 5 ______

Wrist/Hand

Repeated Motion (F) **& Force** (K)

	F1	F2	F3
K1	2	4	6
K2	4	6	8
K3	6	8	10

☐ Score 1

Repeated Motion (F) **& Duration** (J)

	F1	F2	F3
J1	2	4	6
J2	4	6	8
J3	6	8	10

☐ Score 2

Duration (J) **& Force** (K)

	J1	J2	J3
K1	2	4	6
K2	4	6	8
K3	6	8	10

☐ Score 3

Wrist Posture (E) **& Force** (K)

	E1	E2
K1	2	4
K2	4	6
K3	6	8

☐ Score 4

Wrist Posture (E) **& Duration** (J)

	E1	E2
J1	2	4
J2	4	6
J3	6	8

☐ Score 5

Total score for Wrist/Hand
Sum of Scores 1 to 5 ______

Neck

Neck Posture (G) **& Duration** (J)

	G1	G2	G3
J1	2	4	6
J2	4	6	8
J3	6	8	10

☐ Score 1

Visual Demand (L) **& Duration** (J)

	L1	L2
J1	2	4
J2	4	6
J3	6	8

☐ Score 2

Total score for Neck
Sum of Scores 1 to 2 ______

Driving

M1	M2	M3
1	4	9

Total for Driving ______

Vibration

N1	N2	N3
1	4	9

Total for Vibration ______

Work pace

P1	P2	P3
1	4	9

Total for Work pace ______

Stress

Q1	Q2	Q3	Q4
1	4	9	16

Total for Stress ______

Appendix 9: Modified Cornell Musculoskeletal Discomfort Questionnaire (MCMDQ).

Dear participant

My kind greetings. My name is Elvis Chiboyiwa. I am a student at Bindura University of Science Education. You are kindly invited to take part in this participatory study on work-related musculoskeletal disorders (WRMDs) among metal fabrication workers in the informal sector.

Please assist me by filling in the questionnaire below. It is not required of you to put down your name on this questionnaire. Your participation is completely voluntary and you can withdraw at any time without penalty. All data is completely confidential. There are no risks associated with participating in this study. Moreso there are no monetary benefits associated with participating in this study. For further consultation, you may contact my principal supervisor Dr F. Ncube on Cell: +263772654637 and his email is france.ncube257@gmail.com. My contact number is +26377557223l and my email address is: elvischiboyiwa@gmail.com.

Questionnaire Number..

Instructions

- Please fill in the spaces provided.
- Select one response by putting an X in the appropriate box.
- Please explain in short words where you are required to do so.

DATE………………………………

Part 1: Demographic Information

1. Gender: Male: ☐ Female ☐
2. Age …………………………...
3. Height:………………………...
4. Weight:………………………..
5. Marital Status: Married: ☐ Single ☐ Divorced ☐ Separated ☐
6. Highest Academic/ Professional Qualifications Achieved……………………………….......
7. Do you smoke: Yes ☐ No ☐
8. Do you engage in other physical activities like sport: Yes ☐ No ☐
9. If yes please state physical activities that you engage in…………………………………..

Part 2: Information on work activities

10. How long have you been working as a metal fabrication?...
11. How many hours do you work per day?..
12. How many hours do you work per week………………………………………………
13. What position do you mostly adopt while metal fabrication?

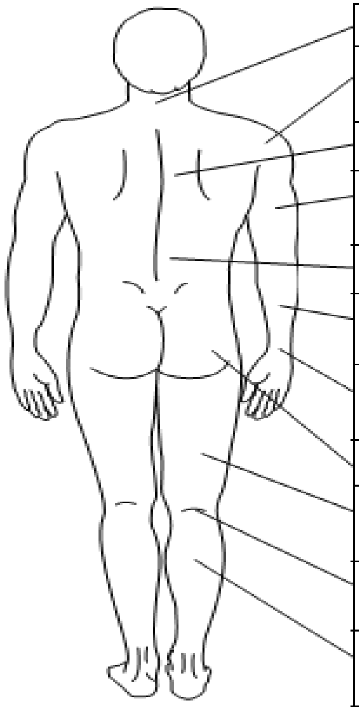
i. Standing: Yes ☐ No ☐
ii. Stooping: Yes ☐ No ☐
iii. Bending: Yes ☐ No ☐
iv. Kneeling: Yes ☐ No ☐
v. Sitting: Yes ☐ No ☐

14.Other...
15. What is the average weight you manually lift per day at your work?..................................
16. How often do you break from work per day……………………………………………..
17. Do you find your work being monotonous………………………………………………
☐

18. Perceived working pressure: Low Moderate ☐ Too Much ☐
19. Job satisfaction: Low ☐ Moderate ☐ Too Much ☐
20. Do you use any lifting equipment: Yes ☐ No ☐

Prevalence and severity of WRMDs

The diagram below shows the approximate position of the body parts referred to in the questionnaire. Please answer by marking the appropriate box.



		During the last work week how often did you experience ache, pain, discomfort in:					If you experienced ache, pain, discomfort, how uncomfortable was this?			If you experienced ache, pain, discomfort, did this interfere with your ability to work?		
		Never	1-2 times last week	3-4 times last week	Once every day	Several times every day	Slightly uncomfortable	Moderately uncomfortable	Very uncomfortable	Not at all	Slightly interfered	Substantially interfered
Neck		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Shoulder	(Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Upper Back		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Upper Arm	(Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Lower Back		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Forearm	(Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Wrist	(Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Hip/Buttocks		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Thigh	(Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Knee	(Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Lower Leg	(Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Appendix 10: Corlett and Bishop Body Map Questionnaire (CBBMQ)

Instructions to participants:

1. Kindly rate your body region discomfort by ticking below the applicable score on the scale 0–5.
2. Please note that a zero (0) denotes no discomfort and a five (5) denotes very severe discomfort.

	Scale (0-5)					
Body region	0	1	2	3	4	5
Neck						
Right shoulder						
Left shoulder						
Upper back						
Right upper arm						
Left upper arm						
Lower back						
Right forearm						
Left forearm						
Right hand/wrist						
Left hand/wrist						
Hip/buttock						
Right thigh						
Left thigh						
Right knee						
Left knee						
Right lower leg						
Left lower leg						