Development of an Evidence-Based Framework for the Prevention and Management of Musculoskeletal Disorders in South Africa

BY

ELRICO DE BRUYN

(ORCID 0000-0002-8093-5687)

THESIS

A thesis submitted in fulfilment of the requirements for the Degree of Master of Science

Department of Human Kinetics and Ergonomics

Rhodes University, 2023

Makhanda, South Africa

ABSTRACT

Background: Musculoskeletal Disorders (MSDs) are multi-causal soft tissue disorders that result in disability, discomfort, and pain. MSDs are prevalent in 21.5% of the world's population and carry a great financial and personal burden to individuals, businesses and countries alike. The multi-casual nature of MSDs has resulted in a vast amount of literature being published on how to prevent and manage the disorders, to the extent that navigating through the literature to find effective and context-specific interventions has become time-consuming and difficult. This is the case in South Africa, where ergonomists have no guide or framework to navigate MSD literature, and context-specific literature is limited.

Aims: This study aimed to assist ergonomists in South Africa navigate the MSD literature to identify and select appropriate MSD prevention and management interventions. To do so, three objectives of the study were identified:

1. Review MSD literature to identify effective MSD prevention and management interventions.

2. Create a framework to act as a guide for ergonomists to navigate MSD prevention and management studies.

3. To verify the suitability of the framework in the South African context

To achieve these objectives, the study took a two-phased approach.

Phase 1: A scoping review of MSD literature was conducted to identify effective MSD prevention and management approaches. Sixteen (n=16) prevention strategies and fourteen (n=14) management strategies were identified. The information from the review was analysed and grouped into five hierarchical levels of interventions ("Law", "Organisational Policies", "Management Systems", Workplace Interventions", and "Individual"). This information, along with a conceptual model created for the navigation of the literature, was used to create a draft framework for musculoskeletal disorder prevention and management. It was concluded that although there were many effective MSD interventions, there was a lack of South African-specific literature.

Phase 2: Interviews with five certified ergonomists working in the South African context were conducted to verify the framework's suitability for a South African working environment. The interviews identified two MSD prevention and three MSD management themes as effective in South Africa. Both prevention themes ("training and education" and "workplace interventions") were also mentioned to be part of the stakeholders' ideal MSD prevention programme, further reinforcing their usefulness. The use of "workplace interventions" was also identified to be effective in MSD management, alongside interventions at the management level and the use of alternative tools and equipment. However, the lack of managerial buy-in was identified as a barrier to MSD prevention. Stakeholders also highlighted that job specification and work hardening was an MSD strategy missing from the framework that was effective in South Africa's MSD management. The use of surveillance practices was found to be ineffective in South Africa, with lots of resistance towards it from workers.

Conclusion: The framework presented in Phase 1 identified many effective MSD interventions; however, only a few were found to be applicable to the South African working context during Phase 2. Future research should focus on identifying the success of different MSD interventions in South Africa with participation from the ergonomists involved in the implementation to create an even more suitable guide that matches the South African ergonomist's needs.

ACKNOWLEDGEMENTS

Thank you, my Lord, for giving me the previsions, patience, and persistence to write this thesis. You are my rock; you prepare my hands for war and fingers for battle (Psalms 144:1).

A massive THANK YOU to Mrs Miriam Mattison, I cannot express how grateful I am to you for undertaking this task with me. Thank you for your patience and guidance and especially for all the long meetings and discussions. Most importantly, thank you for pushing me to beyond my limits, I am forever better for it!

My sincere thanks to the rest of the Human Kinetics and Ergonomics staff, Andrew, Candice, Jono, Swantje and June. Your willingness to assist where needed will always be remembered.

A special thanks to Luke “life is” Goodenough (sorry, I had to do it) and Chris Maher for keeping me sane.

I am deeply indebted to and thankful to my parents and brother. Mama en Papa ek is baie lief vir julle en al die opofferings wat julle vir my gemaak het.

Kayla, my love, thank you for your understanding, willingness to delay dates and for listening to my frustrations and complaints through my whole Masters journey.
I love you!

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

CHAPTER I:
INTRODUCTION

1.1 Musculoskeletal Disorders

Musculoskeletal disorders (MSDs) are conditions that affect the soft tissues of the body (muscles, tendons, ligaments, bursae, blood vessels, and nerves), resulting in a variety of signs and symptoms, including discomfort, numbness, and pain in severe cases (Caroly et al., 2010; HSENI & HSA, 2013). MSDs have multiple causal pathways and include biomechanical, psychosocial, and organisational risk factors which, in combination, contribute to the development of adverse physical conditions (Caroly et al., 2010; Ferreira & Strydom, 2016; Noonan & Wagner, 2010). The wide range of MSDs means that multiple parts of the human body may be affected, such as upper and lower extremity disorders and lower back pain (Caroly et al., 2010; Noonan & Wagner, 2010).

MSDs plague workers worldwide, with an estimated 1.71 billion people suffering from MSDs, which amounts to around 21.5% of people on Earth (Cieza et al., 2020). Prevalence studies in Australia, Canada, Malaysia and the United States have all shown gradual increases in MSDs with age and increased working time under conditions with high MSD risks (Siddharthan et al., 2006; WHO Scientific Group, 2003; Woolf & Pfleger, 2003). Surveys conducted in developed countries on the prevalence rates of MSDs, irrespective of the body region, found that they range from 40%-95% (Alias et al., 2020; Bonini-Rocha et al., 2021; Erick & Smith, 2015; Moom et al., 2015).

The high prevalence of these disorders costs individuals, businesses and the public millions of dollars in treatment, loss of production and compensation payments (WHO Scientific Group on the Burden of Musculoskeletal Conditions at the Start of the New Millennium [WHO Scientific Group], 2003; Woolf & Pfleger, 2003). The cost of having such a high proportion of the workforce suffering from MSDs places a significant financial burden on businesses and, therefore, the economy. For example, the treatment of MSDs has been found to cost between 0.7%-1.2% of economically developed nations' Gross Domestic Product (GDP) (Eggers, 2016; Ferreira & Strydom, 2016; Woolf & Pfleger, 2003). There are also substantial costs associated with compensation claims, training, lost productivity

and lost wages, which cannot be directly measured. A study on Canadian and Australian MSD burdens found that MSD-related symptoms resulted in an estimated loss of work time of 239 345 years, with similar trends being found in Taiwan and Hong Kong (Ferreira & Strydom, 2016; Howarth et al., 2016; Nyawose & Naidoo, 2019; Panel on Musculoskeletal Disorders and the Workplace [Panel on MSD and WP], 2001).

The research into MSD prevalence in South Africa is limited, possibly due to the large proportion of communicable and non-communicable diseases (NCDs) being a more serious concern to the local healthcare system due to their mortality rates. Eggers (2016) and Mody & Brooks (2012) both noted the impact of such diseases on the research focus on MSDs, and it can therefore be inferred that South Africa's quadruple burden of disease (NCDs, HIV, TB and trauma) has placed constraints on MSD research (Farham, 2020). There is also no reporting system on MSDs in South Africa, further decreasing the availability of statistics on these disorders. However, the limited MSD research available in South Africa has found similar trends in the prevalence of MSDs to those of other nations. For example, 69.8%-77.8% of dentists in South Africa reported MSDs that lasted over 12 months (Botha et al., 2014), and a systematic review of the prevalence of MSDs in dentists found that up to 15% of people had to reduce working hours or cease working completely to get relief (Moodley et al., 2018). A study on MSD prevalence in schoolteachers showed the upper limb MSD prevalence in South Africa to be 83.1%, compared with Hong Kong (73.4%), Taiwan (63.4%), Japan (35.4%) and Malaysia (60.1%) (Nyawose & Naidoo, 2019). Furthermore, a study by the WHO Scientific Group (2003) on the lifetime prevalence of MSDs indicated that MSD prevalence trends in South African dentists (69%) and teachers (83.1%) fell into the upper range of MSD prevalence (range: 60%-85%). This finding was further supported by research by Nyantumbu-Mkhize (2017), in which 80.5% of bankers and nurses reported MSD-related pain, with 56.9% being classified as lower back pain. This suggests that South African MSD prevalence is similar, if not worse, than those of developed nations (Moodley et al., 2018; Nyawose & Naidoo, 2019).

If one were to infer the same proportion of MSD-related costs as that of more industrialised countries (i.e., 0.7%-2.1% of GDP), the cost of MSDs in South Africa would range between $2.1 and $3.6 billion using the countries 2020 GDP (Eggers,

2016; Ferreira & Strydom, 2016; Woolf & Pfleger, 2003). However, this is only the direct cost associated with MSDs. Since South Africa is a less economically developed nation with an already overburdened healthcare sector, the prevalence rate of MSDs is expected to be higher, which in turn may lead to increased associated direct and, more notably, indirect costs (Caple, 2012; Lanfranchi & Duveau, 2008; WHO Scientific Group, 2003).

1.2 MSD Interventions

MSDs are multi-causal in their development; hence they require a multi-pronged intervention approach (Oakman et al., 2022; Weale et al., 2022). A multifactorial approach allows for preventive measures to be implemented before unwanted outcomes, such as MSDs, can emerge in the workplace. However, it would be naive to assume that risks can continually be mitigated before unfavourable outcomes are experienced, especially due to the multi-causal development pathways of MSDs. It is, therefore, equally important to acknowledge the role of symptom management and work adjustments after unfavourable outcomes have emerged. “MSD prevention” thus focuses on reducing risk and implementing controls before these disorders occurring, while “MSD management” aims to prevent the aggravation of MSDs once they have occurred to decrease symptoms and reduce the disorders’ impact on the individual and their work performance (Wells, 2009; Yazdani & Wells, 2018).

Most MSD intervention approaches take a form similar to that laid out by Denis et al. (2008), where an analysis of the workplace is conducted, the potential risks are identified, and appropriate controls are developed and implemented. A review of the literature indicated that most interventions used a combination of these steps (or similar) to plan and implement an intervention (Denis et al., 2008). The same study found the larger the scopes of the intervention, the more likely they were to use the ideal version of the intervention process (Denis et al., 2008). The intervention of MSDs is not easy, with countless studies finding barriers to effective interventions. In a systematic review of the barriers and facilitators of MSD intervention, Weale et al. (2022) identified several organisational and individual challenges that needed to be overcome for successful MSD mitigation. Currently, MSD interventions are primarily focused on physiological health at the level of the

individual doing the work, with South African literature pointing towards interventions aimed at individual-task interactions (Ferreira & Strydom, 2016; Richardson et al., 2018). Researchers are calling for more multifaceted approaches to MSD intervention, as traditional biomechanical interventions have been ineffective (Boocock et al., 2007). Instead, interventions that focus on all aspects of work may help reduce overall risk by incorporating multiple single interventions into one approach (Boocock et al., 2007; Oakman et al., 2022; Weale et al., 2022).

Irrespective of whether MSDs need prevention or management, practitioners need to find the most suitable interventions for the MSD(s) they wish to prevent or mitigate while considering the context in which the MSD occurs. However, the sheer number of MSD prevention and management interventions available in the literature complicates the selection of MSD interventions suitable for the context in which they will be implemented. In South Africa, the situation is further convoluted by the lack of context-specific statistical evidence since Human Factors and Ergonomics (HFE) is still a relatively new disciple.

Since the “Ergonomics Regulations” were gazetted in 2019 as part of the Occupational Health and Safety Act of 1993, there has been an increased drive among employers to comply with these new ergonomics requirements (Department of Employment and Labour, 2019). The eleven regulations aim to increase the application of HFE within South African workplaces to benefit both workers and companies. Since the discipline is still relatively new in South Africa, with the Ergonomics Society of South Africa only being formed in 1985, there are only a limited number of practising ergonomists available (Ergonomics Society of South Africa, 2022b). The Ergonomics Regulations stipulate that it is the responsibility of employers to assess and control risk, survey the medical situations of employees, and set a system of record keeping and controls in place (Department of Employment and Labour, 2019). This ensures that businesses and the work conducted match the capabilities of the employees performing them (Department of Employment and Labour, 2019). When the age of the discipline and the regulations are taken into account with the fact that there are only a limited number of practising ergonomists in South Africa, the need to be selective of which problems to focus on, as well as the need to be efficient, becomes evident

(Ergonomics Society of South Africa, 2022a). As the Ergonomics Regulations specifically state risk mitigation as one of its aims, businesses are under pressure to comply and intervene, with MSDs being one of the problems that risk mitigation can tackle. This further increases the pressure on the limited number of ergonomists to meet the demands of their employers while reducing costs and time taken.

1.3 Statement of the Problem

Musculoskeletal disorders are a prevalent and costly global problem. Although there is a lack of statistical evidence, a few studies together with anecdotal evidence suggest that a similar problem may be present in South Africa. Although causal factors and intervention strategies have been well studied, the vast amount of literature on MSD interventions is challenging to navigate, even for ergonomics practitioners who must search for and identify effective MSD interventions specific to their context. This is especially true in countries like South Africa, where ergonomics practitioners are still trying to grow the discipline, using limited context-specific knowledge. The lack of context-specific studies and the vast literature may present a barrier to finding and implementing effective MSD prevention and management strategies. As such, the high cost of these disorders and the challenging literature navigation pose a unique problem for South African ergonomists. This is especially the case when ergonomists are trying to meet the demands of businesses that are only trying to comply with the Ergonomics Regulations. In South Africa, ergonomists have no guide or framework to prevent and manage MSDs, which may make it difficult for them to meet the demands of their clients and mitigate the costs associated with the high prevalence of MSDs across sectors of the economy.

1.4 Purpose of the Study

This study aimed to assist ergonomists in South Africa navigate the MSD literature to identify and select appropriate MSD prevention and management interventions. To do so, three objectives of the study were identified.

1. Review the MSD literature to identify effective MSD prevention and management interventions,

2. Create a framework to act as a guide for ergonomists to navigate MSD prevention and management studies,

3. To verify the suitability of the framework in the South African context.

These three objectives were executed in a 2-phase approach, where objectives one and two were achieved in phase 1 through a scoping review (chapter III). Phase 2 addressed objective three through interviews with key stakeholders in South Africa (chapter IV).

CHAPTER II:
REVIEW OF LITERATURE

MSDs are conditions that affect the body's soft tissues, such as tendons, muscles and ligaments (Caroly et al., 2010; Ferreira & Strydom, 2016; HSENI & HSA, 2013; Noonan & Wagner, 2010). These disorders can affect individuals at work, during leisure activities and even during activities of daily living, and can bring bouts of tenderness, numbness and pain in the affected regions, such as tendonitis, hand-arm vibration syndrome and peripheral neuropathy, to name a few (Morse et al., 2004; Punnett & Wegman, 2004; WHO Scientific Group, 2003). MSDs can affect the lower back (presented as specific and non-specific lower back pain [LBP]), the upper limbs or extremities (UL-MSDs) and the lower limbs or extremities (LL-MSD) (Punnett & Wegman, 2004; WHO Scientific Group, 2003). The large scope of MSD types and affected regions make MSD treatment costly and difficult. MSDs not only carry a personal cost to the individual seeking treatment but also create an economic burden on the employers of these individuals and the overall economy of the governments where they reside.

2.1 Prevalence of MSDs

It is estimated that worldwide, MSDs account for 40% of all occupational disorders, affecting activities of daily living, potentially leading to long-term disability (54% of all MSD cases) and early retirement (Ferreira & Strydom, 2016; Woolf & Pfleger, 2003). Some disorders, such as low back pain (LBP), have higher incidence rates and, as such, are often reported on separately from other MSDs. The Global Burden of Disease Study 2019 found that LBP was ranked in the top ten of prevalent diseases in adults aged between 25-49 years (ranked fourth) and 50-74 years (ranked sixth), with all other MSDs being ranked eighth and eleventh for adults between 25-49 years and 50-74 years respectively. Furthermore, the prevalence of other MSDs increased between 1990 and 2019 (Abbafati et al., 2020; Cieza et al., 2020). These two categories of MSDs (LBP and other miscellaneous MSDs) are only surpassed in the global rankings by non-communicable diseases, injuries from road accidents and HIV, all of which carry a higher risk of mortality and are thus prioritised over conditions that merely impact morbidity (Vos et al., 2020). The high prevalence of MSDs in people aged 25-74

indicates a need for workplace intervention. (Stubbs et al., 2016; Vos et al., 2020; WHO Scientific Group, 2003).

In 1999, it was found that 85% of workers in the United States had experienced symptoms or injuries related to work, and an average of 30% of workers reported that it affected how they worked, including the quality and speed at which tasks were being competed (Aptel et al., 2002; Pransky et al., 1999). In Europe, MSD prevalence figures were estimated to affect 30% and 40% of workers in the Netherlands and Belgium, respectively (Buckle & Devereux, 2002).

By 2010, MSDs had become the top contributor to work-related disability, with disability-adjusted life-years (DALYs) caused by MSDS increasing by 10.1% over 20 years, especially in developing nations, where the DALYs are estimated to be two and half times more than those of developed countries (Gcelu & Kalla, 2015; Macdonald & Oakman, 2015). In 2016, work-related MSDs (WRMSDs) were found to be the leading non-communicable disease contributing to years of living with a disability in the UK and the second leading cause of disability worldwide (Whittaker et al., 2019). However, an accurate estimation of the number of individuals affected by MSDs is difficult to determine due to the underreporting of and wide variations of types of MSDs (Briggs et al., 2018; Rivera-Rodriguez et al., 2013; Whittaker et al., 2019).

In South Africa, information on the prevalence of MSDs is limited, as no official databases for MSDs exist, and only a few studies have looked at MSDs in this context. The South African government does not require employers to record MSDs as, for example, in the United States or Europe; however, some MSD outcomes from South African research studies were similar to those in the rest of the world (Ferreira & Strydom, 2016). Recent studies that have investigated bankers, nurses, teachers and dentists show that the prevalence of MSDs in South Africa is high, with 83.1% of teachers, 69% of dentists, and roughly 80.5% of bankers and nurses reporting MSD-related symptoms (Moodley et al., 2018; Nyantumbu-Mkhize, 2017; Nyawose & Naidoo, 2019). These statistics indicate that South Africa faces similar MSD prevalence rates to developed countries in North America and Europe.

2.2 Burden of MSDs

High MSD prevalence is a significant concern worldwide, plaguing many individuals, organisations and countries, bringing about increased costs of treatment and costs not directly related to treatment (Briggs et al., 2018; Gcelu & Kalla, 2015; Madiba et al., 2013). The burden placed on the government, companies, healthcare systems and individuals by MSDs are greater than just financial or economic costs but also consist of personal burdens, such as an individual's quality of life and psychological state.

The economic burden of MSDs is often divided into direct and indirect costs. Direct costs are those associated with the treatment of the disorders and are made up of hospital visits and admissions, treatments, and administrative expenses, which equate to 0.7%-1.2% of most industrialised nations' Gross Domestic Product (GDP) (Eggers, 2016; Ferreira & Strydom, 2016; Vargas et al., 2018; Woolf & Pfleger, 2003). This amounted to 20% of all healthcare usage in Canada and 22.6% in Sweden (Woolf & Pfleger, 2003). In the Netherlands, the cost of upper limb MSDs directly associated with MSDs equated to around $160 million, and in the USA, these costs amounted to about $576 billion (Buckle & Devereux, 2002; Summers et al., 2015). Although these costs are high on their own, a large proportion of MSD-related costs are indirect. With literature emphasising indirect costs, more recent figures on the direct cost of MSDs were difficult to find.

Indirect costs refer to the economic costs outside of the treatment, including those related to the workplace, such as loss of productivity and sick leave costs. For example, in Thailand, 15.7% of registered nurses took sick leave related to MSDs in a 12-month period, leading to sick leave pay and salaries for nurses to cover shifts (Thinkhamrop et al., 2017). In the UK, upper limb MSDs reported to affect work during the late 1990s led to an estimated 5.4 million days of missed work, further increasing the burden on workers and governments (Aptel et al., 2002; Buckle & Devereux, 2002). However, these statistics ignore lower limb MSDs and lower back pain (LBP) and rely on self-reported MSDs. In the USA, the indirect cost of salaries lost alone equated to 2.9% of the US GDP between 2004 and 2006, a monetary value of $373.1 billion (Summers et al., 2015).

Studies conducted in Europe observed that the indirect costs of MSDs were four times greater than the direct costs associated with MSDs (Caroly et al., 2010; HSENI & HSA, 2013). Furthermore, the indirect costs have knock-on effects, not only for the businesses or organisations in which the MSDs were found but also for the national economy due to lost time, labour, and decreased productivity (Caroly et al., 2010). Increased MSD rates were also found to correlate with higher levels of absenteeism and higher staff turnover, further costing employers time and money to train and reassign employees, on top of potential medical costs and compensation claims (Carayon et al., 1999; Pransky et al., 1999; Punnett, 2000).

The burden of MSDs was still on the rise in the 2010s, with more than 17% of worldwide disabilities being accredited to these disorders (Walker-Bone et al., 2017). In North America, 40% of all lost-time workplace injuries were attributed to MSDs, amounting to $13.9 billion in lost productivity in Canada alone (Crawford et al., 2020). The global burden of disease (GBD) study of 2019 reported that, despite an overall decrease in the overall adverse health effects in the last decade, there was an increase of 30.7% in non-lower back pain MSDs disability-adjusted life-years (DALY) (Abbafati et al., 2020). The study also suggested that this burden would continue to rise as life expectancy became longer and the average age of the working population increased (Abbafati et al., 2020).

Studies have found that the DALY in developing nations, such as South Africa, are 2.5 times higher than those of developed countries (Gcelu & Kalla, 2015; Moradi-Lakeh et al., 2017). Hay et al. (2017) suggested that the high DALY in low socio-economic income countries of Sub-Saharan Africa could be due to high levels of HIV and TB outbreaks, which tax the healthcare system and shift the focus away from non-morbid non-communicable diseases.

Another cost to consider are those directly attributed to the individual. A study on MSD costs in Korea found that insurers only paid 59% of the medical cost of their patients suffering from MSDs (Oh et al., 2011). Individual co-payments for MSD treatment equated to 1.68 billion dollars over the course of a year being attributed (Oh et al., 2011). The Burden of Musculoskeletal Disease in the United States study found that, on average, $4 616 US were lost in earnings for people with MSDs over the course of a year in 2004 (American Academy of Orthopedic

Surgeons [AAOS], 2008). The costs to the individual are scarce in the literature as they are often lumped into the direct medical costs of treating MSDs.

Recent literature revealed one further cost to individuals associated with MSDs. These are the psychological or intangible costs individuals face, such as job security stress, reduced quality of life, stress and pressure from dependents and the pain associated with developing an MSD (Caple, 2012; Lanfranchi & Duveau, 2008; WHO Scientific Group, 2003). These impacts are arguably as severe as the economic costs but are often forgotten due to the difficulty of assigning a monetary value to them. These costs are also noteworthy as they may be a predictor of how much a person may continue to work even whilst injured. Although the psychosocial cost has been reported to result in an increased indirect cost of business, evidence for this is still low (Du et al., 2021).

2.3 Aetiology of MSDs

MSDs have multi-causal pathways and develop over time after multiple exposures to risk factors or hazards, forming what is referred to as the “musculoskeletal hazard chain” (Huang, Feuerstein, & Sauter, 2002). It is accepted in academic circles that MSDs can develop either through acute trauma, where the forces applied by the task exceed the tissue tolerance level of the individual, or through cumulative trauma, whereby repeated submaximal exertions over time cause the tissue tolerance of the individual to decrease (Marras et al., 1999; Mattison & Goebel, 2007; Radwin et al., 2001). The development of a disorder is gradual, initially starting with short bursts of discomfort or numbness during or after a specific movement or activity, generally centred around a joint (Buckle & Devereux, 2002). If the exposure to harmful factors continues, the soft tissues affected may start to deteriorate, and the individual may start perceiving some initial signs and symptoms; for example, pain begins to develop or worsen (Huang et al., 2002; Marras, 2012; Sauter & Swanson, 1996). MSDs develop as the soft tissues start to deteriorate, leading to numbness, discomfort and eventually pain as the disorder worsens (Aptel et al., 2002; Ferreira & Strydom, 2016; Huang et al., 2002). The progression in MSD symptoms is usually associated with continued or increased use and exposure to the affected tissue's risk factors and may eventually lead to a disability (Aptel et al., 2002; Ferreira & Strydom, 2016; Huang et al., 2002).

Although there are many models to explain these pathways, they all start with minor exposures leading to discomfort and pain. Psychosocial, biomechanical, and physiological pathways have been found to lead to an increased risk of experiencing MSDs and pain associated with MSDs (Armstrong et al., 1993; Carayon et al., 1999; Karsh, 2006; O'Sullivan et al., 2016)

One must first understand their aetiology to manage the different risk factors contributing to MSDs. Literature on the development of MSDs is vast, with many researchers proposing diverse theories of how such disorders develop. Despite this, most models agree that MSDs have a multifaceted network of causation but differ in how potential risk factors interact to initiate and aggravate MSDs (Aptel et al., 2002; Buckle & Devereux, 2002; Jay et al., 2016; Marras et al., 2016).

Early models of MSDs focused on biomechanical causation, whereby external forces from the environment applied to the body's tissues result in a negative outcome for the individual if the external stress exceeds the tissues' mechanical strength. Risk factors such as large force production, repetitive motions and non-neutral or awkward joint positions coupled with high intensities, frequencies, or durations, could cause adverse health-related effects on an individual (Aptel et al., 2002; Buckle & Devereux, 2002).

This concept, known as the 'load-tolerance relationship', suggests that tissues can be exposed to these biomechanical risk factors without harm until the load spikes and exceeds the tolerance level of the tissue (Davis & Marras, 2000; Marras, 2012; Marras et al., 2016). The tolerance level of the tissue can vary but generally decreases with exposure over time as a result of various factors and may ultimately be exceeded by the tissue loading, even if the tissue loading itself remains constant. Injuries may worsen over time if the tissue is not given time to recuperate or heal, as is the case with most MSDs (Davis & Marras, 2000; Marras et al., 2016; Melhorn et al., 2001). It is speculated that the tissue's quality and the duration of exposure can contribute to changes in tissue capacity, thus increasing the risk of developing an MSD (Figure 1).

Figure 1 shows selected factors, such as age, genetics and exposure to risk, influencing the functional capacity of tissues to withstand the forces placed on them (Marras, 2012). These are not the only factors that affect tissue tolerance; factors

such as previous disease or injury, psychological stress and level of physical fitness too play a role in the capacity of the individual's tissues to withstand the

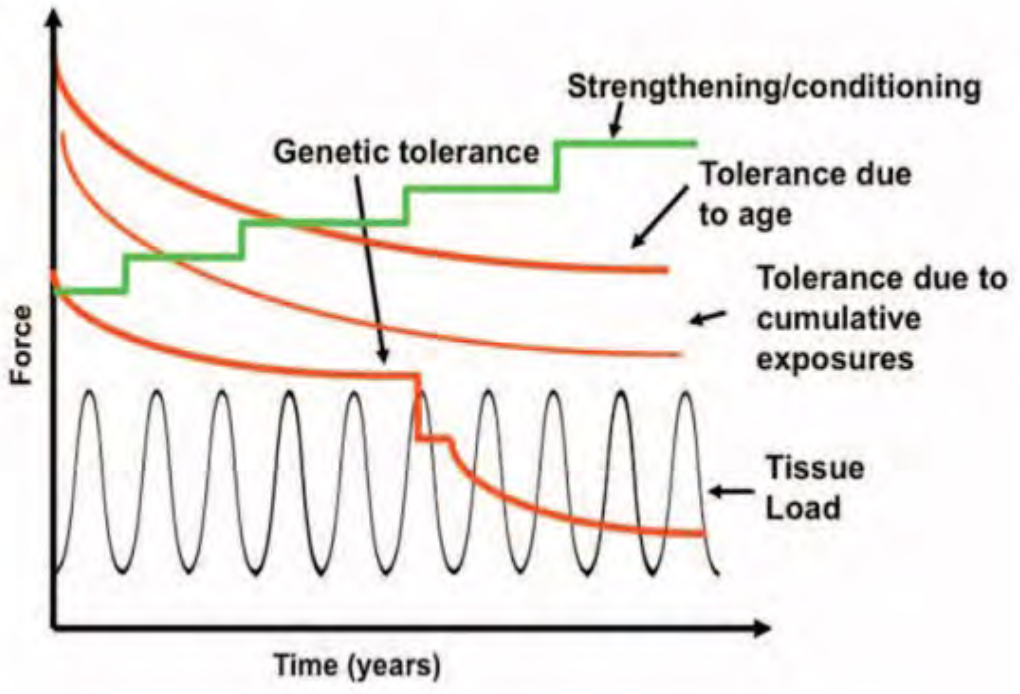

Figure 1. Conceptual relationship of various factors (including tissue tolerance) and duration of load. (Adapted from Marras, 2012)

demands being placed on them (Aptel et al., 2002; Marras, 2012; Marras et al., 2016). Therefore, the risk of developing an MSD is increased if the work-related biomechanical demands placed on the individual (repetitions, exertion, duration and posture, amongst others) outweigh the functional capacity of the tissues (influenced by age, fitness, individual factors and stress, for example) to resist these stresses (Aptel et al., 2002; Kumar, 2001).

A similar theory called the "multi-variate interaction theory of musculoskeletal injury precipitation" proposed that genetic, morphological, psychosocial and biomechanical factors all interact to create the injury pathway (Karsh, 2006; Kumar, 2001). The interactions between the multitude of variables under each risk category may mean that there are multiple pathways to the development of the same MSDs (Karsh, 2006; Kumar, 2001). Researchers realised that risk factors other than biomechanical factors might contribute to the risk of MSD development.

Cognitive and psychological aspects, such as stress, also became increasingly accepted as risk factors for MSD causation, with some models suggesting that these factors play a mediating role in MSD development, although biomechanical factors were still considered to be the primary contributor to MSD formation (Huang et al., 2002; Karsh, 2006; Sauter & Swanson, 1996). The “Ecological Model of Work-Related Musculoskeletal Disorders (WRMSD)” (Sauter & Swanson, 1996) and the “Model of Job Stress” (Carayon et al., 1999) further suggested that the stress placed on workers by organisations and workplaces (e.g., deadlines) added to the social and psychological strain experienced by individuals, also referred to as ‘psychosocial factors’ (Carayon et al., 1999; Karsh, 2006; Kumar, 2001). These psychosocial factors were believed to contribute to physiological responses, such as increased sensitivity to pain, or tissue fatigue, which, in turn, could reduce the capacity of the tissue to withstand biomechanical stresses (Huang et al., 2002; Marras, 2012; Sauter & Swanson, 1996). For example, nociceptors in the body responsible for pain detection may become sensitised by chemical by-products released during biomechanical loading, such as those released during an inflammatory response (Marras et al., 2016). This increased pain sensitivity, in turn, increases the symptoms associated with MSDs (Sauter & Swanson, 1996). Furthermore, the perception of having and labelling an MSD was also proposed to influence the disorder development, which in turn feeds back into the psychological strain component of the model, thus reinforcing the negative perception of MSDs being debilitating and painful (Huang et al., 2002; O’Sullivan, 2012; Sauter & Swanson, 1996). These reactions could then cause changes in how work is done to meet the task demands, which, when combined with traditional biomechanical risk, can result in strain outcomes, e.g., MSDs (Carayon et al., 1999; Karsh, 2006). Work organisation stressors may even lead to behavioural changes that increase risk-taking behaviour (Huang et al., 2002; Karsh, 2006).

This amalgamation of individual factors (psychosocial, cognitive, biomechanical, and physiological) and how they interact with workplace factors (loads and job stress) is shown in Figure 2. This diagram, designed by a panel of 19 MSD experts, represents the workplace and the individual as well as the factors interacting within them that lead to MSD risk (Panel on MSD and WP, 2001). The left side shows how the task (external load) and work environment (social, physical and

organisational) can influence the multiple factors that make up an individual's susceptibility to MSD risk (on the right side). Figure 2 also shows the individual factors and how they add to the stress placed on the person, comprised of stressors outside of the workplace, such as home life or financial stress, which in turn adds to the workplace stress placed on the person (Panel on MSD and WP, 2001).

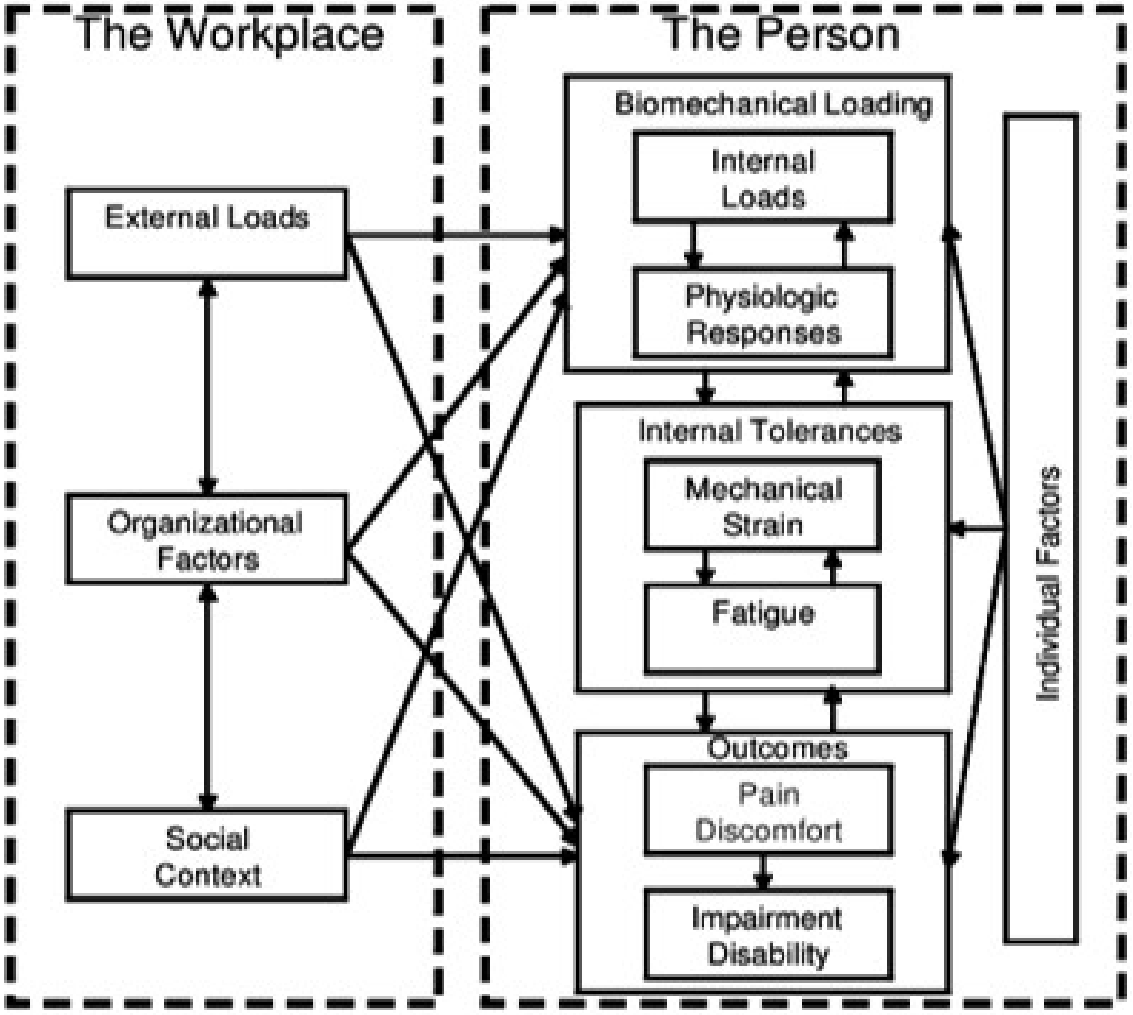

Figure 2. A conceptual model illustrating the various factors that interact in the formation of MSDs. (Adapted from Panel on Musculoskeletal Disorders and the Workplace, 2001)

Furthermore, the idea of feedback loops in MSD development has become more apparent. In a review of popular theories of MSD development, Karsh (2006) noted that five of the nine theories reviewed suggested that the perception of MSDs, pain and the stress they place on the individual influence not only the behaviour of the individual but also their movement patterns and tolerances (Karsh, 2006;

Macdonald, 2012; Oakman et al., 2019). It is now widely accepted that to understand, manage, and minimize the burden of MSDs, the individual and the environment within which they work and live (physical, social and organisational) must be considered. It is essential to acknowledge the psychosocial, physiological and biomechanical stressors placed on individuals and how they interact with the physical and cognitive environments of the organisation they are placed (Marras & Hancock, 2014). This will allow for a more comprehensive understanding of the multiple pathways in which MSDs can occur and allow for more effective prevention and management thereof.

2.4 MSD Intervention Practices

The many pathways leading to MSD development have led to multiple approaches on how to best mitigate their occurrence and associated problems. One school of thought believes that the disorders are best dealt with in a preventative approach, whereby the factors that could lead to a disorder are mitigated to lower the risk of MSD development (Pascual & Naqvi, 2008; Prall & Ross, 2019). Another approach deals with the management of the disorders once they have developed, the aim being to reduce the effects of MSDs on individuals' activities of daily living and work after their development (Melhorn et al., 2001). However, as MSD causation is multi-causal and therefore challenging to prevent completely, a combination of the two approaches should be taken to address the MSD problem, first striving for prevention but setting up management policies for when prevention is no longer an option (Oakman et al., 2022; Whittaker et al., 2019).

Within MSD prevention and management approaches, interventions can be divided into several ways to understand them better. For the purposes of this review, MSD interventions are divided into administrative, engineering and individual controls based on the works by Entzel et al. (2007) and Rostykus et al. (2013). These groups will only be used in the review of literature as a starting point to identify MSD intervention approaches before the scoping review in chapter III.

Administrative and work practice controls refer to changes in the behaviour of workers and the workload through organisation policies such as job rotation, shift scheduling, and training to reduce the demands of the task placed on the worker (Entzel et al., 2007; Rostykus et al., 2013). Engineering controls affect changes to

the physical workplace and the use of tools, equipment, and materials to reduce MSD risk (Entzel et al., 2007; Rostykus et al., 2013). Individual controls aim to increase workers' capacity to be exposed to risk factors through protective measures and behaviour-modifying practices (Entzel et al., 2007; Rostykus et al., 2013). Each other, the three-control type can also be applied in a preventative and management manner.

Administrative controls modify individual behaviour through policies and educational practices (Entzel et al., 2007; Rostykus et al., 2013). A popular preventative administrative control to limit risk exposure is through carefully planned job rotation. Padula et al. (2017) noted a decrease in the cumulative load placed on the lower back and trapezius muscle in assembly line work during a two-hour job rotation schedule. However, if not properly planned, the stresses placed on the body may result in increased strain and, therefore, MSD risk placed on the body region (Padula et al., 2017).

Staff training could also lead to work being done safely within the pre-existing tasks and environment, further reducing intervention costs for businesses (Caple, 2012). Wells (2009) indicated that one significant reason why MSDs are still not solved is due to a lack of understanding and training around how to use tools safely. Ferreira & Strydom (2016) identified that the lack of training of managers and workers on legislation and ergonomics specifications was reducing the application of MSD risk-mitigating practices among teleworkers. This indicates that simple training on understanding and applying the already existing regulations could prevent MSDs from occurring. Moreover, Oakman & Chan (2015) highlighted that using training materials in conjunction with a participatory approach to education is critical in identifying risky behaviour and hazards that may lead to MSDs. Furthermore, Boocock et al. (2007) found that training and behaviour modification, specifically through exercise, lead to an increase in worker health.

Proactive or preventative engineering controls aim at reducing the exposure to biomechanical risks that workers may face (Entzel et al., 2007). One way of lowering exposure to physical stress is through job redesign, where the tools, tasks and the working space are changed to match the capabilities of the person doing the job (Panel on MSDs and WP, 2001; Punnett, 2000; Wells, 2009). A reduction

in exposure to awkward postures and prolonged loads was shown to reduce upper extremity strain and pain (Panel on MSD and WP, 2001; Wells, 2009). Furthermore, The Panel on Musculoskeletal Disorders and the Workplace (2001) expressed the need to assess the environment, tool usage and reported stress. Melhorn et al. (2001) advocated for appropriate risk assessments of both the tasks and the worker. This would allow the ergonomist to assess the risk of both components and any risks that may emerge as part of the interaction between the tasks and the person performing them.

Individual controls included the training and education of workers to promote risk-aversive decision-making and behaviour in the workplace (de Castro, 2003). Boocock et al. (2007) found that modifier interventions, such as physical training and exercise along with training of workers, manage physiological and psychosocial stressors led to a reduction in the number of adverse health conditions in the workplace, including MSDs.

Since it is not always possible to prevent MSDs, a reactive approach is sometimes needed, whereby pre-existing MSDs are treated and managed to reduce symptoms while allowing work to continue (Whittaker et al., 2019).

Management administrative control tries to reduce the risk of cumulative stress by limiting overtime work and scheduling work to accommodate for adequate rest (Carayon et al., 1999). Carayon et al. (1999) observed increased overall exposure to MSD risks during overtime work when individuals were fatigued and tissue tolerance was lowered, which would, according to the load-tolerance relationship, increase the risk of MSD development as the body cannot withstand the forces being placed on it (Marras, 2012).

As with MSD prevention, training is largely beneficial in MSD management (Buckle & Devereux, 2002). However, unlike in prevention literature, the exposure of both managerial employees and the workers to training and education may be the optimal strategy to combat MSDs, as by educating all parties on the ergonomics standards that best reduce risk, the exposure risk factors can be minimised (Buckle & Devereux, 2002; Carayon et al., 1999).

As MSDs are often long-term and chronic diseases, many businesses use medical surveillance to track the severity of pre-existing disorders and the effect the interventions have on them. Melhorn et al. (2001) found that monitoring individuals with MSDs over time led to decreased numbers of MSD incidents as symptoms could be treated as soon as they appeared. It was noted that the most favourable results were seen when the medical surveillance was accompanied by an appropriate risk assessment to not only treat the individual but also change the system to reduce the likelihood of further reoccurrence (Melhorn et al., 2001). Punnett & Wegman (2004) found similar conclusions with the use of self-reporting tools to record the epidemiology of MSDs, and that by understanding the formation of the disorders, mitigating interventions can be put in place to manage them. The medical reporting and surveillance of MSDs may also increase the opportunity for referral to specialists to reduce the MSD effects (Aptel et al., 2002).

MSD symptoms can be managed through engineering controls by reducing the biomechanical stress experienced or increasing the functional capacity of the individual with the disorder, whether it is peak or cumulative (Aptel et al., 2002; Buckle & Devereux, 2002; Carayon et al., 1999). Carayon et al. (1999) also suggested that workplaces may induce awkward postures or static repetitions in their workers due to workstation and system designs that limit movement. As awkward postures and repeated repetitions are both causal factors to MSD formation, the risk of catastrophising existing disorders increases (Piligian et al., 2000). Thus, interventions aimed at identifying and reducing these biomechanical stressors may reduce MSD risk. One way to do so is through workplace interventions, where the task and working environment can be changed to reduce exposure to MSD risk factors (Melhorn et al., 2001; Piligian et al., 2000). A study by Buckle & Devereux (2002) noted that multiple workplace interventions (e.g., reducing biomechanical stress with tool design and decreased load) lead to decreased sick leave, MSD reoccurrence and compensation.

A common individual control practice to reduce MSD pain and symptoms is the introduction of ergonomics tools and equipment to minimise load and awkward postures (Ferreira & Strydom, 2016; Piligian et al., 2000). In a systematic review, Boocock et al. (2007) found that changing workstation equipment leads to positive health benefits for UL-MSDs. In a study on alternate rivet gun usage, Melhorn et

al. (2001) observed that the use of new ergonomics equipment leads to reductions in MSD risk and a reduction in cost due to compensation claims that outweighed the cost of switching to alternative tools. However, such tools are only as effective as the training provided on how to use them. Melhorn et al. (2001) observed an initial increase in risk to employees who had previously used older equipment as they had developed intuitive knowledge of the risk involved based on the tactile feedback for the old rivet guns. Incorrect tool usage can lead to increased stress placed on individuals, leading to worsened MSD symptoms (Boocock et al., 2007; Carayon et al., 1999; Piligian et al., 2000). As such, engineering controls in isolation may not be enough to mitigate MSDs but instead may need appropriate training for effective intervention.

MSD intervention can be challenging for practitioners, as the type of intervention and the approach, whether reactive or proactive, need to be balanced for effective implementation. The aetiology of MSDs does not allow for simple intervention, and practitioners may often find themselves employing a combination of controls from those listed in the paragraphs above to find an effective approach for their context.

CHAPTER III:
PHASE 1 - FRAMEWORK DEVELOPMENT

3.1 BACKGROUND TO THE STUDY

It is well-established that musculoskeletal disorders (MSDs) are a significant cause of poor health, financial burdens and productivity concerns for businesses and their employees worldwide (Aptel et al., 2008; Briggs et al., 2018; Buckle & Devereux, 2002; WHO Scientific Group, 2003). These outcomes, coupled with a high prevalence of MSDs, highlight the need for interventions (Carayon et al., 1999). However, developing and implementing effective MSD interventions is complex due to the multifactorial nature of their development. Interventions are thus generally split into the prevention of musculoskeletal disorders prior to their development and the management of the symptoms associated with them once they have formed (Boocock et al., 2007; Caroly et al., 2010; Melhorn et al., 2001). This leads to two important questions; 1) are there effective methods for preventing and managing MSDs, and 2) is there an evidence-based framework on MSD prevention and intervention methods? Literature reporting on different MSD intervention strategies has shown that interventions can effectively prevent and manage disorders. However, guidelines to aid practitioners in deciding on effective interventions have mostly been limited to micro-ergonomics manual material handling specific tasks, such as those designed by the Health and Safety Authority of Ireland (HSA) and Health and Safety Executive for Northern Ireland (HSENI) (HSENI, & HSA, 2013). These guidelines, although helpful, do not provide a complete multifactorial approach to MSD interventions. Thus, there is a need for a concise, evidence-based framework that details the multiple prevention and management approaches.

The purpose of this phase of the study was to conduct a scoping review of the literature on MSD interventions that have been successful in combating musculoskeletal disorders and to collate the findings into a framework for literature navigation.

3.1.1. What is a Framework

Although an understanding of the MSD aetiology and MSD intervention strategies are an important aspect of MSD prevention and management, such information is of little use without guidance on when these strategies can and should be applied. A framework acts as a guideline with policies, suggested methods, and checkpoints, which can assist in designing or developing programmes to meet specific goals (Imenda, 2014; Rocco & Plakhotnik, 2009). As established by the literature (e.g., Novak, 2004; Punnett, 1999, and Wells, 2009), there are many different types of prevention and management programmes and policies when dealing with MSDs. However, the ease with which occupational health and safety representatives can access these intervention strategies in practice is poor due to vast and potentially overwhelming volumes of academic literature surrounding MSDs, which limits access, even to those who can afford it. Developing a framework that assists with the navigation of the literature on the prevention and management of MSDs first requires an understanding of the different types of frameworks and how they aid researchers in the pursuit of their goals.

Frameworks can either be classified as being theoretical or conceptual frameworks (Fleishman et al., 1984). For both, researchers attempt to understand a phenomenon using theories or concepts (Imenda, 2014). Although these terms are sometimes used interchangeably, there is, in fact, a distinct difference. Concepts are interpretations of an idea that are widely influenced by the context, the problem they are trying to solve and the relationships between the components interacting within them (Imenda, 2014; Jabareen, 2009). On the other hand, a theory is a collection of related concepts used to explain a phenomenon and predict future outcomes (Jabareen, 2009). Keeping the above definitions in mind, a conceptual framework uses a combination of theories (or parts thereof) and literature to develop a model or guide to explain or predict an event broadly and holistically (Imenda, 2014). Such a framework is synthesis driven; it aligns with an inductive research design whereby different models and pieces of information are used to draw new conclusions and explanations (Fleishman et al., 1984; Imenda, 2014). A conceptual framework is an anchor point to allow researchers to keep the research in line with the problem statement laid out for the study (Rocco & Plakhotnik, 2009). On the other hand, a theoretical framework uses a theory or aspects of a single

theory to attempt to explain an observation or natural event (Imenda, 2014). Therefore, a theoretical framework is theory-driven and is usually accompanied by a deductive approach to research, whereby the researcher uses theory to make inferences in an experiment using a quantitative method of data collection (Fleishman, Quaintance, & Broedling, 1984) (Figure 3).

When dealing with complex multifactorial problems such as musculoskeletal disorders, it is best to develop a conceptual framework that will allow the researcher to draw on a multitude of models and theories to best address the problem they are facing (Carayon et al., 2015; Imenda, 2014). Using general concepts grounded

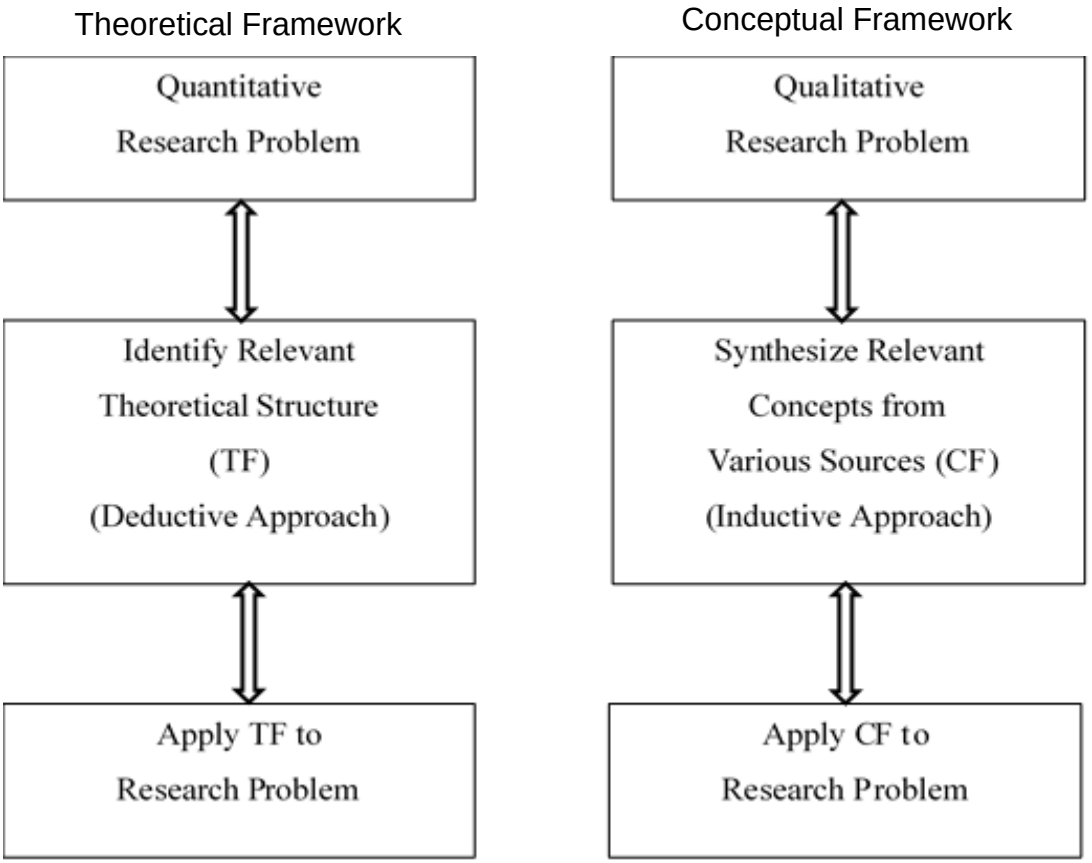

Figure 3. Typical relationships between the Theoretical Framework (TF) and Conceptual Framework (CF) relative to the qualitative and quantitative research paradigms. (Adapted from Fleishman, Quaintance, & Broedling, 1984)

in theory, links and relationships can be developed and tested surrounding the proposed conceptual framework, generating a potentially new way of dealing with an existing problem.

3.1.2. Building a Conceptual Framework

To build a conceptual framework, the researcher must first identify the approach to adopt, then search for, and finally analyse concepts and theories to devise a plan of action (Jabareen, 2009). Concept analysis is the study of concepts, characteristics, and related systems to define and clarify their role within the said system and is the most commonly used approach in framework development (Kosterec, 2016; Nuopponen, 2010). The literature on musculoskeletal disorders contains countless theories on how best to prevent and manage these disorders; however, sometimes, the relationship between how the theory can be used in practice is not well established. The MSD literature lends itself well to a conceptual analysis to build MSD prevention and management frameworks, as the there are a large number of concepts to consider when intervening; however, the links between concepts are not always clear. Researchers aiming to create such a framework may find using a conceptual analysis technique the most appropriate approach to identify concepts and establish relationships between concepts from different theories of MSD intervention (Kosterec, 2016).

There are multiple techniques for conducting a conceptual analysis, such as constructive analysis, detection analysis, and reductive analysis; each one uses a different approach to identify relationships between theories or concepts to improve understanding of these relationships between concepts and thus form new conclusions around the theory or phenomena it examines (Kosterec, 2016; Tähtinen & Havila, 2019). A constructive analysis forms new relations or expands on pre-existing relations between concepts by building upon and testing the relations to develop a new conceptual background (Kosterec, 2016). In detection analysis, the aim is to find equivalent concepts that already exist within the theory to broaden the conceptual background within the existing constraints (Kosterec, 2016). Reductive analysis aims to determine whether one concept forms part of another complete theory or even as a reduced notational variant of another existing theory while remaining in line with a predetermined empirical truth about the concept being reduced (Kosterec, 2016).

All analysis approaches have advantages and disadvantages in the context of MSD interventions. A reductive approach may tame the complex nature of

preventing and managing MSDs. However, further reducing the concepts of MSD prevention and management may run the risk of diminishing the perceived impact and cost that such disorders have on their stakeholders as the solution is presented as simple or easy. Both constructive and detection analyses would also be appropriate for a study on MSDs; however, detection analysis fits the goals of the current study design better than a constructive analysis due to the framework reporting on existing concepts rather than finding relations between concepts, as would be the case for constructive analysis (Kosterec, 2016).

3.1.3. Role of Ergonomics in MSD Intervention

Musculoskeletal disorders are comprised of a multitude of causal factors ranging from biomechanical to physiological to psychosocial factors (Caroly et al., 2010; Novak, 2004). To intervene, one must understand which factors are most prominent during the formation and escalation of such disorders and what kind of intervention is most effective against these risk factors. To do so, it is necessary to look at some ergonomics systems models first to “simplify” the complexity of the problem of MSDs.

According to the work systems model, a business or organisation can be broken down into various components, such as the workers’ characteristics, the task performed, the organisational policies and rules, the tools used and the environment within which the work is performed (Carayon et al., 1999). What needs to be kept in mind is that all these components constantly interact to produce the system's intended outcome (e.g., a product or a service). However, these interactions can also lead to unintended outcomes (e.g., fatigue, errors, MSDs). While some systems are relatively simple, they can also be highly complex as the components are susceptible to internal and external influences (Karsh et al., 2014), causing many ever-changing interactions. This means that interactions of components within the system as well as with its environment can influence the emerging properties of the systems, which in turn can change the interactions of the work systems components again, leading to further adjustments (Karsh et al., 2014; Rasmussen, 1997; Wilson, 2014). Due to the multiple levels of influence in a system, the components and their interactions have been grouped to fit within the micro-, meso-, or macro-ergonomics levels (Karsh et al., 2014; Rasmussen,

1997; Wilson, 2014). “Micro-ergonomics” refers to interactions at the lowest level, e.g., the immediate interaction between the human and the machine and /or task, to promote the well-being of the individual without diminishing the performance of the task (Rivera-Rodriguez et al., 2013; Thatcher & Yeow, 2016; Waterson et al., 2009). In terms of interventions, this is the lowest level, is usually reactive, and focused directly on the problem at hand at the level of the work being done (Wilson, 2014). “Macro-ergonomics” refers to the influences of the organisation and the environment on the work system and the humans within it (Karsh et al., 2014; Kleiner, 2006; Rivera-Rodriguez et al., 2013; Thatcher & Yeow, 2016). “Macro-ergonomics” levels encompass all components of the system and are often used in long-term top-down ergonomics interventions, as any changes that occur at this level impact the meso and micro levels that they encompass (Rivera-Rodriguez et al., 2013; Waterson et al., 2009). “Meso-ergonomics”, albeit the newest conceptual level of ergonomics, fills the ‘gap’ between macro-and micro-ergonomics levels. Here, at least two system components are interacting, and the focus is on the relationship of the interaction and how they affect the intended outcome of the system (Karsh et al., 2014; Rivera-Rodriguez et al., 2013; Waterson et al., 2009).

Understanding how MSD interventions at each ergonomics level of a system ergonomics work makes it possible to define borders to a complex system, allowing ergonomists to design interventions specific to the level at which they are going to be implemented. Therefore, understanding the ergonomics levels allows one to prioritise which ergonomics level the risk of MSD is most significant and where interventions may be most effective. Rasmussen’s (1997) risk management hierarchy (depicted in Figure 4) displays levels within a system as a socio-technical model for levels of decision-making during risk management. Figure 4 shows how decisions made at the top level of a hierarchy can influence those below it; for example, a macro-ergonomics intervention has outcomes on the micro-ergonomics level. Rasmussen (1997) also used this model to show that the environment can directly influence risk mitigation and decision-making through changes in policies, education, or even technology, which allows researchers to provide structure to complex and sometimes chaotic systems and, therefore, appropriate interventions can be implemented. The question remains: At what level would it be most suitable to intervene effectively?

A macro-ergonomics approach will allow the benefits of its interventions to filter through all components it encompasses; however, this also means that the scope of the intervention is incredibly large and, therefore, unmanageable (Purnomo et al., 2017; Thatcher & Yeow, 2016). Although macro-ergonomics interventions have been shown to be significantly beneficial in reducing MSDs, the design of such interventions and their implementation may take a long time as the emerging properties of each interaction within the system need to be analysed to avoid further aggravation of the risk that is being mitigated (Purnomo et al., 2017).

Figure 4. The socio-technical system involved in risk management showing the hierarchy of decision making (Adapted from Rasmussen (1997))

One example to illustrate this is the introduction of an organisational-level job rotation policy for MSD management in manufacturing. Workers rotate between tasks to reduce repetitive movements or awkward positions to reduce the risk of MSD development or aggravation. Workers rotate between three jobs, each with a particular main stress or risk factor: 1) a job involving overhead work with stress on the shoulders, 2) one packing parts onto a shelf with stress on the shoulders and lower back, and 3) a third assembling parts with stress placed on the wrists. If done

correctly, the peak loads placed on workers could be decreased, e.g., workers are rotated through the order 1), 3), 2), 3) and repeated. However, if the rotation was different, e.g., 1), 2), 3), then the cumulative load placed on workers' shoulders may lead to MSD development as both tasks 1) and 2) strain the shoulders (Jorgensen et al., 2005; Kuijer et al., 2005).

The most effective type of intervention also depends on how urgently the risk mitigation is needed. For example, the implementation of a micro-ergonomics intervention, such as the changing of tools used to do a task, could be a quick way to reduce the loads placed on the worker. However, the intervention is only specific to that task and its associated risk(s); thus, multiple interventions may be needed (Oakman et al., 2018). Oakman et al. (2018) presented a model displaying the reliability and level of protection that MSD interventions have, based on how they target the MSD risk factors.

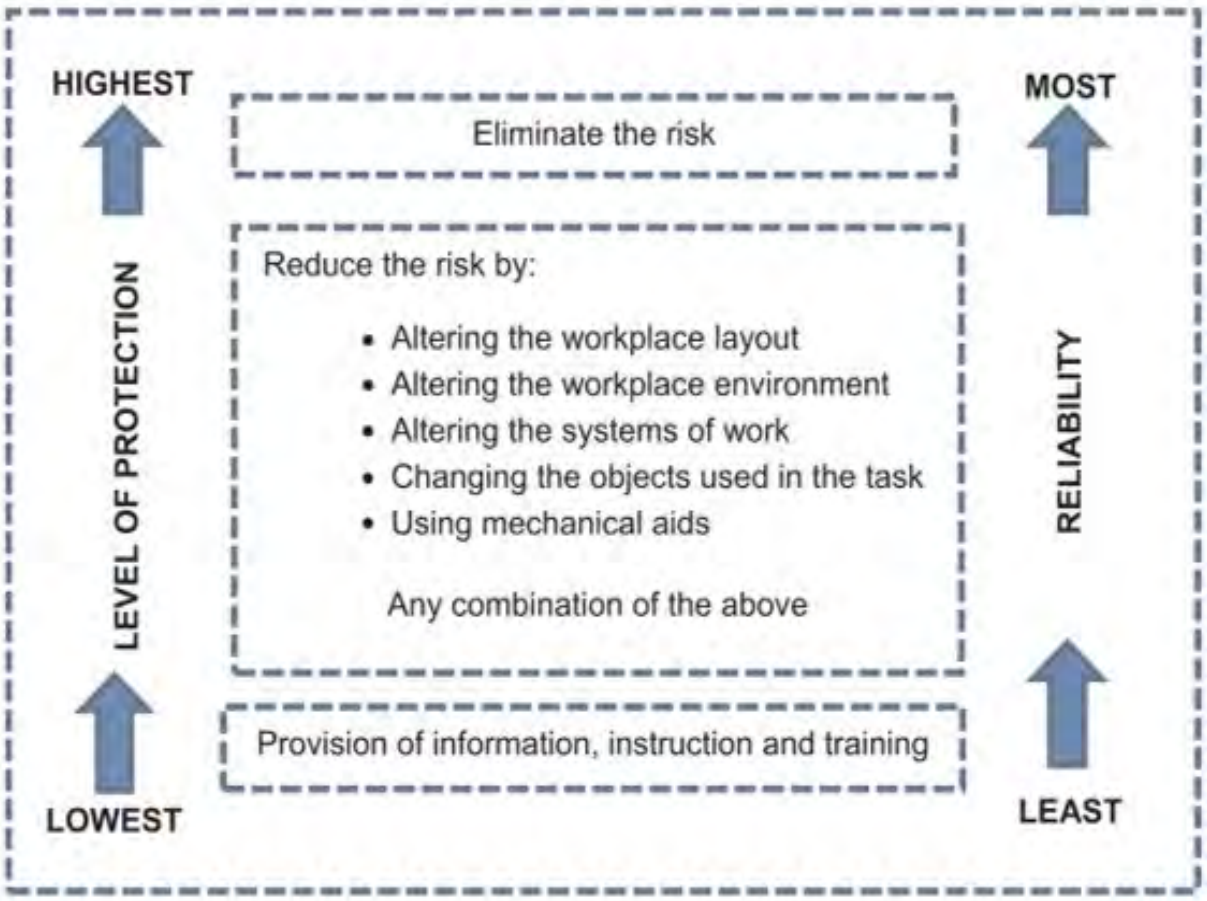

Figure 5. Effectiveness and reliability of risk control measures to reduce risk of musculoskeletal disorders (Adapted from Oakman et al., 2018)

Figure 5 shows that the best approach to combat MSDs is eliminating the risk in a work organisation. The model by Oakman et al. (2018) also shows that when the intervention at the highest level possible is taken, the effects of the intervention may trickle down from the workplace environment to the worker and task in their scenario (Oakman et al., 2018). The model presented by Oakman et al. (2018) remains applicable to the higher levels of the Rasmussen (1997) risk management framework (Figure 4) despite Oakman et al. (2018) only using a workplace-level intervention as an example. A combination of these two models would provide a simple yet effective visual model for combating MSDs in a framework that conveys the need for multiple levels of intervention to do so. As such, it could be used as a guide for the creation of such a framework.

3.2 Methodology

3.2.1. Study Design

To construct a framework aimed at assisting South African ergonomists in navigating the MSD intervention literature, it was necessary first to identify the prevention and management strategies available (Munn et al., 2018). Thus, a scoping review was conducted to determine the MSD prevention and management techniques presented in the literature that has successfully mitigated MSDs. The various results of the scoping review were then grouped by definition, which then led to the creation of a model to assist in the navigation of MSD literature. The grouped results and model together formed the draft framework for MSD prevention and management navigation.

3.2.2. Search Strategy

The search utilised four online databases, namely Google Scholar, EBSCO Host, Scopus and Science Direct, to search for and retrieve relevant articles. A combination of the keywords (Table I) identified during the narrative literature review in Chapter 2 was used to perform the search. The initial search on MSD prevention approaches took place between 10 November 2020 and 15 November 2020 using the four online databases, while the search on MSD management approaches took place between 8 March 2021 and 30 April 2021. The “advanced search”, or similar options, were used where applicable to limit the search to peer-reviewed publications, publications in English, and publication dates between 2000

and 2020. Open-access journal articles relating to the keyword search and the aim of the scoping review were selected for further review using the inclusion and exclusion criteria in Table II. The search was concluded after five consecutive pages of no results or 50 titles not relating to the key phrases or aim of the scoping review.

Table I. Keywords and phrases used during the literature search

Combination	Key Words and Phrases	
	MSD Prevention	**MSD Management**
1	"Musculoskeletal Disorder Prevention" OR "MSD Prevention" AND "Job Rotation" OR "Job Redesign"	"Musculoskeletal Disorder Management" OR "MSD Management" AND "Workplace Adjustment" OR "Workplace Modification"
2	"Musculoskeletal Disorder Prevention" OR "MSD Prevention" AND "Risk Assessment" OR "Medical Screening" OR "Functional Capacity Screening"	"Musculoskeletal Disorder Management" OR "MSD Management' AND "Risk Assessment" OR "Medical Surveillance"
3	"Musculoskeletal Disorder Prevention" OR "MSD Prevention" AND "Legislation" OR "Regulations"	"Musculoskeletal Disorder Management" OR "MSD Management" AND "Load Reduction" OR "Capacity"
4	"Musculoskeletal Disorder Prevention" OR "MSD Prevention" AND "Training" OR "Awareness"	"Musculoskeletal Disorder Management" OR "MSD Management" AND "Legislation" OR "Regulations"
5	"Musculoskeletal Disorder Prevention" OR "MSD Prevention" AND "Equipment" OR "Ergonomic Equipment"	"Musculoskeletal Disorder Management" OR "MSD Management" AND "Return to Work" OR "Conservative Interventions"
6		"Musculoskeletal Disorder Management" OR "MSD Management" AND "Equipment" OR "Ergonomic Equipment" OR "Training"

Publications underwent a three-stage process of elimination during screening. If the initial search criteria were met, then the titles of each article were screened against the inclusion criteria in Table II. The abstracts of the publications that were not excluded from the title screening were then read. Finally, if the abstracts were

related to musculoskeletal disorders or the prevention of musculoskeletal disorders, they moved on to a full article screening process.

Table II. Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
– Peer-reviewed articles – Musculoskeletal disorder related – Relevant to the prevention/management of MSDs – Published between 2000-2020	– Not peer-reviewed newspaper articles, book chapters, magazine articles, dissertations, or theses – Published in a language other than English – Full articles not accessible

3.2.3. Data Extraction & Draft Framework Development

Data extracted from each publication included the reference, study objective and design and MSD intervention outcome as recommended by Denyer & Tranfield (2009). Once the information relating to MSD management and prevention approaches had been extracted from the relevant selected articles, themes were formed by grouping similar concepts together based on their definitions to avoid repeating concepts under different terminology. Data were then further grouped into the following hierarchical levels: “Law”, “Organisational Policies”, “Management Systems”, “Workplace Interventions”, and “Individuals”. These levels were established with guidance from the socio-technical hierarchy of decision-making by Rasmussen (1997) (Figure 4) and the model on the effectiveness and reliability of risk control measures to reduce the risk of musculoskeletal disorders by Oakman et al. (2018) (Figure 5). The results section presents the grouped hierarchy and themes, which were tabulated along with the hierarchical sub-level (containing specific concepts and definitions), the number of articles that fall under each sub-hierarchical level, the references and article notes.

3.3 Results

3.3.1. Screening Process

The online database key phrase search resulted in 1 950 043 articles initially found for ‘MSD prevention’ and 3 123 689 for ‘MSD management’ (Figure 6). 105 of the 1 950 043 searches on MSD prevention were extracted based on the titles (Figure 6). Of these, 33 articles were excluded as duplicates, leading to 72 abstracts screened for relevance and 50 full articles read for relevance. A further eight were excluded for relevance based on the inclusion and exclusion criteria from Table II, leaving 42 articles that were analysed for the MSD Prevention part of the framework. Figure 6 also shows that of the 3 123 689 articles obtained from the initial results for MSD management, 359 articles were retrieved based on their titles. Two hundred and twelve article abstracts were then screened after 147 were excluded as duplicates, and 104 articles were excluded thereafter, leading to 108 full articles. Fifty-five of those were excluded based on the criteria in Table II, which led to 53 articles used in the final analyses for the MSD management component of the framework.

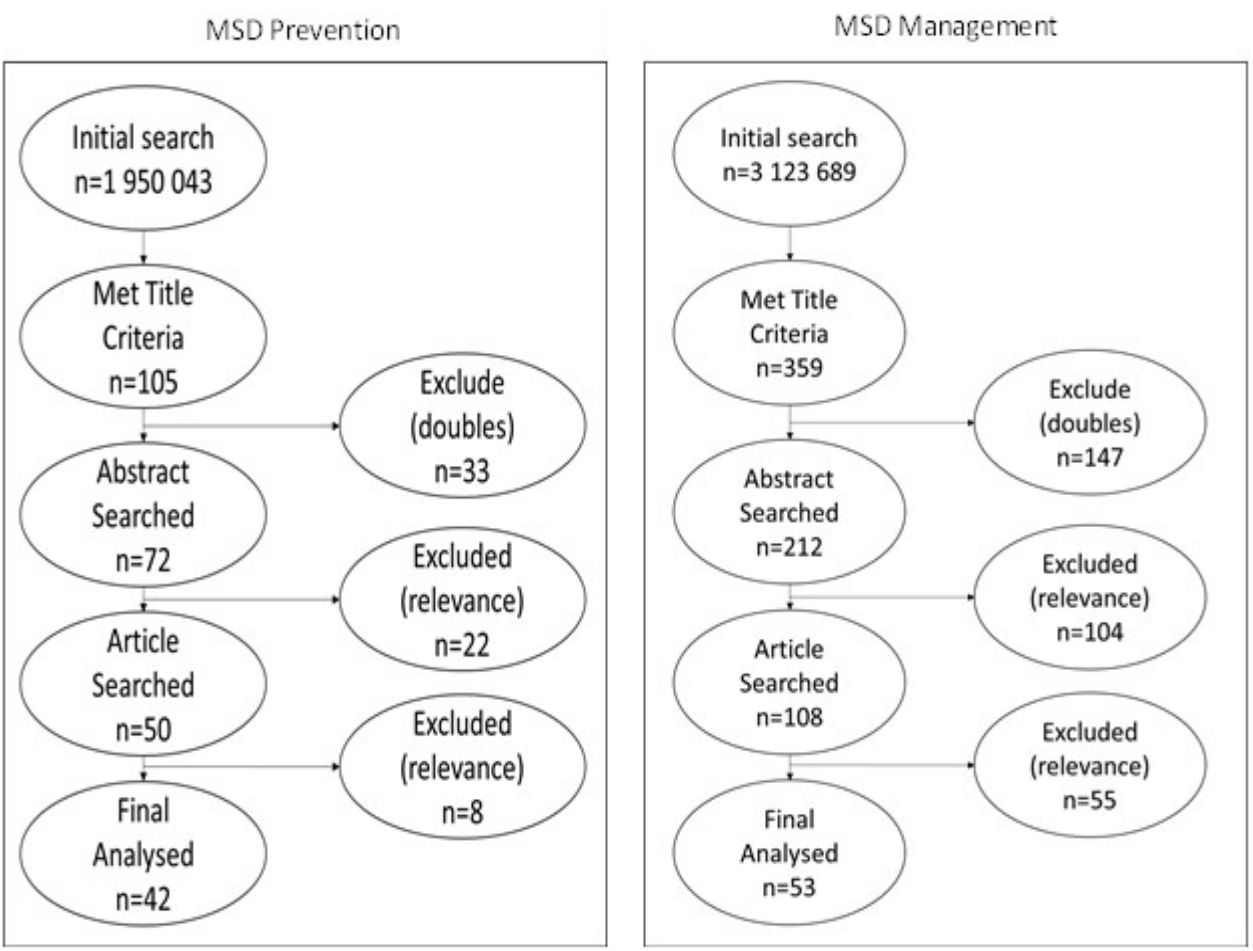

Figure 6. Flowchart showing the scoping review search strategies for the prevention and management searches

3.3.2. Article Analysis and Table Formation

The final article analysis identified and recorded the reference, study objective and design, MSD intervention type and key findings related to the intervention, and its effectiveness. These findings are presented in Table III and Table IV below.

3.3.3. Framework Development and Conceptual Model of Use

The MSD prevention and management interventions identified from the final article analysis were grouped into five 'Hierarchical Levels' based on the models/frameworks of Oakman et al. (2018) and Rasmussen (1997), namely "Law", "Organisational Policies", "Management Systems", "Workplace Intervention" and "Individual" levels, depending on the scope and definition of the intervention. For example, an article on the use of an ergonomics task force as an intervention was placed under "Organisational Policies" as the scope of the task force includes every individual and workstation that forms part of an organisation. Articles within these Hierarchical Levels were further grouped by intervention types, termed "sub-levels" in this study, based on the similarity of the intervention and definition. For example, ergonomics task forces and expert system programs were grouped since both have the same scope and are responsible for evaluating tasks, assessing risks, and making informed decisions on preventing or managing MSDs.

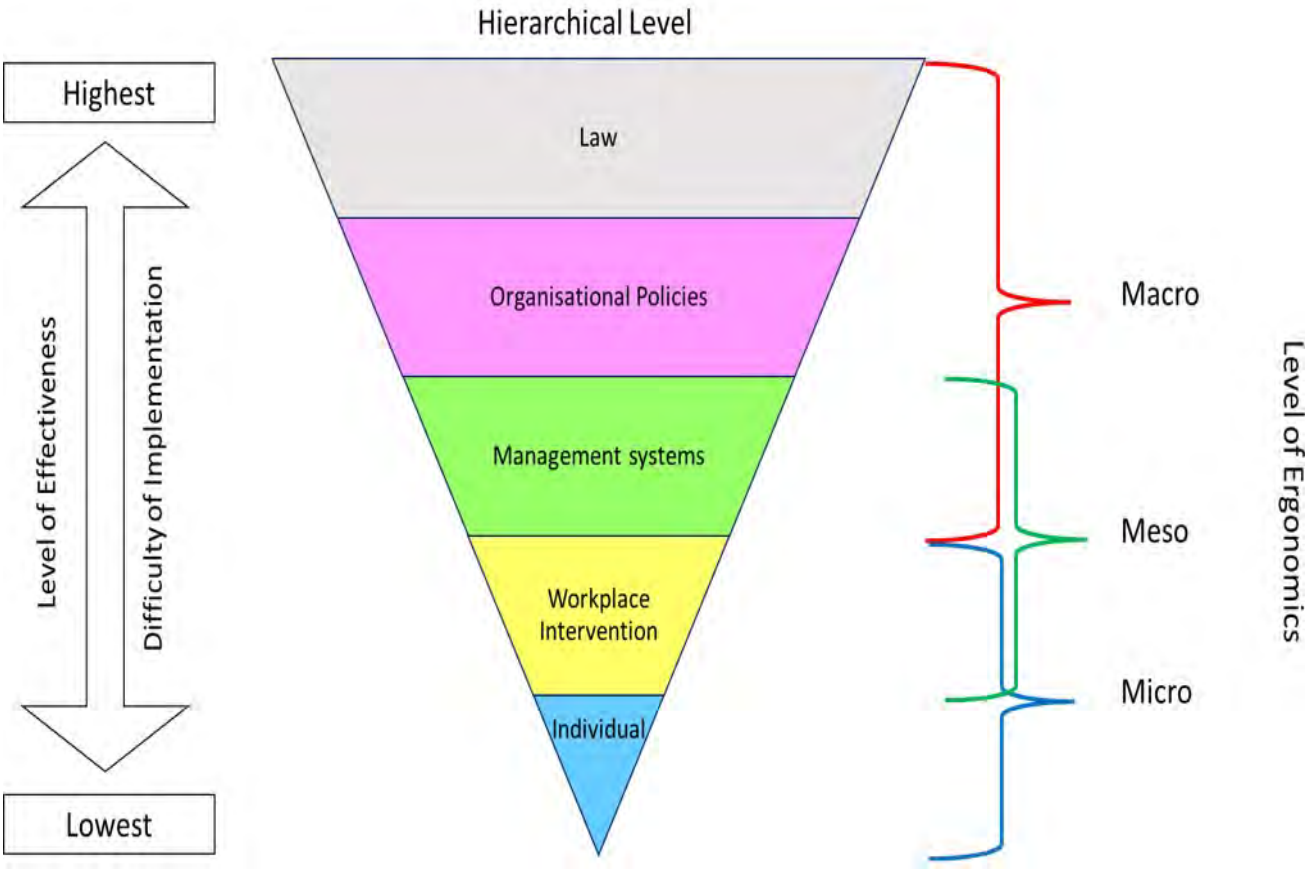

Figure 7. Conceptual Model for the usage of the MSD intervention framework

Figure 7 shows a conceptual model of how decisions on selecting MSD interventions using the draft framework should work. The most effective interventions are those placed higher up in the model; in this case, the macro-ergonomics interventions such as changes in the “Law”, “Organisational Policies”, and “Management Systems” (Oakman et al., 2018). However, these types of interventions are often time-consuming and challenging to implement; hence interventions at meso-ergonomics and micro-ergonomics levels were also displayed, such as changes to “Management Systems” and “Workplace Interventions” or those relating to interventions at the ”Individual” level respectively (represented by the brackets on the right side of the figure). As displayed, each ergonomics level encompasses more than a single hierarchical level in Figure 7; this is due to the researcher's ability to decide and define where the borders for each ergonomics level lie (Waterson et al., 2009). The inverted pyramid shape was chosen to visually assert how interventions at the higher levels of ergonomics can filter or “funnel” down to those below it, allowing users to understand, with one glance, at which level the most effective intervention should be in any organisation when trying to prevent or manage MSDs. The arrow on the left side of the figure indicates that it is more difficult to intervene at a macro-ergonomics level; however, the effectiveness of the intervention should be greater than if interventions were to take place at a micro-ergonomics level.

The objective of this study is to create a Draft Framework for MSD prevention and management and was achieved using the “Hierarchical Levels” in Figure 7. Interventions were then allocated to an “MSD prevention” and an “MSD management” table using the definitions and findings of the corresponding literature. For user clarification, a definition encompassing each of the sub-levels was added. In addition, the number of articles and the reference for those articles were added to the tables. Finally, notes on each intervention’s key findings and effectiveness were added to the respective article reference. In cases where some intervention strategies were only effective when implemented alongside another intervention strategy, the article notes were marked with an asterisk (*). A brief explanation of what the framework aimed to achieve and instructions on how to effectively use it was included in the document, and a navigation tool was also created to make user access easy and efficient. This tool consisted of an interactive

modification of Figure 7, whereby the sub-levels of the interventions are listed alongside the “Hierarchical Levels” with hyperlinks to their corresponding definition in the tables. The draft framework, as sent out to participants in Phase 2 of this research, is presented in Appendix A.

Table III. Information collected from MSD Prevention Review

Reference	Study Objective	Study Design	Findings
Amell & Kumar (2001)	"Review the concept of work-related MSDs and discuss the basis of prevention as a means to occupational injury and illness management." (pg. 256)	Narrative Review	• Government Regulations can be hard to implement but have been found to be the most effective intervention to prevent MSDs, as all companies are required to meet the standards set out by the regulations. • Surveillance Practices work as part of a secondary prevention strategy for early detection and treatment of symptoms before MSD development • Low vibration tasks reduced biomechanical risk as part of a prevention strategy • Risk assessments and workload analysis showed a reduction in MSD risk with correct intervention practices. • Tools that meet the limitations of the user may reduce MSD risk
Aptel et al. (2008)	"To suggest an approach for defining a workstation rotation system, which reduces MSD risk factors, and to list parameters enabling an efficient system to be set up." (pg. 901)	Descriptive	• Workstation/Job Rotation can effectively reduce psychosocial strain but with limited biomechanical risk mitigation • Risk assessments and workload analysis is vital in describing and identifying areas of risk for workplace modifications, both psychosocially and biomechanically
Asensio-Cuesta et al. (2012)	"The design of job rotation schedules that not only are ergonomically beneficial but also optimize the company's production performance by considering the workers' competences in their job assignments." (pg.1162)	Experimental	• Creating job rotation schedules using the ECRot algorithm tool has shown effective MSD prevention

Boocock et al. (2007)	"To fulfil this need (to update current knowledge of MSD programs) by conducting a systematic review and evaluation of the findings of primary/secondary and/or tertiary intervention studies for neck/upper extremity musculoskeletal conditions undertaken between 1999 and 2004." (pg. 292)	Systematic Review	• Workstation adjustment, alternative tools and equipment may reduce the upper extremity risk of MSDs • Strength and flexibility training was found to be • • effective in combination with other interventions
Caroly et al. (2010)	"To analyse the conditions required for this safety/production logic approach to be integrated in the 'continuous improvement' systems of French industry." (pg. 592)	Case Study & Experimental	• Continuous improvement, as part of participatory ergonomics (PE), and efficiency of workstations and tools used to prevent the MSDs. PE led to the innovation of MSD risk assessment • Active worker involvement provides an incentive for reduced-risk movements
Capodaglio (2020)	"To obtain a more defined risk assessment in relation to the critical activities carried out by maintenance personnel within the plant, to develop a better awareness of ergonomically sound methods and work practices in maintenance personnel and to identify priorities for measures to be implemented, in relation to the assessed risk." (pg. 2)	Descriptive & Experimental	• PE saw workers become more proactive in the mitigation of risk. • Training and education were effective in preventing MSD as part of an ergonomics program
Chim (2006)	"To identify the potential risk factors of MSDs for Kitchen Hands and to provide preventive strategies to eliminate or minimize the associated risk of MSDs." (pg. 2)	Descriptive	• Suggested a multi-modal assessment to test multiple components that contribute to a single task's workload

Choi & Woletz (2010)	"To synthesize the recent literature on workplace stretching exercise programs and their effects on reducing WMSDs in different occupational groups." (pg. 5)	Systematic Review	• Effective ergonomics programs reduce ergonomics risks using multiple interventions • Risk assessment is an essential step in an ergonomics program before any intervention • Biomechanical intervention was found to be effective as part of an ergonomics program • On-the-job stretching was found to be effective in combination with multiple other individual category interventions
Colombini & Occhipinti (2006)	"To summarize experiences of close cooperation between ergonomists, machinery designers and job designers to guarantee productivity and prevention of MSDs and to examine current ergonomics standards in the field of manual physical work and suggest preliminary criteria for their implementation." (pg.442)	Descriptive & Observational	• Workload analysis is essential in risk assessment programs • Increased need for collaboration between ergonomists and manufacturers to reduce MSD risk for successful workstation adjustment
Comper et al. (2017)	"To investigate the effectiveness of job rotation in reducing working hours lost due to sick leave for musculoskeletal diseases among industrial manufacturing workers." (pg.1)	Cluster Randomised Controlled Trial	• Job rotation led to a decrease in the wrist and hand MSDs

de Oliveira Sato & Cote Gil Coury, (2009)	'To compare long-term indicators of workers' health, through analysis of occurrences of previous sick leave due to musculoskeletal disorders, with relatively short-term indicators among individuals exposed to work variability.' (pg.708)	Cross-Sectional Descriptive	• Ergonomic Workplace Analysis (EWA) used to evaluate the workplace, tasks, and biomechanical risk • Use of RPE scales in measuring exertion to prevent overuse alongside an ergonomics task force
Denis et al. (2008)	"To paint a detailed and critical picture of the interventions published in the literature in order to (1) verify whether the traditional MSD prevention model is the one that actually predominates in the interventions reported, and if need be, to be able to explain possible differences; and consequently, (2) propose improvements to current intervention practices." (pg. 2)	Critical Review	• Continuous change works best with an Ergonomics Task Force to lead the changes. • Job Rotation resulted in a complete intervention • Risk Assessment was a crucial part of identifying the potential risk that may lead to MSDs, however only when combined with effective interventions • Workstation Adjustment allowed for prescribed and individual adjustments to be made after training • Changes/adaptations to standard tool design, as well as purchasing more ergonomically designed tools, were beneficial in risk reduction • Training could be effective when the broader context of the workplace is taken into consideration
Gangopadhyay & Dev (2014)	"To demonstrate the beneficial effect of a combined work design and ergonomics approach, especially for the redesign of a workstation." (pg.2)	Case Study	• Found using alternative tools to be effective as part of a complete ergonomics intervention program
Garg & Kapellusch (2009)	"Reviews and discusses applications of biomechanical principles and models to prevent musculoskeletal disorders (MSDs) in workplaces." (pg. 36)	Narrative Review	• Reduced biomechanical load to match the tissue capabilities of workers decreases MSD risk

Gerr (2005)	"To examine the effect of two workstation and postural interventions on the incidence of musculoskeletal symptoms among computer users." (pg.478)	Randomised Controlled Trial	• Workstation Adjustment was effective but not when done alone
Hochdörffer et al. (2018)	Develop an integer linear programming (ILP) based heuristic, which solves the scheduling problem gradually for each rotation round and generates a holistic job rotation schedule for an entire workday.	Explorative Experimental Design	• Creating long-term job rotation schedules using the BEQR method has shown a reduction in MSD risk
Holtermann et al. (2010)	"… describes the background, design and conceptual model of the FINALE programme, a framework for health promoting interventions…characterized by high physical work demands, musculoskeletal disorders, poor work ability and sickness absence." (pg. 1)	Randomized Controlled Trials And Exploratory Case-Control	• Exercise resulted in increased tissue capacity, which lowers MSD risk*
Huang & Feuerstein (2004)	"Provide an empirical basis for guiding future efforts to reduce/ eliminate the impact of specific workplace stressors on worker musculoskeletal health and associated costs." (pg.15)	Cross-Sectional Investigation	• The management style used may reduce the psychosocial component of MSD formation • Found that high-risk job categories can be easily identified through specific risk assessment throughout an organization • Reduction in biomechanical risk as part of a job redesign intervention mitigated risk • Reduction in cognitive stress may increase the tolerance of individuals, leading to a lower risk of MSDs

Jorgensen et al. (2005)	"To assess the current utilization of job rotation from a sample of manufacturers in the Midwest United States, and to ascertain the level of perceived benefits and limitations associated with the implementation of job rotation." (pg.1723)	Descriptive	• OHS provides guidelines on job rotation practices and recommendations • Job rotation effective in medium-term (5-8 years) MSD prevention with increased productivity, but only when assigned correctly. Incorrect job assignments could increase cumulative biomechanical exposure and risk of MSD development.
Kennedy et al. (2010)	"The research answers the following question: 'do OHS interventions have an effect on upper extremity musculoskeletal symptoms, signs, disorders, injuries, claims and lost time?'. Further, we seek to identify which specific types of OHS interventions are effective." (pg.128)	Systematic Review	• Training and education may reduce MSD risk • Workstation adjustment has a positive effect on MSD reduction only when paired with ergonomics training
Kogi et al. (2003)	"To discuss the types of simple improvements, which were achieved in work improvement action training activities in the Philippines and known to have reduced musculoskeletal load." (pg.180)	Narrative Review	• Low-cost tools decreased tissue loads
Kuijer et al. (2005)	"To evaluate the effect of job rotation in refuse collecting on the need for recovery, prevalence of musculoskeletal complaints, and sick leave due to musculoskeletal complaints." (pg.395)	1-Year Prospective Study	• Job rotation reduces peak biomechanical load. Incorrect job assignments could increase cumulative biomechanical exposure and risk of MSD development.

Leider et al. (2015)	"To summarise evidence on the effects of job rotation on musculoskeletal complaints, exposures related to musculoskeletal complaints and sustainable working life parameters." (pg.19)	Systematic Review	• Job rotation is beneficial if job demands are matched to workers' capabilities, e.g., rotation occurs between high demand and a low-demand task
Lima & Coelho (2011)	"To make an assessment of the risk of MSDs in 12 workstations of a recently built office workplace (in use for one year at the time of the observations) in Portugal." (pg.398)	Descriptive Cross-Sectional	• Workstation Adjustment is effective in preventing MSDs after installing ergonomics equipment for correct usage • Alternative Tool and Equipment was effective when the proper training to use the equipment was administered
Lincoln et al. (2000)	"To evaluate interventions for the primary prevention of work-related carpal tunnel syndrome." (pg.37)	Systematic Review	• Alternative Tool and Equipment is a positive short-term reduction in MSD risk • Training with new equipment or tools is important to reduce MSD risk
Norval et al. (2019)	"Proposes indicators of situational operational leeway to increase the representativeness and reliability of the risk assessment tools for MSDs." (pg.430)	Explanatory	• Operational Leeway has evidence for increased accuracy of MSD risk identification Risk Assessment is the first step in identifying where and what potential risks of MSD are in the workplace
Nunes (2009)	"Presents an ergonomic analysis tool, FAST ERGOX, designed to support ergonomic auditing activities related with work-related musculoskeletal disorders." (pg.133)	Descriptive Case-Study	• User input is tested against historical correlations and knows the causes of MSDs to produce an evaluation and recommendation to reduce risk

Oakman et al. (2018)	"Investigated current workplace risk management practices in two industry sectors with a high risk of both MSDs and MHDs and evaluated the extent to which risk from psychosocial hazards is being effectively managed." (pg.220)	Cross-Sectional Exploratory	• OHS Councils have lists of identified risks and undesirable behaviors to avoid, which may reduce MSD risk. • Training and Education can be helpful, especially when introducing new tools or equipment. Training workers to identify potential risks of MSD can also lead to increased early intervention • Largely ignored in the assessment process, and thus no interventions occurred. It may reduce MSD risk. • The assessment process largely ignored psychological stress reduction; thus, no interventions occurred. May reduce MSD risk
Otto & Battaïa (2017)	"Provide an overview of the existing optimization approaches to assembly line balancing and job rotation scheduling that consider physical ergonomic risks." (pg.467)	Survey	• Job rotation reduced cumulative biomechanical load under a balanced schedule
Ouellet & Vézina (2014)	"To contribute new knowledge to the issue of company training, and to propose changes to a company concerning training content, training organization and the learning conditions of apprentices so as to more successfully prevent MSDs." (pg.24)	Descriptive Study and Experimental Longitudinal Study	• Training alone is not effective; however, when paired with learning conditions, it may result in reduced MSD risk

Padula et al. (2017)	“1) How do job-rotation programs impact work-related musculoskeletal disorders (MSDs) and related risk control for these MSDs, as well as psychosocial factors? and 2) How best should the job rotation programs be designed?” (pg.386)	Systematic Review	• Taskforce used to design job rotation schedules effectively
Pavlovic-Veselinovic et al. (2016)	“Outlined the development of an ergonomic expert system (SONEX) that has been designed to be implemented for widespread everyday use by ergonomists, other experts, and even end-users themselves.” (pg.138)	Descriptive	• SONEX computer expert system tool used to replicate human problem-solving abilities
Rissén et al. (2002)	“To evaluate the effects of the introduction of a job rotation model on supermarket cashiers, with respect to psychophysiological stress reactions, muscle activity of the trapezius muscle and musculoskeletal symptoms in the neck and shoulders.” (pg.128)	Pre-Post Experimental Study	• Job rotation resulted in a decrease in awkward postures
Schroeder (2005)	“Describes one program that has been successful in reducing work-related MSD in a packaging manufacturer.” (pg.48)	Case Study	• The ergonomics program successfully identified and managed risks for MSDs, thus preventing future MSD occurrence
Shoaf et al. (2000)	“To develop a comprehensive work system model, to optimize human performance in the workplace, which captures the individual and interactive effects of these singular variables.” (pg.35)	Descriptive	• Risk assessment provides a systematic approach to assessing risk. Notes that accurate descriptions of risks and hazards can lead to more effective MSD prevention

Winnemuller et al. (2004)	"To measure the comparative ability of employers, represented by their supervisors and workers, to assess the MSD risk factors present in the jobs at their workplace." (pg.414)	Cross-Sectional	• Using a non-ergonomics specialist to do the initial risk assessment check was suitable for MSD prevention; however, a more detailed examination of tasks required an ergonomist's input.
Yan et al. (2017)	"This study developed a real-time motion warning personal protective equipment (PPE) that enables workers' self-awareness and self-management of ergo-nomically hazardous operational pattern for the prevention of WMSDs based on wearable Inertial Measurement Units (WIMUs)." (pg.2)	Exploratory	• The use of PPE increased self-management of risk during task performance
Yazdani et al. (2015)	"To both identify and summarize the available evidence on embedding the prevention of MSD within OHSMS and thus integrating this specific aspect of prevention into an organization's management system." (pg.255)	Scoping Review	• OHS/NIOSH Regulations provide a systematic approach to preventing all injuries, not just MSDs • Participatory ergonomics increased acceptance of interventions by workers • During continuous organizational change, feedback from workers is vital to ensure that the changes are not negatively affecting another part of the system • Multiple assessments are crucial in the initial risk identification process, especially in an ergonomics program
Yazdani & Wells (2018)	"To identify the common barriers experienced during the implementation of MSD prevention activities, as well as determine facilitators for the implementation process." (pg.122)	Scoping Review	• Participatory ergonomics is effective for the prevention of MSDs in an isolated part of the business without affecting the whole business • The use of ergonomists throughout the design increased the effectiveness of MSD prevention

Yazdani et al. (2018)	"This study examines key informants' perspectives on the integration of MSD prevention programs into management systems as a solution to issues associated with isolated or separate programs." (pg.110)	Qualitative Cross-Sectional	• During continuous organizational change, the implementation of 'end users' feedback is key for effective long-term intervention
Yu et al. (2013)	"Evaluated the effectiveness of participatory training and didactic training programs on MSD prevention among frontline workers in Shenzhen, China." (pg.431)	Randomised Control Trial	• Participatory ergonomics training • Reduced occurrence of lower extremity MSDs
Ziam et al. (2020)	"To examine the application of MSD prevention practices among nursing staff and to identify organizational factors that may or may not support their application." (pg.1)	Exploratory Survey	• On the job, context-specific training is more beneficial, especially when a participatory ergonomics approach is taken

Table IV. Information collected from MSD Management Review

Reference	Study Objective	Study Design	Outcome
Abdollahi et al. (2020)	"This study aimed to examine the effect of an ergonomics educational program on MSDs among nursing staff working in the operating room." (pg.1)	Quasi-Randomized Controlled Trial (Pre-Post)	• Training and education decrease the prevalence and risk of MSDs
Andrén & Svensson (2012)	"To examine if it is beneficial for individuals on sick leave due to MSDs to be on part-time sick leave compared to full-time sick leave." (pg.418)	Explanatory	• Occupational Health Physician have a better evaluation of RTW schedule than General Practitioners for workers with MSDs • Part-time sick leave increased the likelihood of recovering from MSDs and RTW in less time
Barredo & Mahon (2007)	"Examines the effects of exercise (irrespective of technique) and rest breaks (irrespective of length and frequency) on musculoskeletal discomfort during computer task." (pg.151)	Systematic Review	• Exercise moderately decreased MSD symptoms
Bolton & Cox (2015)	"To establish whether the current training of student sonographers in both academic and clinical settings is sufficient for educating about the dangers of work-related musculoskeletal disorders (WRMSDs)." (pg.145)	Survey	• Rehabilitation with strength and conditioning programs can decrease MSD symptoms and increase RTW • Prescribed exercise decreased MSD symptoms • Training had a positive effect on risk and symptom management

Boocock et al. (2007)	"To fulfil this need (to update current knowledge of MSD programs) by conducting a systematic review and evaluation of the findings of primary/secondary and/or tertiary intervention studies for neck/upper extremity musculoskeletal conditions undertaken between 1999 and 2004." (pg.292)	Systematic Review	• Workstation Adjustments decreased the risk of worsening MSD symptoms • Exercise decreased MSD symptoms and associated pain with multiple interventions
Bornhöft et al. (2019)	"To evaluate the cost-effectiveness from the societal perspective of this new care pathway through primary care regarding triaging patients with MSD to initial assessment by physiotherapists compared to standard practice with initial GP assessment." (pg.1)	Randomised Controlled Trial	• Triage employees as they report MSDs to keep track of the severity of the disorder as part of a surveillance practice • Physiotherapy led to decreased sick leave and MSD symptoms. Physiotherapy also had a lower cost than a GP for similar results
Bouffard et al. (2019)	"To provide workplaces with an adapted tool to support them in managing GRTWs (gradual return to work)." (pg.625)	Mixed Methods Explanatory	• Gradual RTW programs with MM (margin of manoeuvre) allow for a decrease in MSD symptoms as workers have the latitude to complete a task using their own method.
Breloff et al. (2019)	"To determine if a knee pads and/or knee savers are able to reduce knee MSD risk in a roofing environment." (pg.2)	Repeated Measures Experimental	• Alternative tool and equipment decreased biomechanical load and risk of aggravation to the disorder if used correctly

Butwin et al. (2017)	"What combination of mind-body techniques, taught to a cohort of novice sonography students, would provide a reduction in the risk of WRMSDs?" (pg.393)	Exploratory	• Biofeedback training with appropriate education decreased MSD symptoms • Mindfulness training decreased the risk of aggravation and reduces MSD symptoms
Caplan et al. (2017)	"To determine the association of community-based physiotherapy treatment for musculoskeletal pain with changes in HRQoL, and to determine whether these associations are influenced by the anatomical site of pain." (pg.1)	Retrospective	• A decrease in MSD symptoms with physiotherapy
Cochrane et al. (2017)	"To determine the effectiveness of early multidisciplinary interventions in promoting work participation and reducing work absence in adults with regional musculoskeletal pain." (pg.1466)	Systematic Review, Meta-Analysis	• RTW programs with Part-time sick leave have resulted in reduced symptoms • Early intervention and rehabilitation decreased the RTW time of MSD patients
Coskun Beyan et al. (2020)	"Purposed to determine the prevalence of MSC and workers' perceptions of the ergonomic risk factors that could contribute to work-related injury, and to evaluate the effect of tailored ergonomic interventions on self-reported musculoskeletal wellbeing parameters in ICU nurses, based on ergonomic risk assessment." (pg.2)	Pre-Post Experimental	• Ergonomics Program Encompassing multimodal interventions has been effective in managing MSDs • Exercise led to a decrease in MSD symptoms • Training and Education are effective but only in multimodal interventions

Cullen et al. (2018)	"To synthesize evidence on the effectiveness of workplace-based return-to-work (RTW) interventions and work disability management (DM) interventions that assist workers with musculoskeletal (MSK) and pain-related conditions and mental health (MH) conditions with RTW." (pg.1)	Systematic Review	• Decreased RTW time and symptoms with multiple interventions, especially CBT • Cognitive Behavioral Training led to decreased RTW time for MSD patients
Decker et al. (2016)	"To determine the short-term effects of wearing the Posture Shirt: on objective functional assessments of head and shoulder posture, respiratory function, and manual strength; and as subjective perception of fatigue, energy level, and productivity in the workplace." (pg.551)	Exploratory	• A novel elastic garment that may reduce MSD symptoms and risk
Desmeules et al. (2012)	"To update the evaluation of the expanding role of advanced practice/extended scope physiotherapists in the management of patients with musculoskeletal disorders." (pg.1)	Systematic Review	• Physiotherapy decreased MSD symptoms and RTW time
Donovan et al. (2017)	"To determine whether a workplace-based early intervention injury prevention program reduces work-related musculoskeletal compensation outcomes in poultry meat processing workers." (pg.24)	Retrospective Analysis	• Decrease the delay between diagnosis and interventions, thus decreasing the severity of MSD symptoms (early recognition is vital). It also led to a reduction in treatment costs due to MSDs • Medical surveillance was used as part of an initial prevalence survey to intervene early in MSD onset and decrease compensation claims

Grayson et al. (2004)	"To describe the implementation of the ergonomic evaluation program, including the extent to which recommendations generated from this program were implemented in the workplace." (pg.451)	Experimental	• Conducting ergonomics evaluations to perform risk assessments on the individuals, specific tasks and the worker capabilities to promote a return to work
Hu et al. (2020)	"To provide current evidence on the mechanism of action, clinical applications, and controversies of PEMFs in musculoskeletal disorders." (pg.2)	Narrative Review	• Novel treatment using Pulsed Electromagnetic Fields (PEMFs) may decrease MSD symptoms in selected cases
Hutting et al. (2019)	"Argue that self-management strategies are essential to the management of persistent musculoskeletal disorders and outline the physical therapist's role in supporting effective self-management." (pg.1)	Viewpoint	• Non-invasive Medical Treatment, along with self-management practices, led to long-term reductions in MSD symptoms • Training is used to increase independent self-management of symptoms and pain
Jakobsen et al. (2015)	"Investigated the effect of workplace versus home-based physical exercise on musculoskeletal pain among healthcare workers." (pg.153)	Randomized Controlled Trial	• Appropriate ergonomics training with exercise reduces MSDs and the risk of MSDs
Jakobsen et al. (2018)	"To evaluate the effect of workplace versus home-based physical exercise on pressure pain threshold and musculoskeletal pain intensity in multiple body regions among healthcare workers." (pg.89)	Secondary Analysis of Cluster-Randomized Controlled Trial	• Workplace-based exercise with ergonomics training reduced MSD-related pain

Kuijer et al. (2005)	"To evaluate the effect of job rotation in refuse collecting on need for recovery, prevalence of musculoskeletal complaints, and sick leave due to musculoskeletal complaints." (pg.395)	Pre-Post Perspective Study	• Job Rotation decreased cumulative load exposure in workers and reduced MSD symptoms and future risk
Larson (2012)	"Provides a brief summary of both types of ergonomics program strategies and describes my experiences leading two corporate ergonomics programs." (pg.29)	Narrative Review	• Macro-level interventions led to decreased MSD symptoms and related costs
Legge et al. (2013)	"To evaluate the validity of a job-specific pre-employment functional assessment in terms of its ability to predict musculoskeletal injury risk in healthy mine workers in the Australian coal mining industry." (pg.2208)	Prospective Cohort Study	• Pre-employment screening to match worker capacity to the demands of the task assigned to them decrease MSD risk
Lloyd et al. (2008)	"To examine current evidence for any added impact of depression on return-to-work prospects among people with work-related musculoskeletal disorders." (pg.23)	Review	• Psychosocial Enhancement increased the effect of the RTW program and prescribed treatment
Mansi et al. (2014)	"To investigate the evidence for effectiveness of pedometer-driven walking programs to promote physical activity among patients with musculoskeletal disorders (MSDs)." (pg.1)	Systematic Review	• Pedometer usage increased physical activity and functionality in lower limb MSDs. It also reduced MSD-related pain

Marinho & Pereira (2020)	“To assess the available evidence on the efficacy and safety of the topical formulations of the NSAID etofenamate in patients with musculoskeletal disorders.” (pg.393)	Systematic Review	• Nonsteroidal Anti-Inflammatory Drugs (NSAIDs) decreased the pain and symptoms of MSDs
Masiero et al. (2020)	“To evaluate pain reduction in people with musculoskeletal disorders using continuous SWD at 4 or 8 MHz frequencies, according to a personalized administration protocol.” (pg. 981)	Observational Study	• Short Wave Diathermy (SWD) reduced pain in MSD patients
Mehrparvar et al. (2014)	“Compared the effect of ergonomic modifications and workplace exercises on musculoskeletal pain and discomfort in a group of office workers.” (pg.1)	Interventional Study	• Workstation Adjustments decreased MSD complaints and symptoms • Exercise reduces MSD symptoms
Melhorn et al. (2001)	“To review successful examples of prevention and management of MSDs in the workplace using an individual and job risk assessment instrument.” (pg.1802)	Narrative Review	• A comprehensive ergonomics program creates an opportunity for better MSD management • Screened workers pre-employment to monitor potential MSD risk • Alternative tools decreased the severity of MSD symptoms

Menta et al. (2015)	"To evaluate the effectiveness of exercise compared to other interventions, placebo/sham intervention, or no intervention in improving self-rated recovery, functional recovery, clinical, and/or administrative outcomes in individuals with musculoskeletal disorders and injuries of the elbow, forearm, wrist, and hand." (pg.507)	Systematic Review	• Exercise is effective but only as part of a multimodal intervention
Moore et al. (2006)	"To establish the current state of knowledge regarding risk factors, interventions, and barriers to their implementation." (pg.1)	Systematic Review	• OHS programs which address existing, previously identified hazards may lead to increased effectiveness of MSD management techniques • Early risk detection and intervention after early reporting of MSDs • Tools suited to the task being performed and that was maintained correctly reduced MSDs*
Oakman & Bartram (2017)	"To examine whether occupational health and safety (OHS)management used to manage musculoskeletal disorders (MSDs) in the aged care sector reflects contemporary research evidence of best practice to reduce the incidence of these disorders." (pg.331)	Descriptive	• Programs addressing the OHS mandate showed a decrease in psychosocial and physiological risk of MSD and decreased MSD symptoms
Oranye et al. (2017)	"To compare workers' perception and experience of workplace policies and practices on injury prevention, people-oriented work culture, and return to work." (pg.69)	Survey-Based Descriptive	• A safety-first approach to RTW led to reduced sick leave

Pascual & Naqvi (2008)	"To investigate which ergonomics tools were used most often in industry and how easy they were to use, investigate the ergonomics risk assessment methods used by JHSCs, and examine the ergonomics content in the curriculum taught to JHSCs." (pg.238)	Survey-Based	• Alternative tool use is effective in reducing MSD symptoms with training on proper usage
Pintakham & Siriwong (2016)	"To evaluate the effectiveness of multidimensional ergonomic intervention (MEI) model to reduce musculoskeletal discomfort (MSD) among street sweepers." (pg.275)	Quasi-Experimental Study	• The multimodal approach showed a reduction in MSD symptoms
Prall & Ross (2019)	"To describe the effect that work-place injuries have on employees and the economic burden on employers." (pg.194)	Narrative Review	• Stretching and strengthening exercises decreased pain and increased RTW success when done • Training and education increased the RTW effectiveness and reduced pain
Purnomo et al. (2017)	"This research study used the macro-ergonomic analysis design (MEAD) methodology, which focuses on systematically mapping out organisational problems and solutions by involving all work system elements. The related macro-ergonomic research proposes to improve work satisfaction and decrease MSD symptoms." (pg.48)	Descriptive	• Macro Ergonomic Analysis Design (MEAD) decreased the risk of MSD reoccurrence and reduced symptoms

Randhawa et al. (2015)	"To determine the effectiveness of structured patient education for the management of musculoskeletal disorders and injuries of the extremities." (pg.350)	Systematic Review	• Corticosteroid injections provide short-term pain relief • Exercise is only effective in multimodal interventions • Training and education may offer a long-term solution to MSD management
Rose et al. (2020)	"The objective of this paper is to facilitate the application of RAMP to systematically manage MSD risks, and thereby contribute to the reduction of MSDs globally." (pg.3)	Descriptive	• Surveillance Practices as part of the Risk Assessment and Management tool for manual handling Proactively (RAMP) to manage and reduce MSDs
Rostykus & Mallon (2017)	"Details the few leading measures specific to MSDs that are proven to ensure leadership support and resources, and to sustain the ergonomic improvement program across multiple locations and across time." (pg.37)	Narrative Review	• Assessment of risk allows for early interventions to reduce risk and MSD prevalence
Schakenraad et al., (2004)	"To evaluate the effect of a multidisciplinary treatment programme on well-being, disability and return to work in patients with chronic non-specific upper-limb disorders." (pg.576)	Longitudinal And Uncontrolled Design With Pre-Post	• Return to work programs decreased upper limb MSD symptoms when a multidisciplinary approach was taken

Shariat et al. (2018)	"To evaluate the effectiveness of exercise, ergonomic modification, and a combination of training exercise and ergonomic modification on the scores of pain in office workers with neck, shoulders, and lower back pain." (pg.144)	Randomized Controlled Trial	• Workstation Adjustments with exercise may reduce pain in the long term • Exercise reduces MSD pain
Sherrod et al. (2013)	"Describes the case management of musculoskeletal disorders for an employee in a college work environment using both chiropractic care and applied ergonomics." (pg.45)	Case Study	• Workstation Adjustments with proper training may lead to long-term reductions in MSD symptoms • Non-invasive Medical Treatment decreased MSD-associated pain.
Smith et al. (2016)	"To systematically review the literature describing the prevalence, impact and current management of musculoskeletal pain in older people living in care homes." (pg.55)	Systematic Review	• Psychosocial Enhancement Helped decrease pain
Smith-Young et al. (2014)	"To understand workers' perspectives on how they managed to work after they developed a WMSD." (pg.218)	Interview Explorative	• Cognitive behavioural training was used as a coping mechanism in patients with severe pain.
Southerst et al. (2015)	"The purpose of this study was to critically appraise and synthesize evidence on the effectiveness of noninvasive interventions, excluding pharmacological treatments, for musculoskeletal thoracic pain." (pg.521)	Randomized Controlled Trial	• The multimodal intervention increased self-reported improvement

Stanos (2007)	Describes the effects of topical agents on relieving MSD pain	Narrative Review	• Topical NSAID decreases the local pain associated with MSDs
Tsertsvadze et al. (2014)	"To systematically review trial-based economic evaluations of manual therapy relative to other alternative interventions used for the management of musculoskeletal conditions." (pg.343)	Systematic Review	• Manual therapy decreased some MSD symptoms. * Could decrease the cost of treatment when aligned with GP recommendations
van Niekerk et al. (2012)	"To appraise the evidence base for the effectiveness of a chair intervention in the workplace to reduce musculoskeletal symptoms." (pg.1)	Systematic Review	• Workstation Adjustments With training, they may reduce MSD symptoms
Vermeulen et al. (2009)	"To describe the structured and stepwise process of development, implementation and evaluation of a theory-and practise-based participatory RTW program for temporary agency workers and unemployed workers, sick-listed due to musculoskeletal disorders (MSD)." (pg.1)	Exploratory	• A participatory approach to designing an RTW program using the Intervention Mapping protocol decreased MSD symptoms and increased faster RTW
Viikari-Juntura et al. (2012)	"To assess the effects of early part-time sick leave on return to work (RTW) and sickness absence among patients with musculoskeletal disorders." (pg.134)	Randomized Controlled Trial	• Early part-time sick leave decreased RTW time and increased full recoveries of MSDs • Workstation Adjustments as a part of part-time sick leave reduced MSD symptoms by reducing the time spent performing the task

Waddell (2006)	Proposes the use of the biopsychosocial model to understand the incapacity of non-specific conditions	Narrative Review	• Promoting a positive attitude towards RTW and rehabilitation; decreased time of MSD-induced sick leave • Screening with work modifications decreased MSDs • Workstation changes based on post- screening recommendations may decrease symptoms • Used the biopsychosocial model to address MSDs, resulting in a decrease in MSD symptoms and a reduction in the catastrophizing of existing disorders. Increase the effectiveness of RTW programs

3.4 Discussion

Two main approaches to musculoskeletal intervention strategies are indicated in the literature. “MSD prevention” focuses on reducing risk and placing controls to avoid these disorders from occurring. “MSD management”, on the other hand, aims to prevent the aggravation of MSDs once they have occurred by reducing symptoms and, therefore, the disorders’ impact on both the individual’s well-being and the work performance by accommodating the altered capabilities of individuals with such disorders (Wells, 2009; Yazdani & Wells, 2018). The scoping review considered both types of MSD intervention approaches; however, although all interventions found were reported to be effective in combating MSDs, the extent to which they were effective was not analysed. This was due to some interventions only being labelled effective when they were used in conjunction with another or multiple other interventions. Furthermore, the author of this thesis believed that since the intervention strategies could be used in various contexts, the effectiveness of interventions would most likely also change according to the context and the number of different MSD interventions used.

3.4.1. MSD Prevention Strategies

The scoping review resulted in sixteen MSD prevention strategies, presented under the “Hierarchical Sub-Level” across forty-two articles grouped by their definition into insert a summary table of the levels, sub-levels and definitions (Table V). The review results largely agreed with the works of Oakman et al. (2018) and Rasmussen (1997), who stated that interventions falling under the “Law” and “Organisational Policies” sub-levels were more effective but could be very time-consuming and expensive to implement. Articles reporting on interventions falling into the categories of “Management Strategies”, “Workplace Intervention”, and “Individual” levels also concurred with the works of Oakman et al. (2018) and Rasmussen (1997), who found that the interventions at the lower ergonomics levels, although more abundant, were less effective in overall MSD prevention.

Table V. MSD Preventions grouped by Hierarchical Sub-Level

Hierarchical Level of Framework	Hierarchical Sub-Level	Definition
Law	Government Regulations	Rules set out by government for all bodies to adhere to. Includes minimum standards and expectations of both employers and employees
	OHS/NIOSH Regulations	Recommendations and guidelines set by Occupational Health and Safety bodies to systematically improve health and safety in the workplace. These include regulations regarding injury and preventative practices that can be assessed against the policies implemented by organisations.
Organisational Policies	Participatory Ergonomics & Operational Leeway	Policy whereby the workers are involved in the development of the intervention, using their knowledge of the workplace alongside expert knowledge to create a suitable preventative approach. Examples of participatory ergonomics include using training surrounding risk and ergonomics awareness of MSDs and MSD prevention, and collecting feedback from workers to then incorporate changes into the organisation's prevention plan.
	Continuous Organisational Changes	Systematic changes to the current policy or intervention strategy in an organisation to increase the scope of the intervention practices over time. This in turn allows for multiple level interventions to be implemented as the ergonomist or team conduct risk assessments and various intervention strategies form a policy that best fits the particular organisation within which it is implemented in.
	Ergonomics Task Force/ Expert Systems	A task force or program responsible for evaluating tasks, assessing risk and making informed decisions on how to intervene to prevent MSDs, using evidence based off the initial assessment. The process is then repeated with the new interventions
Management systems	Surveillance Practices	Programs for the screening of employees over the course of employment
	Workstation/ Job Rotation	The systematic rotation of employees from one task to another after a set amount of time to reduce repetitive movements and overuse of particular body parts, in an effort to lower risk and increase rest
	Management Style	The ability for employees to provide feedback to managers or supervisors about potential risks, safety concerns or ideas promoting safety

Workplace Intervention	Low Vibration	Reduction in vibration-based tasks
	Risk Assessment and Workload Analysis	The use of appropriate ergonomics risk assessment tools to identify both potential and current medium and high-risk tasks/workstations and application of interventions to mitigate the risk prior to MSD development.
	Physical Demand Reduction/ Biomechanical intervention	Interventions to reduce the effect of vibrations, high loads, awkward postures and other biomechanical hazards
	Workstation Adjustment	Changes to the physical workstation to meet the needs of the user, including layout, equipment set up and tool usage.
Individual	Alternate Tool and Equipment	Tools that are ergonomically designed to reduce awkward postures, strains, vibrations, and high loads, thus reducing the risk of MSD formation, especially in high repetition tasks
	Exercise	Stretching, at home or on-the- job strength and conditioning programs or physical activity.
	Training and Education	Programs or courses that teach the basic principles of ergonomics, risk and hazards to workers. This allows for the assessment and mitigation of risks and hazards to prevent MSDs
	Cognitive Stress Reduction/ Psychosocial Enhancement	Training, support, and educational practices that are aimed at decreasing the psychosocial risk of MSD development

Law Level

At the highest level of MSD prevention, especially under the sub-level “Government Regulations”, intervention strategies were effective when implemented, particularly where business compliance leads to changes in how work is done (Amell & Kumar, 2001). Under the “Occupational Health and Safety (OHS)/National Institute for Occupational Safety and Health (NIOSH) Regulations”, the three articles in question identified that NIOSH, Occupational Safety and Health Administration (OSHA), and OHS regulations act as guides to a wide range of occupational health disorders, including MSDs (Jorgensen et al., 2005; Oakman et al., 2018; Yazdani et al., 2015). The NIOSH and OSHA guidelines for potential and established risk factors and controls aimed at preventing work-related MSDs. However, the

literature indicates that these recommendations were mainly followed by businesses to comply with the law rather than reduce MSD risk. They, therefore, did not have the reach intended by an intervention higher up on the hierarchy of levels (Figure 7) (Jorgensen et al., 2005; Oakman et al., 2018; Yazdani et al., 2015). Although these guidelines assist in preventing MSDs as they require compliance from businesses, they are not specific to the prevention of any particular MSD. The regulations and guidelines available pertaining to MSDs do so broadly, which may suggest that interventions at the level of the law should be a precursor to increasing the likelihood of companies and individuals to implement a combination of interventions at lower hierarchical levels.

Organisational Policies Level

At the “Organisational Policies” level, the focus was on strategies that, when implemented correctly, affect every individual and task occurring in an organisation to prevent MSDs. It must be noted that although the literature does not differentiate between sectors or industries in which these interventions took place, the interventions need to be tailored to the business or organisation where the intervention is to be implemented. Within this hierarchical level, three main sub-levels were identified from eighteen studies, the first being “Participatory Ergonomics and Operational Leeway”, which relate to the inclusion of workers in developing an identification and intervention plan for dealing with MSDs and using their knowledge in conjunction with an ergonomist’s input to create a suitable intervention approach. Studies found that the use of participatory ergonomics and operational leeway increased worker buy-in (Capodaglio, 2022; Yazdani et al., 2015), increased effectiveness and innovation in task design and risk detection (Caroly et al., 2010; Norval et al., 2019) and reduced MSD occurrences (especially in the lower extremities) (Yu et al., 2013). However, these studies also indicated that benefits were only seen if the approach was applied correctly and workers’ feedback was suitably incorporated into the prevention tactics. Doing so can be very time-consuming, depending on the number of tasks and individuals working at the organisation.

The second intervention sub-level refers to “Continuous Organisational Changes”, where the organisation’s policies regarding implementing preventative strategies

systematically expand in scope, allowing for increased intervention over time. This type of intervention was highly effective for multiple-level interventions when led by an ergonomics expert or an ergonomics task force (Denis et al., 2008). A vital part of this approach is the continuous feedback of workers to reduce the effect of potential adverse outcomes of such a high-level intervention and ensure long-term sustainable prevention (Caroly et al., 2010; Yazdani et al., 2015, 2018). As such, the use of a participatory approach and incentives for feedback and reporting were seen to be a priority to ensure the success of these interventions (Caroly et al., 2010; Yazdani et al., 2015).

The third intervention sub-level under “Organisational Policies” was the use of an “Ergonomic Task Force or Expert Systems”, where a group of experts or an expert program is used to assess and devise intervention recommendations for the prevention of MSDs (Nunes, 2009; Padula et al., 2017). Two of the six studies found in the literature focused on using expert computer programs to prevent MSDs. Expert systems programs have been shown to replicate human problem-solving to make recommendations based on historical knowledge; however, using such software to design and oversee a complete ergonomics program is still untested (Nunes, 2009; Pavlovic-Veselinovic et al., 2016). Thus, the use of an ergonomics task force is still seen as the preferred option, as studies have shown that programs designed and overseen by the task force (such as job rotation, task design and risk assessments) are highly effective in identifying potential MSD risks and mitigating them through the use of controls in a variety of contexts (Choi & Woletz, 2010; Padula et al., 2017; Schroeder, 2005; Yazdani & Wells, 2018).

The use and implementation of interventions at an organisational level should not be taken lightly. It is easy to be distracted by what a “perfect” theoretical program would be without addressing the contextual and individual needs of the work at hand (Woods & Cook, 2002). Therefore, the importance of expert knowledge cannot be emphasised enough, as any intervention at the macro-level not only drives the meso- and micro-levels but also affects the already emerging properties of the system in which it acts (Rasmussen, 1997; Wilson, 2014; Woods & Cook, 2002). In other words, changes implemented at the organisational level must be continuously monitored for their effects throughout the system, as they can result

in undesirable outcomes that may not be obvious to practitioners. Therefore, an understanding of the context in which these interventions are implemented, as well as the system(s) as a whole, is vital to ensure MSD prevention is attained throughout the organisation as a whole (Melo & Costa, 2020; Wilson, 2014; Woods & Cook, 2002).

Management Systems Level

The third intervention tier is the managerial level, where the interventions straddle the macro- and meso-levels of ergonomics. At this point, interventions still encompass many tasks and individuals, but the focus is on the interactions lower down in the hierarchy (Rivera-Rodriguez et al., 2013). The first strategy identified was “Surveillance Practices”, where employees are screened throughout their employment to track the effects of their work on their physical and mental well-being. When used as an MSD prevention strategy, surveillance practices were found to be an early detection technique to identify risks and hazards through MSD, such as symptoms experienced by individuals, to intervene before MSDs developed (Amell & Kumar, 2001). Such intervention only works as an identification tool and should be used alongside an intervention suitable to mitigate the identified risks. It also involves a continuous need to screen employees, which may be costly and disruptive to work processes (Amell & Kumar, 2001).

A well-researched strategy for MSD prevention at the level of Management Systems is “Workstation or Job Rotation”. Studies relating to rotation highlighted that although the effectiveness of job rotation in reducing MSD risk is high, it can also be detrimental if not designed and implemented correctly. Some studies showed that well-designed job rotation schedules resulted in decreased cumulative and peak biomechanical strain and reduced awkward postures if schedules were balanced and designed with the individual in mind (Aptel et al., 2002; Jorgensen et al., 2005; Kuijer et al., 2005; Leider et al., 2015; Otto & Battaïa, 2017; Rissén et al., 2002). However, Jorgensen et al. (2005), Kuijer et al. (2005), and Otto & Battaïa (2017) all warned that incorrectly designed schedules could lead to an increase in cumulative biomechanical load and therefore increase the risk of MSDs occurrence. As with “Organisational Policies”, using expert knowledge in the context of interventions and systems is vital if job rotations are to be carried out for

effective MSD prevention. Expert knowledge may also be necessary as, in some cases, job rotation was only found to be effective as part of an ergonomics program or when implemented in conjunction with secondary intervention strategies (Asensio-Cuesta et al., 2012; Denis et al., 2008; Padula et al., 2017).

Finally, “Management Style(s)” that promote the reporting of MSD risks to management were found to increase the identification of MSD risk factors and reduce the psychosocial component of MSD development (Huang & Feuerstein, 2004). This is particularly important as many MSDs are underreported; therefore, employees are empowered to report signs and symptoms if the management style is one that encourages and welcomes this and may thus result in early detection and intervention (Morse et al., 2004; Strazdins & Bammer, 2004).

Workplace Intervention Level

At the fourth level of MSD prevention, the focus is on the interactions between the task, the environment, and the individual. The results of the scoping review identified four main intervention strategies. At this level, most interventions, although easy to implement, are ineffective in isolation and may need to form part of a greater ergonomics program to prevent MSDs or be implemented in combination with other interventions at this level.

Under the “Low Vibration” sub-level, Amell & Kumar (2001) identified that lowering vibration in high-vibration environments was key to reducing the biomechanical risks associated with MSDs. The second strategy identified under the “Workplace Intervention” hierarchical level was classified as “Risk Assessment and Workload Analysis” techniques, where appropriate ergonomics tools were used to identify potential medium and high-risk tasks and workstations to allow for interventions to take place before MSDs developed (Aptel et al., 2002; Denis et al., 2008; Norval et al., 2019; Yazdani et al., 2015). Many studies identified the use of these techniques as an essential initial step towards MSD prevention if used within an ergonomics program or with the appropriate intervention to mitigate the risk (Amell & Kumar, 2001; Chim, 2006; Choi & Woletz, 2010; Colombini & Occhipinti, 2006; Denis et al., 2008; Huang & Feuerstein, 2004; Norval et al., 2019; Yazdani et al., 2015). A study by Winnemuller et al. (2004) noted that even a non-specialist could perform the initial risk screening due to the systematic approach and the easy-to-

use nature and availability of programs that assist with the assessment and which may result in reduced costs for businesses. However, an expert may be needed if the implementation of mitigating factors is necessary (de Oliveira Sato & Cote Gil Coury, 2009; Shoaf et al., 2000).

Another “Workplace Intervention” strategy identified was the “Physical Demand Reduction or Biomechanical Intervention”, where biomechanical and biophysical loads and strains are mitigated to avoid awkward postures, vibrations and high loads (Garg & Kapellusch, 2009; Kogi et al., 2003). This strategy proved effective when combined with low-cost micro-level interventions (such as “Alternative Tools and Equipment” and “Training and Education”) and as part of an ergonomics program. Evidence was also found that biomechanical interventions are effective when included as part of a job redesign risk mitigation task to match the worker’s capabilities to the task demands (Choi & Woletz, 2010; Garg & Kapellusch, 2009; Huang & Feuerstein, 2004; Kogi et al., 2003).

The fourth intervention strategy identified at the “Workplace Intervention” level was “Workstation Adjustment”, which entails making physical changes to the workstation to meet the users’ requirements. Four of the six studies in this intervention sub-level highlighted that workstation adjustments are only effective when implemented in conjunction with other intervention strategies, such as alternate ergonomics tools and training in the use of the equipment and the workstation (Denis et al., 2008; Gerr, 2005; Kennedy et al., 2010; Lima & Coelho, 2011). The Boocock et al. (2007) and Colombini & Occhipinti (2006) studies found evidence for MSD risk reduction, with the Colombini & Occhipinti (2006) study calling for collaboration between manufacturers and ergonomics in workstation design for MSD risk to be successfully mitigated.

Finally, it should be noted that the boundary between the “Workplace Interventions” and the “Individual” hierarchical level can sometimes be confusing and blurred, depending on the context and nature of the intervention. This is due to the “Workplace Interventions” sometimes being part of the meso-ergonomics level and sometimes part of the micro-ergonomics level (Figure 7). Meso-ergonomics considers the interactions between system levels, and due to the amount of crossover between the workplaces and the individuals using them, this level of

MSD prevention is a prime example of meso-ergonomics as well as why multiple levels of ergonomics intervention may be needed to accurately combat MSDs (Karsh et al., 2014; Rivera-Rodriguez et al., 2013; Waterson et al., 2009).

Individual Level

The final level of MSD prevention considers the interventions that directly affect the "Individual" at the micro-ergonomics level. Many studies have focused on MSD prevention strategies that target this level due to the ease and low cost of implementation. The first sub-level intervention strategy identified through the scoping review was "Alternate Tools and Equipment", which involves using ergonomically designed equipment to reduce strain, awkward postures, vibrations and loads to reduce MSD risk. Of the nine studies that found this to be a viable option, six did so only when used in conjunction with either an ergonomics program or in conjunction with another micro-level intervention, with the most popular being proper training (Amell & Kumar, 2001; Boocock et al., 2007; de Oliveira Sato & Cote Gil Coury, 2009; Denis et al., 2008; Kogi et al., 2003; Lima & Coelho, 2011). Short-term positive effects were found even when tools were not expensive or only personal protective equipment was offered to mitigate the risk of MSD occurrence (Kogi et al., 2003; Lincoln et al., 2000; Yan et al., 2017).

The use of exercise to prevent MSDs was the next sub-level of intervention identified; its primary purpose was to condition workers to increase their physical capacity and, therefore, better resist biomechanical loading to the musculoskeletal system. All studies that found this to be an effective tool performed physical exercises in conjunction with other micro-level interventions, of which ergonomics training was most prevalent (Andersen et al., 2016; Boocock et al., 2007; Holtermann et al., 2010; Kennedy et al., 2010).

The second most cited "Individual" MSD prevention strategy was "Training and Education", aimed at teaching workers the basic principles of ergonomics, identifying and avoiding risks, and correctly using equipment to mitigate the risks of MSDs. Most studies identified training and education in combination with tool usage or as part of a broader ergonomics approach, to be an effective way to reduce MSD risk (Capodaglio, 2022; Denis et al., 2008; Kennedy et al., 2010; Lincoln et al., 2000; Oakman et al., 2018; Ouellet & Vézina, 2014; Ziam et al.,

2020). It is important to note that none of the studies in the review indicated that training alone might reduce MSD risk, and it should be used alongside another intervention.

The final individual MSD prevention strategy under the “Individual” level of the hierarchy was aimed at “Cognitive Stress Reduction or Psychosocial Enhancement” of the workplace to reduce the psychosocial components of MSD development, such as the catastrophising of risk and potential symptoms. Psychosocial training towards an individual’s perception of MSDs and MSD-related symptoms may increase the capabilities and tolerance of individuals whilst doing work, thus reducing further MSD risk. However, as the psychosocial factor of MSD assessment is often ignored, the extent of its effectiveness on its own is still unknown (Huang & Feuerstein, 2004; Oakman et al., 2018).

3.4.2. MSD Management Strategies

The scoping review identified fourteen strategies for the management of MSDs. These strategies, which fall under the five hierarchical levels of the draft framework, comprised MSD management techniques grouped by definition from fifty-nine articles Table VI. Similar to MSD Prevention Strategies, the results at the higher ergonomics levels of

the MSD Management Strategies largely corresponded with the works of Oakman et al. (2018) and Rasmussen (1997). The “Law” and “Organisational Policies” hierarchical levels showed three strategies available for such high levels of intervention, with one strategy at the meso-ergonomics level, while at the micro-level, ten strategies were identified by the scoping review.

Table VI. MSD Management grouped by Hierarchical Sub-Level

Hierarchical Level of Framework	Hierarchical Sub-Level	Definition
Law	Occupational Health and Safety (OHS)/National Institute for Occupational Safety and Health (NIOSH) Regulations	Recommendations and guidelines set by Occupational Health and Safety bodies to systematically improve health and safety in the workplace. These include regulations surrounding rehabilitation, return-to-work practices and decrease in symptoms, that can be assessed against the policies implemented by organisations.
Organisational Policies	Ergonomic Task Force/Expert Systems	A task force or program responsible for evaluating tasks, assessing risk and making informed decisions on how to intervene to reduce MSD symptoms and reoccurrence, using evidence based on the initial assessment. The process is then repeated with the new interventions
	Return to Work Programs (RTW)	Organisational programs that promote and facilitate the return to work of an employee after a period of rest or absenteeism due to injury or chronic disorders, such as MSDs. These programs include rehabilitation practices, monitoring, workstation interventions, training and exercise techniques to facilitate a speedy recovery, while not putting the individual at further risk.
Management systems	Surveillance Practices	Programs for the screening of employees over the course of employment including risk assessments and medical analysis
Workplace Intervention	Workstation Adjustments	Changes to the physical workstation or task design to meet the needs of the user, including layout, equipment set up and tool usage; thus, decreasing the demands of the task
	Biofeedback Stations	Garments and techniques used to remind the worker to correct their posture thus reducing the risk of MSDs due to awkward postures
	Job Rotation	The systematic rotation of employees from one task to another after a set amount of time to reduce repetitive movements and overuse of particular body parts, in an effort to lower risk and increase rest
Individual	Alternate Tool and Equipment	Tools that are ergonomically designed to reduce awkward postures, strains, vibrations, and high loads, thus decreasing the risk of MSD formation, especially in high repetition tasks

Non-invasive Medical Treatment	Diagnosis and rehabilitation practices from physical therapist, physiotherapist and occupational health care physicians to reduce symptoms and severity of MSDs and improve RTW time.
Drugs and Medicine	Medication to relieve the pain and symptoms induced by MSDs
Exercise	Stretching, at home or on-the- job strength and conditioning programs or physical activity.
Training and Education	Programs or courses that teach the basic principles of ergonomics, risk and hazards to workers. This allows for the assessment and mitigation of risks and hazards to prevent MSDs
Cognitive Stress Reduction/ Psychosocial Enhancement	Training, support, and educational practices that are aimed at decreasing the psychosocial risk of MSD development
Sick Leave (Part-Time)	Either a reduction in number of hours worked or time off of less than six months allowing for the rest and recovery of MSDs

Law Level

At the top level of MSD management, the scoping review identified only one intervention type, namely the “Occupational Health and Safety (OHS)/National Institute for Occupational Safety and Health (NIOSH) Regulations”. Oakman & Bartram (2017) found that the implementation of OHS regulations that align with the current organisational policies in place may lead to improved MSD management and mitigation. However, Oakman & Bartram (2017) also noted that accurate translation and communication of the regulations would be needed for the benefits of the intervention to be successfully implemented at the workplace. Moore et al. (2006) found the need for a systemic approach to implementing MSD management strategies, whereby a global approach to OHS regulations is implemented to account for MSD risk mitigation. Although both studies falling under this strategy lobby for the increased effectiveness of intervening at a macro-ergonomics level, they both address concerns that the time required to implement

these strategies, as well as the financial strain induced by change, may lead to minimal efforts invested by organizations to comply with legal standards rather than increase staff wellness and safety with respect to MSDs (Moore et al., 2006; Oakman & Bartram, 2017).

Organisational Policies Level

Articles falling under the “Organisational Policy” interventions focus on implementing strategies that affect individuals and tasks within a single organisation to promote MSD management. A key factor at this level is tailoring and aligning the strategies to the business in which they are being implemented. The results of the MSD Management scoping review identified two sub-level interventions, the first being “Ergonomic Task Force/Expert Systems”, which aims at using ergonomists or ergonomics programs to evaluate, assess, recommend and implement changes suitable to the task and environment to reduce the effects of MSDs (Coskun Beyan et al., 2020; Grayson et al., 2005; Larson, 2012; Moore et al., 2006). The use of ergonomics programs under the guidance of experts was shown to provide businesses with effective assessment tools which could then be used to select appropriate intervention tactics (Coskun Beyan et al., 2020; Donovan et al., 2017; Grayson et al., 2005; Melhorn et al., 2001; Oakman & Bartram, 2017). The importance of using the appropriate assessments was emphasised through the selection of meso- and micro-ergonomics level interventions, often in combination with one another, and which were applied throughout the organisation for effective MSD management and promotion of a timely return to work (Coskun Beyan et al., 2020; Grayson et al., 2005; Moore et al., 2006). Seven of the ten studies under “Ergonomic Task Force/Expert Systems” found a reduction in MSD-related symptoms as a result of ergonomics program usage (Donovan et al., 2017; Larson, 2012; Moore et al., 2006; Oakman & Bartram, 2017; Pintakham & Siriwong, 2016; Purnomo et al., 2017; Southerst et al., 2015), two of which reported a reduction in the cost of treatment (Donovan et al., 2017; Larson, 2012). Donovan et al. (2017) also found that ergonomics programs may reduce the delay between assessment and intervention, which may lead to a decrease in initial MSD symptom severity.

The second intervention type for MSD management identified under the "Organisational Policies" level was "Return to Work Programs (RTW)". The purpose of these programs is to facilitate the gradual reintroduction of employees to work after a period of sick leave to promote rehabilitation and reduce further musculoskeletal risk (Bouffard et al., 2019; Viikari-Juntura et al., 2012). Most RTW programs had a positive outcome in the reduction of MSD symptoms, with six of the eight intervention articles reviewed finding some symptom relief, especially when paired with cognitive training to address the psychosocial impact that such disorders may have on employees' perceptions of work (Bouffard et al., 2019; Cochrane et al., 2017; Cullen et al., 2018; Schakenraad et al., 2004; Vermeulen et al., 2009; Viikari-Juntura et al., 2012). Return-to-work programs were also shown to reduce the amount of sick leave taken and the amount of time until employees could return to "normal" workloads (Oranye et al., 2017; Vermeulen et al., 2009; Viikari-Juntura et al., 2012; Waddell, 2006). What the articles do not explicitly state is that only a well-designed and correctly implemented RTW program resulted in effective MSD management; for example, the findings of three articles suggested that RTW programs alone may be ineffective and should be coupled with either cognitive behavioural training to manage stress or early part-time sick leave (Cullen et al., 2018; Schakenraad et al., 2004; Viikari-Juntura et al., 2012). These studies show a need to address the psychological aspect of having MSDs to effectively mitigate the risk of further development.

Despite the low number of strategies found at the higher two levels, the implementation of these interventions will have repercussions for the lower hierarchical levels. Implementations at the "Law" and "Organisational Policy" levels filter down to all aspects of work they encompass. For example, by introducing a policy to have an ergonomics task force working for a company, the company will experience the benefits of all the risk assessments, education and other interventions that the ergonomists are able to identify and implement. Thus, the time and cost of implementing such a change have benefits ranging from workstation layout to individual tool usage.

Management Systems Level

At the “Management Systems” level of intervention, the strategies used apply to the meso-ergonomics level, where the scope of the intervention is significantly reduced. This level focuses on smaller groups of people and the interactions between themselves and the task being performed (Rivera-Rodriguez et al., 2013). The scoping review only identified one “Management Systems” intervention strategy, which may indicate that MSD management at a higher level of the business hierarchy is more challenging to implement, especially when compared to the number of strategies available for implementation at the “Workplace Intervention” and “Individual” sub-levels.

“Surveillance Practices” are programs in place to continuously screen employees’ health and performance throughout their employment to identify any changes from their pre-employment state (Amell & Kumar, 2001; Donovan et al., 2017). During MSD management, surveillance was mainly used as an early intervention tool, thus allowing for interventions to occur early in the disorder's development and thus limiting the severity of symptoms experienced (Bornhöft et al., 2019; Donovan et al., 2017; Moore et al., 2006; Rose et al., 2020; Rostykus & Mallon, 2017). Surveillance also allowed for clear channels of MSD reporting, further mitigating MSD risk (Bornhöft et al., 2019; Moore et al., 2006). The second major use of surveillance in MSD management was to match the task demands to the worker’s capacity or to modify the workplace to mitigate other MSD risks (Bornhöft et al., 2019; Legge et al., 2013; Melhorn et al., 2001; Waddell, 2006). It was also mentioned that surveillance practices could be used as an assessment tool to determine the success of an intervention, particularly when used in conjunction with RTW programs and as part of an ergonomics program. However, it was unclear to what extent this increased successful MSD management.

Workplace Intervention Level

The fourth level of “MSD management strategies” falls on the borderline of the meso- and micro-ergonomics levels. Although the focus is mainly on the interactions between the individual, the task, and the environment in which work is being done, the extent to which it focuses on either one of the three system components will determine whether it falls into the meso- or micro-ergonomics

level. During the scoping review, three interventions were identified, and as most of the articles focused on the interactions at the workstation, the researcher saw it fit to categorise them under the “Workplace Intervention” level rather than the “Individual” level. Despite this, the scope of “Workplace Intervention” is still relatively small, with many of the intervention strategies identified needing a secondary intervention to prove successful.

The first intervention identified was “Workstation Adjustments”, whereby the physical changes to the workstation were made to meet the user’s needs. Seven articles identified this as a successful MSD management tool, with six of them highlighting decreases in pain and MSD-related symptoms after workstation adjustments (Boocock et al., 2007; Mehrparvar et al., 2014; Shariat et al., 2018; Sherrod et al., 2013; van Niekerk et al., 2012; Waddell, 2006). It should be noted that of these six articles, only three found effective symptom reduction when combined with secondary interventions, such as ergonomics training and exercise (Shariat et al., 2018; Sherrod et al., 2013; van Niekerk et al., 2012).

The second intervention identified was the use of “Biofeedback Stations”, where specialised garments and techniques are used by employees as reminders to avoid awkward postures and with the goal of reducing MSD-related strain. The evidence for this intervention strategy was limited to two articles, both showing positive results for MSD symptom reduction; however, one study only found this strategy beneficial when implemented with appropriate ergonomics education (Butwin et al., 2017; Decker et al., 2016). Due to the limited evidence, caution should be practised before implementing this strategy. However, the novelty of the intervention may lead to more promising findings in future research.

The final “Workplace Intervention” strategy identified was “Job Rotation”, which involves systematically rotating employees between workstations, decreasing cumulative loads and, therefore, decreasing MSD-related symptoms. The scoping review, however, only yielded a single article that found this strategy beneficial for MSD management (Kuijer et al., 2005).

Individual Level

At the lowest level of intervention, the focus shifts to micro-ergonomics interventions and the individual. Most of the intervention strategies identified from the literature fell into the lower levels of ergonomics, with seven of the fourteen total MSD management strategies being at the “Individual” level of intervention. One of the strategies identified was “Alternative Tools and Equipment”, where ergonomically designed tools were used to reduce the biomechanical strain and loads of the individual while doing a task. The four articles all suggested that correct tool usage resulted in a reduction of MSD-related symptoms; however, they also all indicated that this was only possible when used in combination with another intervention, especially training and education on correct usage (Breloff et al., 2019; Melhorn et al., 2001; Moore et al., 2006; Pascual & Naqvi, 2008).

Numerous articles (eleven) indicated that the use of “Non-invasive Medical Treatment” was effective in managing MSD symptoms and reducing RTW time (Andrén & Svensson, 2012; Bolton & Cox, 2015; Bornhöft et al., 2019; Caplan et al., 2017; Cochrane et al., 2017; Desmeules et al., 2012; Hu et al., 2020; Hutting et al., 2019; Masiero et al., 2020; Sherrod et al., 2013; Tsertsvadze et al., 2014). The literature here suggested that physiotherapy, manual therapy and rehabilitation lead to a decrease in MSD symptoms (Bolton & Cox, 2015; Bornhöft et al., 2019; Caplan et al., 2017; Desmeules et al., 2012; Hutting et al., 2019; Tsertsvadze et al., 2014). However, seven of the eleven studies suggested that non-invasive treatment alone was not enough to manage MSDs effectively and advocated the use of a secondary intervention (Andrén & Svensson, 2012; Bolton & Cox, 2015; Caplan et al., 2017; Cochrane et al., 2017; Desmeules et al., 2012; Hutting et al., 2019; Tsertsvadze et al., 2014). It is important to point out that the literature indicates that the person implementing the treatment is vital to its success. One study suggested that using a general practitioner’s (GP) recommendations was vital for successful and cost-effective intervention (Tsertsvadze et al., 2014), whereas another found that occupational health physicians were more suitable than GPs to implement non-invasive treatment and improve RTW (Andrén & Svensson, 2012). Yet another study suggested that using physiotherapists over GPs would reduce costs while still producing similar results (Bornhöft et al., 2019; Tsertsvadze et al., 2014). Despite these different findings,

what is evident across all studies is that there is some merit to using “Non-invasive Medical Treatment” to manage MSDs regardless of the medical practitioner used in the process.

“Drugs and Medicine” were identified by the scoping review to reduce pain and symptoms of MSDs. The three articles highlighting this type of intervention showed a decrease in local and short-term pain using corticosteroid injections and Non-steroidal Anti-inflammatory Drugs (NSAIDs). However, this may result from symptomatic treatment rather than treatment of the MSD itself (Marinho & Pereira, 2020; Randhawa et al., 2015; Stanos, 2007).

“Exercise” was the next strategy identified, whereby stretching or strength and conditioning were used to mitigate the negative effects of MSDs by increasing the worker’s physical capacity. Eleven articles were reviewed, all of which found exercise to be effective in the reduction of MSD-related pain and symptoms or an increase in their functionality (Barredo & Mahon, 2007; Bolton & Cox, 2015; Boocock et al., 2007; Coskun Beyan et al., 2020; Jakobsen et al., 2018; Mansi et al., 2014; Mehrparvar et al., 2014; Menta et al., 2015; Prall & Ross, 2019; Shariat et al., 2018). Six of the eleven studies did, however, only find exercise as an effective tool to use in multimodal interventions (Barredo & Mahon, 2007; Bolton & Cox, 2015; Boocock et al., 2007; Coskun Beyan et al., 2020; Menta et al., 2015).

Another strategy identified by the scoping review was the use of “Training and Education” regarding ergonomics and MSD risk and hazards to provide workers with the knowledge and tools to assess and recognise risks early. Six of the eight articles in this group found training and education to reduce pain and symptoms related to MSDs; however, three studies only found this to be true in multimodal approaches (Butwin et al., 2017; Coskun Beyan et al., 2020; Jakobsen et al., 2018). What did appear to be evident amongst the studies was the suggestion that the education of workers may provide more independence in avoiding aggravating risk factors. As a result, MSD prevalence and risk were reduced, thus providing a potential long-term solution to managing existing MSDs as part of a self-management program for employees (Abdollahi et al., 2020; Bolton & Cox, 2015; Hutting et al., 2019; Menta et al., 2015).

“Cognitive Stress Reduction/Psychosocial Enhancement” was the sixth strategy identified under the “Individual” sub-level, where the use of training, support, and education is used to treat the psychological effects associated with MSDs. The results of the six studies identified showed that cognitive support might lead to a reduction in MSD symptoms as well as a decrease in the duration that employees partake in RTW programs (Butwin et al., 2017; Cullen et al., 2018; Lloyd et al., 2008; Smith-Young et al., 2014; Smith et al., 2016; Waddell, 2006). Waddell (2006) even found that the biopsychosocial model for managing MSDs increases the effectiveness of other prescribed treatments. The psychosocial aspects of MSDs are still new, and studies on them are scarce, and without considering any form of cognitive support, a potentially effective tool for MSD management may be dismissed due to it being largely unseen (Carayon et al., 1999; Karsh et al., 2001).

The final strategy identified under the “Individual” hierarchical level for MSD management was the prescription of part-time “Sick Leave”, where a period of rest is allocated to individuals with the anticipation of recovery mitigating the effects of the MSD. Only three articles found this intervention to work, all of which found it only effective alongside RTW to aid faster recovery (Andrén & Svensson, 2012; Cochrane et al., 2017; Viikari-Juntura et al., 2012).

The abundance of literature on the “Individual” level of intervention may be misleading to most practitioners. This is partly due to the low number of macro-and meso-ergonomics level studies found during the scoping review relating to the management of MSDs and partly due to the high number of effective micro-ergonomics interventions. However, as shown by the literature, most “Individual” level interventions require secondary or tertiary interventions to be implemented together to succeed. When implemented in isolation, intervention at this level may not have the desired effect.

3.5 Conclusion

There are a multitude of effective MSD intervention options ranging from the macro-ergonomics level down to the micro-ergonomics level. The interventions near the top of the conceptual model/framework rely on the knowledge of experts and the selection, design and implementation of the appropriate MSD intervention. In comparison, the lower-level interventions require a multimodal approach to

mitigation, with most cases needing more than a single intervention to mitigate MSDs effectively. All interventions identified by the scoping review were deemed effective in managing or preventing MSDs in one way or another; however, most studies were not based in South Africa. This raises the question of which of these prevention and management strategies would be effective when implemented in South Africa and which interventions used in South Africa have not been identified by the scoping review.

CHAPTER IV:
PHASE 2 - KEY STAKEHOLDER INSIGHTS

4.1 Introduction

The framework presented thus far was purely based on published international academic findings. The framework described in Chapter III was aimed to improve MSD literature navigation in a South African context. Since the effectiveness of MSD interventions is dependent on their context, it was essential to assess whether this framework would be suitable for use in the South African context. As the literature on MSD intervention in South Africa is scarce, ergonomists working there have become an important source of information to identify which interventions work. Key stakeholders working in the field of human factors and ergonomics in South Africa were consulted to obtain their professional opinion of the draft framework and identify improvement areas for future versions to achieve the following three objectives.

1. the intervention strategies identified by the scoping review were viable to implement in South Africa,

2. any effective intervention strategies had been omitted from the framework, and

3. the draft framework's design and purpose were suitable for its intended user population.

4.2 Methodology

4.2.1. Study design

A qualitative, interview-based approach was adopted to achieve the objectives of this phase of the research. The purpose of the interviews was to gather feedback on the draft framework content and its design from working professionals who deal with MSD prevention and management interventions as part of their daily work.

4.2.2. Participant Sample

Inclusion criteria

Only individuals certified with the Ergonomics Society of South Africa (ESSA) were eligible to participate in this study. Participants were required to be registered as either a Certified Professional Ergonomist (CPE) or a Certified Ergonomics Associate (CEA). Participants were also required to have been practising ergonomics for at least four years in South Africa. This was to ensure that participants had appropriate ergonomics qualifications as acknowledged by the Professional Affairs Board (PAB) of ESSA and that they had appropriate "working" knowledge of MSDs in South African work environments.

Recruitment Strategy

A purposive sampling strategy was used for this study. Participants were recruited via email, using the contact details available on the ESSA "CEA and CPE: Contact List" webpage (https://ergonomicssa.com/cea-cpe/). Due to the limited number of practising CPEs and CEAs in South Africa (17 in total at the time of the study), a minimum of five and a maximum of ten participants were required. The number of participants was decided upon with guidance from Bryman (2012). CPEs were contacted first, and only when the minimum sample size was not reached were CEAs contacted to participate.

Sample size

The ten CPEs on the ESSA contact list were contacted to participate in the study, and since only four agreed to participate, the seven CEAs were contacted. In total, seven of the seventeen registered ergonomists showed interest in participating; however, two individuals pulled out at a later stage, leaving only five ergonomists who agreed to be interviewed, resulting in a response rate of 29%.

4.2.3. Tools and Materials

The interview made use of a semi-structured approach, as this allowed the researcher to ask follow-up questions and participants to elaborate on answers. The interview (Appendix B) consisted of 29 questions divided into four sections, focusing on 1) participant demographics, 2) questions relating to MSD prevention,

3) questions on MSD management, and 4) the ease of use of the framework itself. Section one was comprised of questions relating to the region and industry of work, experience and education in ergonomics and qualifications they have obtained. For the questions relating to MSD prevention and management (sections 2 and 3 of the interview), participants were first asked about their experiences with MSDs as encountered in their line of work and their opinion of what MSD prevention or management should entail. Further questions related to the information presented in the draft framework when implemented in a South African context. Questions in the fourth and final section of the interview focused on the clarity, layout and design of the draft framework.

The interviews were conducted virtually using the video conferencing software “Google Meets” and “Zoom”. Meetings were recorded using the in-program function, and an external voice recorder collected an audio-only version.

4.2.4. Ethical Considerations

This project was reviewed and granted ethical approval by the Human Research Ethics Committee of the Rhodes University Ethical Standards Committee (approval number: 2021-5206-6364) (Appendix C1).

4.2.5. Procedures

Eligible participants were contacted via an email containing the “Letter of Information to Participants” (Appendix C2) requesting to partake in the study. Once participants responded favourably to this email request, the draft framework and the interview schedule were sent to them for review and preparation. A consent form (Appendix C3) was also sent for signing. An interview date and time were set for each participant, allowing for enough time for participants to review the draft framework before the interview. Participants were informed that the interviews were anticipated to last 45 minutes to an hour.

The interviews started with an introduction and a verbal confirmation of consent to participate in this study (in addition to the signed consent form. Permission to record the interviews was also obtained. A brief overview of how the draft framework works and its intended purposes were explained, and participants were allowed to ask questions about the study and draft framework. The interview

followed the order mentioned above under “Tools and Materials”. After the interview, participants were asked if they would like feedback once the study had been completed.

4.2.6. Data Analysis

Interview recordings were transcribed using the *Otter.ai* transcription software and were then checked manually for accuracy and errors. A thematic analysis of the transcripts was conducted using the six sets for thematic analysis proposed by Braun & Clarke (2006) and the NVivo Thematic Analysis Software.

Step one consisted of familiarization of the data, whereby the researcher read and re-read transcripts and listened to the audio recordings several times (Braun & Clarke, 2006). During this step, notes and interesting findings were noted, allowing the researcher to first analyse the context and origin of the participants’ answers in an informal way. During step two of the thematic analysis, initial codes were created for each transcription. This study took a primarily deductive approach to coding, whereby the codes were created beforehand based on the structure of the draft framework and the interview schedule. However, noteworthy information not part of the pre-prescribed codes arose were also coded and noted for further assessment in phase three of the analysis.

Upon completion of the second step, codes that shared similar features were clustered, and initial themes were created and, in step 3, defined by the components of their codes and their relationships to one another. The researcher constantly reviewed and interrogated the themes as they developed to ensure that themes were coherent, strong, and of high quality, with supporting data as recommended by Braun & Clarke (2012) (step 4). The *NVivo* software was used to visualise and track the formation and relationships of themes.

Finally, steps 5 and 6 of the thematic analysis had the researcher define and name the established themes and then report on them (Braun & Clarke, 2006). During these last two phases, the themes are constantly scrutinised and refined until the researcher can fully describe the themes concisely (Braun & Clarke, 2006).

4.3 Results

4.3.1. Participant Characteristics

Five participants were interviewed and consisted of four CPEs and one CEA with an average of 19.60±10.01 years of overall ergonomics experience, of which an average of 16.80±10.55 years were spent practising. Three participants worked as consultants, and two held permanent positions at businesses. Work conducted by these individuals had been conducted across most provinces in South Africa, namely Gauteng (n=4), Western Cape (n=3), Northern Cape (n=2), Limpopo (n=1), KwaZulu Natal (n=1) and Eastern Cape (n=1), as well as across various industries, namely, retail, mining, transport, aero-defence, automotive and manufacturing.

4.3.2. Interview Results

The interviews were conducted between 17 November 2021 and 10 December 2021 and lasted an average of 1hr2min43s (±23min10s). Themes were created and collated following the thematic analysis and separated into four broad categories based on the structure of the interview schedule, namely “Prevention of MSDs”, “Management of MSDs”, “Document format and clarity”, and “Uncategorised Themes”. Under the “Prevention of MSDs” and “Management of MSDs” categories, themes were further split according to the participants’ opinions and experiences of what interventions entail and whether they found the interventions listed in the draft framework to be effective or ineffective within a South African context. The relationships between MSD intervention themes are shown in Figure 8 and highlight the three key relationships between themes from MSD prevention, management and the stakeholder’s opinion of what MSD intervention should entail; in other words, that surveillance is recommended but is not effective in South Africa, that workplace interventions are effective in both management and preventative cases, and that training and education is a recommended practice and has been seen as effective in preventing MSD in South Africa.

Figure 8 summarises the themes obtained from the interviews and their relationships. Stakeholders' opinions on what MSD interventions should entail are presented in blue. Furthermore, stakeholders’ feedback on the effectiveness of

interventions in the draft framework in a South African context is presented in the green, yellow, and red boxes. The arrows indicate whether the theme originated in MSD prevention or MSD management, while nodes that touch each other, such as the ones in the centre of the diagram, indicate a relationship between themes. The level of ergonomics at which each theme is situated is displayed on the right of the theme relationship map.

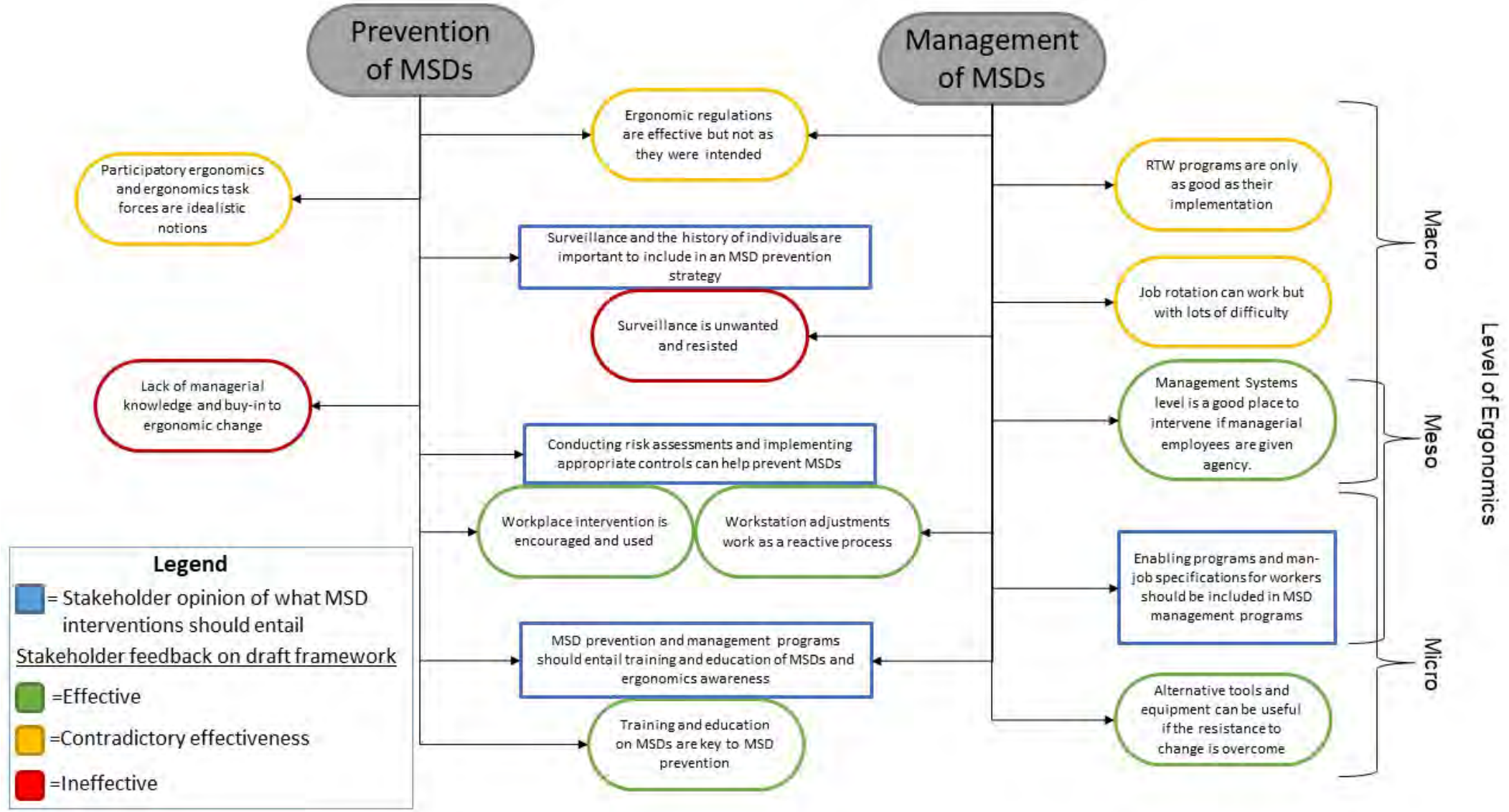

Figure 8. Diagram summarising the relationships between MSD intervention themes.

Themes relating to the Prevention of MSDs

Eight themes related to the prevention of MSDs were identified and are presented in Table VII, with a definition of the themes and supporting evidence from the transcripts of participants. Three of these themes were based on the opinions and experiences of the participants (themes a-c), while five originated from the intervention strategies presented in the draft framework (themes d-h in Table VII).

Table VII: Prevention of MSD themes

Theme		Framework or Experience-based
a.	Surveillance and the history of individuals are important to include in an MSD prevention strategy	Experience
b.	Conducting risk assessments and implementing appropriate controls can help prevent MSDs	Experience
c.	MSD prevention programs should entail training and education of MSDs and ergonomics awareness	Experience
d.	Ergonomics regulations are effective but not as they were intended	Framework
e.	Participatory ergonomics and ergonomics task forces are idealistic notions	Framework
f.	Lack of managerial knowledge and buy-in to ergonomics change	Framework
g.	Workplace intervention is encouraged and used	Framework
h.	Training and education on MSDs are key to MSD prevention	Framework

a. Surveillance and the history of individuals are important to include in an MSD prevention strategy

Surveillance refers to the recording of what and how work is being done in an attempt to identify potential risky behaviour or environments that workers may find themselves in. The practitioners interviewed recommended that surveillance, as well as knowledge of workers' pre-existing work and medical histories, are important for any MSD prevention program.

> *"Surveillance [works] as well. Doing regular assessments so that they understand what their strength is, what their capabilities are, what the function is…. And if they have a better understanding of how they're moving, then they'll understand why [certain behaviour is risky]."*

> *"[MSD prevention should involve] screening people and make it this first part of your medical management in order to detect [MSD risk and worker discomfort]."*

b. Conducting risk assessments and implementing appropriate controls can help prevent MSDs

The use of regular risk assessments and use of controls in the South African context was strongly agreed upon by several participants. Controls applied should fit the risks identified in the risk assessment in order to mitigate the likelihood of MSDs occurring. According to participants, MSD prevention should entail the following:

"[MSD prevention should entail], just having like control measures and, and things in place. "

"Doing regular assessments so that they understand what their strength is, what their capabilities are, what the function is."

c. MSD prevention programs should entail training and education of MSDs and ergonomics awareness

Training and education on MSDs and increasing ergonomics awareness were recommended by participants as part of what MSD prevention should entail. More specifically, it was recommended that training should discuss the difference between "normal" and "at-risk" discomfort levels, as well as what the capabilities of workers' bodies are and how to use the tools and workstations to which they have been assigned. Participants highlighted the following:

"People are not even aware that the discomfort that they are experiencing [during work is a sign], even though some are pretty serious."

"What I had, 151 [workers with lower back pain] were complaining about the chairs. And I was like, 'Well, yeah. Did you ever go to the nurse and have a look in your back?'... 'No, no, we didn't'…There is a lot of education needed [about what is normal and what is potentially risky]."

"I think awareness is the biggest [intervention strategy that should be included in MSD prevention] because if people are aware, you can predict. If they are] aware that these are the risk factors that are in, you know, associated with the task they're doing, then we could prevent MSDS."

"But if the worker understands why, why the prevention strategy is important, then that's your … first step [in designing a prevention strategy]. And then you're getting the worker to understand prevention, basically. And

then …, once you have the workers' buy-in, I think it's a lot easier to move forward."

d. Ergonomics regulations are effective but not as they were intended.

Stakeholders found that the South African Ergonomics Regulations had increased the number of ergonomics interventions and risk assessments conducted in South Africa. However, this was perceived more as a requirement for legal compliance rather than to prevent MSDs. This has resulted in the regulations being less effective than they potentially could be, as MSD prevention is just an emerging by-product of compliance with the regulations rather than a distinct sought-after result. When commenting on which MSD prevention strategies in the draft framework were effective, participants stated:

"Oh, definitely the government regulations [for ergonomics], because like I said, like half of the people that contact me, they're basically just doing a risk assessment. Because…it's now illegal if you don't have an ergonomics program. So definitely all of the regulations and anything that is needed for compliance."

"The government regulations…I haven't yet seen them being well used in the prevention [of MSDs], you know, haven't seen evidence yet [of them being used]. I'm sure they will, for sure."

What did, however, emerge under this theme was the optimism of the Ergonomics Regulations being used as intended in future, even though more stringent enforcement of the ergonomics regulations may be needed for this change to occur.

"[Stakeholders opinion of the ergonomic regulations being ineffective in South Africa] is only purely because…I personally haven't seen it implemented, or I haven't seen the results yet."

"So by, by having laws or regulations on [a] number of statutory documentation is only really effective if you can enforce it."

e. Participatory ergonomics and ergonomics task forces are idealistic notions

The use of participatory ergonomics and ergonomics task forces was seen to be both effective and ineffective by the participants, with some participants attributing the ineffectiveness to how much buy-in there needs to be from workers and others

on the still small and growing discipline of ergonomics in South Africa. When commenting on the use of participatory ergonomics in South Africa, participants said the following:

"Participatory ergonomics [works] when there's buy-in from … the workers."

"Participatory ergonomics. [There] is just quite a big level of resistance"

"In my view, in South Africa, [participatory ergonomics] hardly ever works because to be able to do participatory ergonomics, you must know something about ergonomics."

"I think that [participatory ergonomics] is an idealistic view of, of the work environment. I don't think I've seen that [the use of task forces and participatory ergonomics]."

The results of Participatory Ergonomics usefulness in South Africa are, therefore, still inconclusive.

f. Lack of managerial knowledge and buy-in to ergonomics change

Participants found MSD preventative interventions at the managerial level of the draft framework very difficult to implement. The main contributors cited were the lack of knowledge of ergonomics and ergonomics programs, as well as resistance to change.

"Management thereof [MSD interventions] is severely hampered by the knowledge of managers on … how to implement and measure the effectiveness of their programs."

"The change management is probably the hardest part [of implementing preventive measures]."

g. Workplace intervention is encouraged and used

It was agreed upon by most participants that interventions at the level of the workplace were the best approach to implementing effective MSD prevention controls in South Africa. The interventions from the draft framework that were mentioned as effective under this level varied from workstation adjustment and design to job demand analysis. With regards to the question regarding what interventions were most effective in preventing MSDs, participants answered:

"I believe that a lot of the prevention of MSDs can actually be … addressed by proper workstation design."

"Workstation adjustments, definitely."

"Physical demand reduction, biomechanical intervention, workstation adjustments, definitely."

h. Training and education on MSDs are key to MSD prevention

The final theme that emerged as an effective practice from the draft framework in South Africa related to the use of training and education for MSDs among workers. It was suggested that through such interventions, an increase in worker knowledge of the signs, symptoms and risks associated with MSDs would allow for early intervention. In relation to education and training for MSD prevention, participants stated the following:

"Definitely training, training and education"

"Yeah, those [interventions that worked] were training and education. Yes. So those are the ones that jumped out to me now as a practising ergonomist"

"You need training, again; I can't emphasize the, you know, the importance of training and education."

Themes relating to the Management of MSDs

Nine themes relating to the management of MSDs emerged from the thematic analysis (Table VIII). Two themes were based on the participants' opinions and experiences of what an MSD management strategy should entail (themes a and b), and the remaining seven were based on the intervention strategies presented in the draft framework (themes c-i). These themes are followed by supporting evidence from the transcripts of participants.

Table VIII: Management of MSD themes

Theme		Framework or Experience-based
a.	MSD management programs should entail training and education of MSDs and ergonomics awareness	Experience
b.	Enabling programs and man-job specifications for workers should be included in MSD management programs	Experience
c.	Ergonomics regulations are effective but not as they were intended	Framework
d.	Return-to-Work programs are only as good as their implementation	Framework
e.	Surveillance is unwanted and resisted	Framework
f.	Job Rotation can work but with lots of difficulties	Framework
g.	Management Systems level is a good place to intervene if managerial employees are given agency.	Framework
h.	Workstation adjustments work as a reactive process	Framework
i.	Alternative Tools and Equipment can be useful if the resistance to change is overcome	Framework

a. MSD management programs should entail training and education of MSDs and ergonomics awareness

Based on their experiences, participants identified the use of training and education on MSDs and ergonomics awareness as being a crucial part of an MSDs management program. Such an intervention was identified to increase both MSD symptom reporting and MSD risk reporting, improving equipment usage, and understanding and complying with rules and regulations that exist within the company as well as from governing organizations.

> *"I think it's important to take a step back and teach companies… what an MSD is and how it was recognized and…that it's an existing problem. And that it's way more prevalent in the country than the company thinks because South African people are not gonna go and report."*

When commenting on workstation adjustment, ergonomics tool use and mitigating risk, participants commented:

> *"One of the important things is education. You must train the person to actually do his job properly. But you must also train him to set him up correctly."*

"So your management systems are basically…you need rules, you need regulations that guide for compliance purposes, you need training, again, I can't emphasize the … importance of training and education."

"Constant reminders, and constantly providing little parts of that credential program to keep people aware [of MSDs and tool usage]. And because they are aware, because they have knowledge of what you're doing, then they're more likely to participate in different strategies."

b. Enabling programs and man-job specifications for workers should be included in MSD management programs

Regarding the interventions detailed in the framework, participants identified one missing strategy from the MSD management side of the framework. They suggested including an intervention that quantifies the capabilities of the worker and matches the worker to a task with appropriate demands. The assessment should take place regularly to determine the physical conditioning of the worker before reassigning them to different tasks or work.

"An assessment…of the task, of the…individual and the work that they're doing"

"Functional human capability point of view, where you can actually stretch the capabilities of the human to the level."

"While they're at work, they would be physically active. That is nothing else than very good task-related conditioning. "

"Whole man-job specification thing. And I'm not sure where that will fit into [in the draft framework]."

c. Ergonomics regulations are effective but not as they were intended

Participants found that the ergonomics regulations had the intention and potential to be used to manage MSDs successfully; however, it was found that in South Africa, this was not the case. This was attributed to the regulations generally not being embraced by businesses in South African business yet (at the time of the interviews)

"[Ergonomics] regulations... even though that's not really existent, but it would be effective."

d. Return-to-Work (RTW) programs are only as good as their implementation

RTW programs refer to the facilitation of employees returning to work after absenteeism or a period of rest. Participants' opinions on RTW programs showed that the extent of effective implementation of such programs is limited by the way in which they have been implemented. One participant even stated that such programs only work while they can be monitored.

> *"Return-to-work programs, if they're done properly, if they're implemented correctly, and…thought has gone into them, they're really, really good."*

> *"I'd like to say that the return-to-work programs, but they're very effective until the person returns to work. So while you have control over them [the worker], from the medical side or the prevention side, then they're very, they're great. But once they're on the shop floor, then everything falls to pieces. "*

e. Surveillance is unwanted and resisted

The use of surveillance as a tool for MSD management was perceived to be ineffective in South Africa, with resistance to implementation from workers and trade unions, despite managerial advocacy for its use. It was noted that participants may have misinterpreted the definition of 'surveillance', focusing on the monitoring of employees while they work rather than 'medical surveillance' as indicated in the Ergonomics Regulation.

> *"They put cameras as well. So, they're watching everyone, and they just revolted. People didn't use it. And they said they didn't care, the trade union stepped in. And it was just, it was just chaos."*

f. Job Rotation can work but with lots of difficulties

Job rotation was identified by participants as an effective but limited strategy for managing MSDs. Participants identified that aspects of job rotation could be effective; however, it was hard to implement in practice.

> *"Job rotation, that is something I find regularly [works when implemented] but, but slowly."*

> *"Job rotation definitely [works]. Things like… your work scheduling, so your work or your work to rest ratios, those sorts of things."*

"Job rotation [is effective], it's theory, it's difficult to implement."

g. Management Systems level is a good place to intervene if managerial employees are given agency.

Participants identified the "Management Systems" level suitable for MSD management interventions to take place and be efficient. Management Systems were identified as being a good starting point for implementing controls and interventions. It was pointed out that in order for managers to successfully and continuously implement change, some agency needs to be given to these managers to make decisions instead of waiting for approval from superiors. When commenting on where to effectively intervene, participants stated:

"you will probably have to have it somewhere in the management system at least to start your, your control input. "

"All your management of the MSD on an individual level comes to nothing if the manager is not entitled to sign off because of very straightforward criteria for intervention."

h. Workstation adjustments work as a reactive process

Workstation adjustments were perceived to be a reactive process to identifying MSDs in the workplace and were therefore identified by all the participants as an effective MSD management tool.

"Workstation adjustments…as a reactive process to … managing them [MSDs], definitely."

i. Alternative tools and equipment can be useful if the resistance to change is overcome

The implementation of tools and equipment was deemed to be difficult to implement with resistance from the management level; however, it was identified as a good intervention to manage MSDs if the implementation could be done effectively.

"Alternate tools and equipment, sometimes it's difficult [to implement]."

"it's difficult to implement [new] tools, tools and equipment. So that's also something that there's a lot of resistance for change from the management."

Themes relating to document clarity and layout

The third category of themes is related to the opinions of the participants on how easy the framework was to understand, navigate and use. The three themes detailed in Table IX emerged from the interviews.

Table IX: Clarity and layout of the framework themes and where they originated

Theme	Framework or Experience-based
a. The importance of multiple levels of intervention is conveyed	Experience
b. Access to the journal articles cited would be helpful	Experience
c. Specify who the framework is for and simplify it for use in the working environment.	Experience

a. The importance of multiple levels of intervention is conveyed

Participants commented positively on the multiple levels at which ergonomics interventions could be implemented. Furthermore, they considered the way each ergonomics level is related to the others as being useful and highlighted the need to convey this. The use of a diagram showing these ergonomics levels at the micro-, meso- and macro-ergonomics levels may assist in visualizing how to plan an intervention.

> *"Your hierarchical sub-level for prevention is spot on…if I want to refer somebody to what prevention hierarchical sub-levels imply and what does MSD prevention entails, I would say 'go and read Elrico de Bruyn's framework'. And, and this is wonderful information."*

> *"It's nice to look at it like this, because you can almost … it helps to plan a strategy better. So you can plan from the bottom with the top in mind. And then the middle layers can almost gradually be incorporated through the top and the bottom. I mean, they all link together. So yeah. It's easy to, to link everything. It's really great."*

b. Access to the journal articles cited

Participants pointed out that users would need to be able to access the articles listed in the framework. This would aid them in quickly gaining further information about each individual MSD intervention strategy.

“But yeah, that would be nice if the actual article would be there. And that you can just click it open, you know, you can still see where you are.”

“And I couldn’t put my finger on it immediately [what the intervention involved]. So, my point is that access to the references will probably be important as well, for the user.”

c. Specify who the framework is for and simplify for use in the working environment.

A strong concern from participants was that the framework was not suitable to use in a working environment, especially for people that are not knowledgeable about ergonomics. Clarity on who the framework is for needs to be stated, and the language used should be simplified for quick reading and understanding. A major concern was that the instructions and reasoning for the framework were too convoluted and too long for it to be successfully used by its intended users in a South African work environment.

“You must have an introductory paragraph that will address your target audience with a proper target audience description”

“You might have to find a way to make it even more dumb, if that makes sense, you know what I’m saying? To me, it’s clear I have a Master’s thankfully. ... If you intend to send this out to people to clients in the real world, and I’m saying that in quotes, you’re gonna have to really dumb it down.”

“I didn’t understand that page [page 5 showing the navigational tool]. And then I looked at the framework, and I read all the literature guides and the stuff below. And then when I went back and read it the second time, then I clicked, I was like, Okay, that makes sense. Now, that’s how it works. I think it’s more just getting an understanding of what it actually was first.”

Uncategorised themes

The results in this section emerged from what participants said that was not directly related to specific questions asked or sections of the draft framework. Two such themes were identified (displayed in Table X) but were still relevant to the study as they identified a potential pitfall with only using literature-based interventions and reinforced the need for supporting documentation for MSD intervention.

Table X: Uncategorised themes and where they originated

Theme	Framework or Experience-based
a. What works, in theory, does not always translate into practice	Experience
b. Need for a South African-based intervention guide	Experience

a. What works, in theory, does not always translate into practice

Participants regularly made reference to strategies which could be effective but are limited in their application in the South African context, such as,

> *"Job rotation… you can get all the theory behind it. But the practical implementation of it is very difficult."*

> *"I'd like to say that the return-to-work programs, but they're very effective until the person returns to work."*

Such statements allude to the participants' understanding of the benefits of these practices, but the theory of these practices did not match the practical South African work environment.

> *"I think that would be helpful, because it's nice to have all these papers and understand the theory behind it. But when it comes to actually applying it [the interventions], it ends up being a joke"*

b. Need for a South African-based intervention guide

Support for the draft framework emerged in the form of participants stating that there is a gap in the South African context in terms of an MSD intervention guide. Most participants relied on international-based guidelines and documentation during their course of work, whilst others based decisions regarding MSD prevention and management on experience. There was strong support that a South African-based framework for MSD management is needed, as well as more South African-based intervention studies.

> *"It's all pretty much all international based. Which is actually why I found this really, really interesting, this work that you're doing, because that would be amazing to have a South African guideline framework."*

“it caught me; the whole … framework for MSD prevention and management caught my eyes, it’s something…I’ll be very, very interested in.... it can add a lot of value.”

“it’s such a great framework that you put together. And it’s really, really helpful. You don’t understand how much time is wasted just trying to find stuff that’s relevant in your region.”

4.4 Discussion

Musculoskeletal disorders take up a large portion of ergonomists’ time in South Africa and preventing and managing these conditions may come at a cost to businesses. However, the costs of ignoring MSDs can be even greater. MSDs are a burden to working individuals and the healthcare system in the nation as pain, and other related symptoms, need to be treated. Thus, the need for stakeholder feedback and opinions on what MSD interventions are effective in the South African working context is a vital part of a framework for MSD prevention and management.

The South African context is a unique one, with a variety of languages (11 official languages), cultures and huge socio-economic disparity. Although predominately separated by geography, many workplaces in South Africa are made up of workers from these different cultural, ethnical, and socio-economic backgrounds, which means there is no “one-size fits all” solution to dealing with matters such as MSDs. People from these different groups may have various views on participating with management on work-related matters, including reporting any injuries or challenges. An example of this was found in a pilot study on the barriers and enablers to reporting of MSDs and MSD risk at a university in the Eastern Cape (de Bruyn, 2019). The study found that amongst a diverse range of workers (predominantly ‘Coloured’ and ‘Xhosa’) reporting of MSDs was avoided out of fear of embarrassment or dismissal (de Bruyn, 2019). These factors, especially the fear of dismissal, are important considerations in South Africa, where the remnants of the Apartheid system are still felt in labour relations. Furthermore, Francis and Webster (2019) reported that the Gini coefficient in South African continues to grow, with inequality in post-Apartheid South Africa being similar to that during Apartheid, and with the majority (91%) of the Gini coefficient being attributed to wage inequality. At the end of 2022, the unemployment rate in South Africa stood

at 32.9%, with a common perception amongst managers and supervisors being that workers are expendable and replaceable, especially those involved in manual labour (South African Reserve Bank [SARB], 2022). The perception of an expendable workforce may lead to many workers being desperate to keep their jobs and not engage with mangers in any way that may be controversial and, by extension, detrimental to their income, even if it negatively affects their wellbeing.

Although only five stakeholders were interviewed, each had experience working in different industries and regions of South Africa, and as such it can be inferred that their experiences, and thus the emerging themes, are based off how the framework would work in a variety of cultural, ethnical, and socio-economic environments. Thus, the working context and the people within are directly related to how effective interventions may be perceived in South Africa. As such, it is important to understand that the perceptions of stakeholders and thus their responses and emerging themes are heavily influenced by the region and cultures they were engaged with.

The emerging themes for the stakeholder interviews suggest that not all MSD intervention practices work in South Africa; however, when an intervention does work, it seems to be widely used; for example, training and education of workers and workplace interventions. Some of the less commonly used but still effective practices will also be discussed, as well as those with contradicting evidence regarding their efficacy. The participants also presented a clear need for a South African-based guide, especially one that bridges practice and theory.

The MSD-related themes can be divided into two main groups, namely the stakeholder's opinion on what MSD intervention should entail based on their experience alone and stakeholder opinions of which interventions listed in the draft framework are effective in South Africa.

4.4.1. Stakeholders' opinions on interventions based on practical experience.

Stakeholders' opinions on what MSD interventions should entail included: "Surveillance and the history of individuals are important to include in an MSD prevention strategy", "Conducting risk assessments and implementing appropriate

controls can help prevent MSDs", "MSD prevention and management programs should entail training and education of MSDs and ergonomics awareness" and "Enabling programs and man-job specification for workers should be included in MSD management programs". Of these four themes, two were recommendations for MSD prevention, one for MSD management, and one for both. This is discussed in further detail below.

The theme "Surveillance and the history of individuals are important to include in an MSD prevention strategy" suggests that by understanding the history of individuals' health and exposure to risk as well as surveying the way they work, one can assess risk and intervene prior to MSDs occurring, thus preventing them. Although stakeholders recommended the inclusion of surveillance as a preventative tool as part of a theoretical MSD prevention program, further evidence from the stakeholder interviews did not support the recommendations that surveillance practices work to prevent MSDs in South Africa. The evidence of the thematic analysis on the surveillance practices showed that the stakeholder found surveillance practices ineffective and resisted by both workers and trade unions when implemented. This indicates that although the use of surveillance seemed like a good way of preventing MSDs in theory by the professional in the field, in reality, the implementation of such practices proved problematic.

It should be noted that surveillance practices only arose during the MSD management portion of the interview. However, since the nature of the surveillance intervention is similar in both a preventative and management context, it can be presumed that the reaction to surveillance may be similar if used as an MSD prevention strategy. What is important to note here is that the definition of surveillance may have been interpreted by stakeholders differently than was intended. The draft framework defines surveillance as "programs for the screening of employees over the course of employment". This definition is vague and allows for much interpretation by the reader. In the literature and the South African Ergonomics Regulations, surveillance is referred to as the monitoring of employees medically rather than observation of the way they work (Amell & Kumar, 2001; Department of Employment and Labour, 2019).

Practitioners advocated for the use of regular risk assessments and implementation of controls in an ideal MSD prevention program, whereby the controls that are implemented meet and mitigate the identified risks. Choi & Woletz (2010), Colombini & Occhipinti (2006), Shoaf et al. (2000), and Yazdani et al. (2019) all agreed that risk assessment or workload analysis should form part of a greater systems approach or ergonomics programme to effectively mitigate MSDs. The endorsement of such an intervention strategy was reinforced by two themes that emerged from MSD management and prevention interventions. The interview participants pointed out that workplace interventions were generally effective in MSD prevention and advocated for risk assessment, job demand and workload analysis and workstation adjustments. These statements agreed with the literature surrounding risk assessment, especially the wide benefits they bring if used effectively (Mark Melhorn, 2001; Panel on MSDs and WP, 2001). However, unlike the literature, the participants of the study didn't indicate how much of a role the correct implementation of controls to combat the MSD risk played (Amell & Kumar, 2001; Denis et al., 2008). Stakeholders also indicated that workstation adjustments, one of the most cited effective MSD intervention practices found in the literature, were beneficial in preventing and managing MSDs in South Africa (Boocock et al., 2007; Colombini & Occhipinti, 2006; Denis et al., 2008; Kennedy et al., 2010; Lima & Coelho, 2011; Mehrparvar et al., 2014; Viikari-Juntura et al., 2012; Waddell, 2006). Unfortunately, stakeholders were not specific about which workplace intervention(s) had been useful in South Africa. This leads to the conclusion that workplace interventions, especially those relating to risk assessment and changes implemented to mitigate the risk, may be effective in preventing or at least minimising MSD development in South Africa.

The third theme emerging from stakeholders suggests that any MSD intervention program, both proactive and reactive, should involve some training and education on what MSDs are, MSD risk factors and general ergonomics awareness, as suggested by Capodaglio (2020), Denis et al. (2008) and Ziam et al. (2020), who recommended that training and education should form part of a greater MSD intervention program. Stakeholders suggested that MSD prevention programs should focus on informing workers about the capabilities of their bodies, the demands of the task they are performing and the steps they could take if there was

a mismatch between the two. In doing so, workers could start identifying and reporting areas and tasks with high MSD risk before any detrimental MSD developments. This can be seen as a way of reducing MSD risk, but only if the relevant risks are being addressed by training and educational campaigns (Abdollahi et al., 2020; Jakobsen et al., 2015; Randhawa et al., 2015). Training and education were identified in the draft framework as an effective strategy to prevent MSDs in South Africa. However, this was not the case in managing MSDs, possibly due to management programs in South Africa emphasising increased reporting of MSDs and MSD symptoms in the workplace to reduce pain and increase self-sufficient treatment rather than educating its workers on it (Bolton & Cox, 2015; Hutting et al., 2019; Prall & Ross, 2019). The socio-political past and variety of cultural, ethnical, and socio-economic groups within South Africa make reporting MSDs difficult due to social norms and pressures, and can often lead to an underreporting and, therefore, inadequate treatment of MSDs (Siddharthan et al., 2006).

An increase in MSD reporting would increase the identification of high-risk MSD activities or tools, which could lead to training on correct usage and adjustments, thus mitigating further risk (Pransky et al., 1999). Although it was suggested that MSD management should entail education, evidence of it being an effective tool in South Africa was inconclusive. Even though no themes relating to the effectiveness of training and education in managing MSDs in a South African context were identified, stakeholders still recommended its use in MSD prevention and management programs. The absence of evidence supporting the efficacy of education and training in managing MSDs should not be seen as evidence against its working.

4.4.2. Stakeholders' opinions of interventions listed in the draft framework.

Stakeholders reviewed and identified the MSD interventions listed in the draft framework that effectively prevented the MSD problem in South Africa and those that were ineffective. Despite the use of training, education, and workplace interventions (mentioned above), no other interventions had strong support from stakeholders as effective intervention strategies. However, two preventative

strategies were identified as having contradicting opinions of whether they were effective or ineffective as preventative practices in the South African context (Figure 8). The first of these strategies was the effectiveness of the Ergonomics Regulations. Stakeholders suggested that, since their promulgation, the Ergonomics Regulations have resulted in an increase in the number of ergonomics assessments conducted and interventions implemented in South Africa. However, participants also believed that the increase in ergonomics activities was due to the need to comply with the law rather than being convinced of its effectiveness.

Stakeholders' concern about the regulations being ineffective was based on a fear that the need for compliance was the only reason why interventions were occurring rather than the conviction that Human Factors and Ergonomics could assist in this problem. Stakeholders believed that the regulations were being used as a guideline for the necessary intervention rather than the interventions focused on mitigating MSD risk. The ineffectiveness of the Ergonomics Regulations was further reinforced by a comment from one stakeholder, who indicated that if companies were not held accountable, the need to comply with the regulations would decrease, and ergonomics activities would cease because "*having laws or regulations on [a] number of statutory documentation is only really effective if you can enforce it".* This comment suggests that the benefits of ergonomics activities in line with the Ergonomics Regulations are not understood by organisations, which may result in unsuitable intervention implementation in South Africa. Furthermore, a lack of understanding or appropriate application of the Ergonomics Regulations in South Africa can lead to a decrease in the reputation of the still-growing discipline of ergonomics in the country.

The second controversial MSD prevention theme was the use of ergonomics task forces and participatory ergonomics in the work context. Multiple participants identified using these tools as an effective way to prevent MSDs, as indicated by the literature (Caroly et al., 2010; Yazdani & Wells, 2018); however, the comments made also stated that they were ineffective in a South African work environment. Participants mentioned that the resistance to using participatory ergonomics and an ergonomics task force was high (*"quite a big level of resistance"*) and that organisations did not always see the need for them. This could possibly be due to

a lack of understanding of ergonomics as well as the high economic pressures experienced by businesses in a low-to-middle-income country. It was also suggested that the time taken to implement these two intervention approaches did not match the timelines of managers, especially as the South African work environment differs greatly depending on the cultures of the workers in the region (Vink et al., 1995). The resistance to change could also be attributed to the fear of dismissal or redundancy from workers of a lower socio-economic background. Since the inequality in South Africa is high and with a growing unemployment rate, workers may be unwilling to adopt changes, especially when it requires them to learn a new task or work with unfamiliar equipment that may result in poorer performance and thus, job loss (de Bruyn, 2019; Francis & Webster, 2019; SARB, 2022)

Only one theme for ineffective MSD prevention practices was identified and was situated at the managerial level of intervention. Stakeholders suggested that a significant barrier to MSD interventions was the lack of knowledge and buy-in to ergonomics change by managers in organisations. This theme does not point towards a single intervention as being ineffective, but rather that the lack of managerial buy-in may hinder the effectiveness of all interventions. The “Management Systems” level of intervention (Figure 7) can thus be identified as a critical area that should be addressed for MSD prevention to become more effective overall. A lack of knowledge from managers and organisations was cited in all three ineffective MSD prevention themes above, suggesting that a lack of ergonomics awareness and knowledge in South Africa may be the largest barrier towards effective MSD prevention (Weale et al., 2022). A possible solution to the lack of understanding and buy-in of managers has already been identified by participants for effective MSD prevention. Training and education of ergonomics awareness targeted at the managerial and organisational levels of intervention and not only the individual level could potentially reduce the barrier of lack of knowledge and lack of buy-in (Abdollahi et al., 2020; Bolton & Cox, 2015; Denis et al., 2008; Randhawa et al., 2015). Moreover, based on the themes identified, ergonomists in South Africa find the use of training and education as an effective MSD preventative practice; thus, this barrier can and should be reduced with more targeted educational interventions.

An alternative explanation for the ineffectiveness of interventions at the managerial level and the resistance to participatory approaches may be due to the lack of, or poor, change management. Change management refers to how an organisation plans, facilitates and reviews its own polices, structures and directions for adaptation to work and outcome demands (By, 2005). It was indicated that leaders in the workplace, specifically those holding managerial positions, play a crucial role in facilitating changes within an organisation, especially if they are included in the goal setting and risk identification leading up to the implemented change (Oakland & Tanner, 2007). Sirkin et al. (2005) noted that the visible endorsement of change by mangers has a direct impact on the perception and willingness to partake in change by employees. Furthermore, the article suggests that clear and consistent communication as to the benefits and reasoning for change is of utmost importance (Sirkin et al., 2005). This means that strong managerial support to MSD intervention is key for success. By (2005) identified that managerial support towards change tends to be reactive if they are left out of the decision-making process, resulting in poor buy-in and resistance to change. As management play a leadership role, the buy-in to change would positively influence the effective guidance they provide to subordinates, and thus enable reaching the intended goals and outcomes of the intended change (By, 2005; Oakland & Tanner, 2007).

The ergonomists who participated in this study identified three interventions they considered effective in MSD management. Three further interventions had contradictory evidence, while one was considered an ineffective intervention (the use of surveillance practice mentioned earlier) when used in South Africa. In addition, one intervention emerging from the interviews was missing from the draft framework altogether. Besides the use of workstation adjustments (as discussed in the previous section), two other themes were identified as effective for managing MSDs. The first theme identified the management level as a good starting point for implementing MSD management strategies. Unlike the themes that emerged from MSD prevention questions, stakeholders identified this level as a facilitator for effective MSD intervention if managers are given the authority to make decisions regarding the basic ergonomics interventions. This theme suggests that when managers buy into interventions and can make decisions to ensure their proper implementation, workers below them tend to comply with the implemented changes

(Oakman & Bartram, 2017). Thomson et al. (1999) found that employee buy-in leads to more successful policy implementation and increased performance. It also allows the managers to track which interventions work and which do not, and they can improve the interventions being implemented. What was not explicitly stated by the stakeholders, but should be considered, is that for managers to be given agency to make decisions regarding basic MSD interventions, ergonomics knowledge and training would be required. If this is not done, decisions made could be detrimental to workers with existing MSDs and those without.

The proper use of tools and equipment at the individual level of intervention was highlighted as an effective way to intervene. However, using ergonomics tools and adjustable equipment, and workstations does not guarantee a reduction in MSD risk and symptoms. Incorrect usage may be more harmful as the users may be unaccustomed to the new dangers that their bodies are being exposed to (González et al., 2020). Therefore, stakeholders recommended training and education on tool use as part of the equipment change. Empowering workers to make the correct adjustments to workstations and use tools can alleviate MSD risks and MSD-related symptoms without constant supervision. *"You must train the person to actually do his job properly. But you must also train him to set him up correctly."*.

The stakeholders did not agree on the effectiveness of all the interventions, and three themes yielded contradicting opinions on whether the interventions highlighted in each of these themes were effective in managing MSDs in South Africa. The first contradictory theme related to the effectiveness of the Ergonomics Regulations in managing MSDs. Stakeholders believed that the regulations would be beneficial in managing MSDs; however, they had yet to see the benefits in practice. The lack of full implementation of the Ergonomics Regulations mentioned by the stakeholders was put down to the fact that the regulations were still relatively new and that the need for organisations to meet the requirements of the Ergonomics Regulations had not yet been enforced. Unfortunately, there is limited information about the effect of similar regulations on MSD intervention internationally. One study in Australia noted that the focus of regulations and policies affected how they were interpreted and, therefore, how they were

implemented, implying compliance rather than the guidance of the regulations (Oakman & Bartram, 2017). However, this study did focus on regulations already in place and how they aligned with existing policies in the workplace.

The use of return-to-work programs was also found to be effective, albeit to a limited extent. Some stakeholders found that proper implementation of RTW programs led to positive results; however, poor RTW programs may exacerbate the existing disorder(s). While it's been well established in the literature that RTW could be beneficial for MSD management or, at the very least, alleviate pain associated with MSDs, little is known on how RTW programmes can exacerbate the disorders, except that the exposure to risk is cumulative if done incorrectly (Oranye et al., 2017; Viikari-Juntura et al., 2012; Waddell, 2006). Some participants found that using RTW was only beneficial if complete control over employee work was maintained. One participant even exclaimed that the RTW programs were *"very effective until the person returns to work",* indicating that some benefits may arise from such a program; however, these benefits may be short-lived. Both these approaches showed an authoritarian approach to applying for RTW programmes instead of a participatory approach whereby the worker is included in the design of their personal RTW programme (Vermeulen et al., 2009). Although such a participatory approach would be ideal, it can be costly and time-consuming as each individual would need to have a personalised RTW programme; however, the results of the study indicated faster RTW once the participatory programmes were started, with lower MSD incidence (Vermeulen et al., 2009). Alternatively, a more cost-effective way of implementing RTW in South Africa to address the concerns of needing control over the workers could include using cognitive behavioural training in conjunction with RTW programmes (Cullen et al., 2018). Through training to modify their behaviour, individuals could reduce the risk of MSD reappearance by decreasing risky behaviours, although it may increase RTW time (Cullen et al., 2018).

The final theme identified job rotation as an effective intervention in managing MSDs, although it could be difficult to implement and execute properly. The need to design and schedule shifts that allow rotations to occur in a manner that doesn't increase MSD risk on workers is challenging and can therefore be slow to

implement. Although there is contradicting evidence between and within participants' opinions, it was primarily suggested that when done correctly, job rotation can be an effective intervention to reduce MSD symptoms, as was the case in Canada, where workers engaged in self-regulated job rotation (Smith-Young et al., 2014).

One theme that emerged from the draft framework as missing from MSD management was a program designed to match workers' capabilities to task demands (Karsh et al., 2001). References to man-job specification, job-hardening and on-the-job training were made by various stakeholders during the interviews, although none suggested under which level such an intervention should fall. In any case, including such a management strategy in a future version of the draft framework should be considered, as participants referred to it several times, indicating that participants considered it to be an effective MSD management strategy. It was stated that *"While they're at work, they would be physically active. That is nothing else than very good task-related conditioning".*

For the remainder of the draft framework, stakeholders' opinions varied greatly on which interventions were effective in South Africa and which were not, with no other common themes being identified. However, there appeared to be a trend about what stakeholders identified as effective interventions and which they found to be ineffective across both MSD prevention and management. Of the five themes identified as effective, four interventions fell under the micro-ergonomics levels of Figure 7, with the remaining theme (namely, "Management Systems level is a good place to intervene if managerial employees are given agency") relating instead to a facilitator for effective intervention rather than the intervention strategy. This suggests that ergonomists find it challenging to implement MSD interventions at higher levels in South Africa. This is of concern because for successful interventions in the workplace, the organisational policies and systems need to be addressed (Punnett et al., 2009). The difficulty in implementing macro-level interventions is further supported by the contradictory evidence of whether or not the interventions falling under the "Law", "Organisational Policy", or "Management Systems" in the draft framework are effective in a South African working environment. Punnett et al. (2009) stated that without a macro-ergonomics

approach, OSH (and, by extension, MSD interventions) could not be successful, and Purnomo et al. (2017) found macro-ergonomics engagements to lead to more successful micro-ergonomics interventions and a significant reduction in MSDs. Effective MSD prevention and management strategies may not be enough to reduce MSD risk in South Africa if the barriers to macro- and meso-level MSD interventions are not overcome.

4.4.3. Stakeholders' feedback on the draft framework.

The purpose of the draft framework was to assist ergonomists in navigating the MSD literature for suitable intervention selection. To do so, the framework should allow its users to gain the information they need from it quickly and easily. A convoluted or complicated framework may confuse users and slow the intervention process. Participants were asked to review the clarity of instructions and figures, the suitability of the layout and if the framework matches the expected need for a guideline that matches a South African working climate.

Stakeholders commended the display of the multiple levels at which ergonomics interventions for MSDs can occur. Comments made by the stakeholders suggested that the visual representation in the document (Figure 7) assisted them in planning a complete intervention strategy, stating, *"So you can plan from the bottom with the top in mind".* Using such a visual representation may also assist ergonomists in overcoming some of the ineffective interventions mentioned. It was found that ergonomists in South Africa saw the managerial level as a barrier to effective MSD prevention due to a lack of knowledge and buy-in from managers. To address this, simple education and ergonomics awareness campaigns may help increase awareness of the benefits of early interventions. Information from the interview suggests that in South Africa, such strategies have primarily been aimed at individuals doing the work and being exposed to the risk rather than supervisors and managers. Reminders to ergonomists of the multiple ergonomics levels at which intervention can take place; and the relationship between the micro-, meso- and macro-ergonomics levels whilst planning an intervention may aid in designing a complete intervention. Such reminders may help recognise that some interventions, such as education and awareness, can target multiple levels at once

and filter up and down the hierarchical structures of an organisation for a more comprehensive intervention approach.

The stakeholders raised two concerns about the framework; the first being that they had no quick access to the articles in the draft framework document. The interventions were all defined, and the authors' names of individual journals were available in the framework for further research. However, the stakeholders felt that the time it would take to find and gain access to articles to read about specific interventions and how to implement them was not worth the time it would take. This was especially the case if it was not the correct type of intervention for the problem or context. Risk assessment for MSDs and intervention development is only one of many tasks that ergonomists need to fulfil, and as such, their amount of knowledge on different interventions may be limited. Ergonomists are further governed by the time frame and cost of the interventions by their employers, especially those practitioners working as consultants. It is presumed that the practitioners, therefore, want quick access to information to quickly and effectively implement interventions to satisfy employers and lobby for themselves to potential new clients. The interview participants were also concerned about access to all the articles, as some journals require a subscription or fee to access them.

The second concern raised was whom the draft framework was designed and written for; in other words, stakeholders found that it was unclear who the intended audience and users of the draft framework were. Educational and practical requirements exist to become a CPE or CEA in South Africa. This implies that a certain level of education is expected, and key terms and concepts do not need to be explained in detail. However, if it were intended for use by anyone in the South African working context other than an individual with an ergonomics education, it would need a lot more explanation of key concepts and phrases to simplify the draft framework *"might have to find a way to make it even more dumb".* These two concerns raised by the participants may be minor considerations for possible future adjustments to the framework. One of the next steps in framework design is validating the framework once it's been created (Jabareen, 2009). Such an approach allows researchers to develop a framework without the influence of other researchers or practitioners, only gaining feedback and validation once the design

is complete. The draft framework presented in this study took such an approach, basing the design of the draft framework on the literature from the scoping review alone. Taking a participatory ergonomics approach prior to identifying keywords for the scoping review may have been more applicable in creating an MSD framework. Participatory ergonomics seeks to involve participants (in this case, ergonomists that will use the draft framework) in the design of the interventions or programs (Broday, 2021; Rodrigues & Rocha, 2022). Broday (2021) found that the performance of MSD interventions and programs was greater when participants were involved in the design. This suggests that the earlier involvement of South African ergonomists may enhance the framework's success. A participatory approach to the draft framework design may also have focused on the target audience more, as the information would be specific to ergonomists.

A strong theme that was identified throughout all the interviews was that theory does not always translate into practice. Many of the interventions listed in the draft framework were based on international studies, meaning they were designed for and tested in working environments which may be vastly different to those found in South Africa. The draft framework was based only on such studies, and the information in the framework assumed that work in South Africa is done similarly to the context in which the interventions were tested. Therefore, the draft framework looked at "work-as-imagined" in South Africa, especially as it lacked participatory input from ergonomists working in South Africa (Catchpole & Alfred, 2018). The fault in translating theory into practice lies in the methodological setup of the draft framework design. As the stakeholders were only contacted after the initial output of the draft framework, the value of their expertise was not gained until after feedback on the interventions listed in the draft framework. The absence of early involvement of key stakeholders may have decreased the applicability of the draft framework to a South African context. This, in turn, could have led to selecting interventions that had successfully translated theory into practice in a South African working environment. For example, the theory regarding using RTW programs to manage MSDs states that it is an effective tool to manage MSDs throughout their implementation ("work-as-imagined"). However, according to the participants of the interviews, RTW stops being effective once workers can no longer be monitored.

As worker surveillance was pointed out as a highly ineffective tool, such monitoring of workers cannot be done (“work-as-done”).

Finally, participants were asked what resources, if any; they had available to them for MSD interventions, and the overall reply was that most used a combination of personal experience and international based literature and guides, such as NIOSH and HSENI/HSA (Cheung et al., 2007; HSENI & HSA, 2013). These guidelines are predominantly based on the population of developed nations, where MSD prevalence has been noted to be the same or lower in developing nations (Woolf et al., 2008; Yazdani & Wells, 2018). MSDs in developed countries may also be of a different nature due to the number of resources available for treatment and prevention, lower healthcare burden and increased training and knowledge of the risk of MSDs (Woolf et al., 2008; Yazdani & Wells, 2018). Participants also identified a need for a South African-based framework for MSD intervention, stating that such a framework could “add a lot of value” in dealing with MSDs. Yazdani & Wells (2018) identified two of the most significant barriers to successful MSD implementation: a lack of resources and time. Both barriers can be addressed through the inclusion of a South African-specific framework that gives users access to interventions they know are effective within a South African work context, as stated by one of the participants, *“You don’t understand how much time is wasted just trying to find stuff that’s relevant in your region”*.

4.5 Conclusion

The thematic analysis of the interviews showed that not all MSD interventions identified in the literature were considered suitable in South Africa’s diverse working context. Although, it was demonstrated that interventions targeted at the meso- and micro-ergonomics levels (workplace interventions and the individual) were the most popular and effective in South Africa the findings indicated resistance to macro-ergonomics interventions, even though there were indications of some anticipated success once the opposition was overcome. The fact that the macro levels of ergonomics are not currently not considered effective should not be seen as a deterrent for ergonomist practicing within South Africa. Instead, the focus of MSD interventions and HFE in South Africa should be on maximising effectiveness of the micro- and meso-level interventions, in order to increase the

buy-in and to promote the still growing discipline. Ergonomists should emphasise that these treatments and interventions are the most effective for the current state of work within South Africa; but do so while acknowledging and advocating for higher levels of interventions, particularly at the managerial levels. Oakland and Tanner (2007) showed that consultants, the position which most ergonomists in South Africa occupy, are an import part in adding value during the change management process, i.e., while implementing interventions. Therefore, in order for the discipline of ergonomics to grow, particularly if the focus is on MSD interventions, ergonomists need to intervene where it is currently effective to show the value of ergonomics and use this as a steppingstone for the educating management about the true value that interventions at a higher level can provide.

The participants' responses also indicated that some changes should be affected at the higher hierarchical levels, "Law", "Organisational Policies", and "Management Systems", as well as defining who the framework is aimed at. Overall, the interview results suggest that the "Workplace Intervention" and "Individual" levels of the framework are useful in their current form to assist ergonomists in selecting appropriate interventions. These changes and recommendations, especially at the meso- and micro-ergonomics levels, should be considered and integrated into a new version of the framework; one that is more applicable and sensitive to the culturally, ethnically, geographically, and economically diverse working context of South Africa. The lack of effectiveness of higher-level MSD interventions and the concerns about managerial buy-in and understanding should also be taken into account. Future versions of the framework could consider, at least for the immediate time being, including sections dedicated to educating management on the different levels of interventions and how implementation of intervention affect all stakeholders within an organisation, from the people at the top (macro) level to the worker at the bottom (micro) level.

CHAPTER V:
CONCLUSION

5.1 Summary

Musculoskeletal disorder intervention is a well-researched topic, and the literature is filled with numerous studies indicating prevention and management strategies. However, the volume of literature poses a problem to ergonomists trying to find appropriate interventions for their contexts. There is no guideline to assist ergonomists in navigating the MSD literature for effective strategies, let alone to find interventions that will work in South Africa. This study aimed to assist ergonomists in South Africa in navigating the MSD literature to identify and select appropriate MSD prevention and management interventions.

The purpose of Phase 1 was to identify effective MSD prevention and management practices in the literature through a scoping review and create a framework for ergonomists to use to navigate MSD intervention literature. The review identified sixteen MSD prevention strategies across 42 articles and fourteen MSD management strategies across 53 articles. These were sorted into five hierarchical levels of MSD intervention, ranging from macro-ergonomics to micro-ergonomics levels. The results of the review showed that the most effective interventions appeared at the micro-ergonomics level, targeting the individual. In contrast, interventions at the top were found to be most effective in long-term interventions but occur seldomly. These interventions were tabulated and, along with a conceptual model of MSD navigation usage, compiled into a draft framework to assist users in navigating MSD interventions. Although all interventions included were considered in the literature to be effective for MSD prevention and management, it was unknown if they would be suitable in the South African working environment.

The purpose of Phase 2 was to gain the insights of key stakeholders' (ergonomists) professional opinions on the viability of the interventions presented in the framework in a South African context. Stakeholders also reviewed the layout and design in comparison to its purpose. The results of the interviews identified five themes related to effective MSD intervention, two for prevention and three for

management. Four of these themes focused on intervention at the micro-ergonomics level of intervention, where literature indicated most MSD interventions occur. However, the themes from the interviews did not identify whether a multimodal approach to micro-interventions is suitable or even necessary in South Africa, as was the case with most of these types of interventions in the literature. The interview results on intervention at the macro-ergonomics level yielded contradictory evidence among participants about their effectiveness. Themes at this level indicated that interviewees were in favour of conducting such high-level interventions and that the benefits they carried would filter down the levels of the organisation to the workers. However, the resistant climate of the South African workplace and lack of understanding and expertise on how to implement these interventions led to sub-par and sometimes ineffective results. Only two themes were identified as ineffective interventions and related to the surveillance of workers and the lack of managerial knowledge and buy-in. Although only a few interventions were identified as being wholly effective or ineffective in South Africa, many interventions from the framework were mentioned to be useful, albeit in a limited capacity. However, more evidence was needed to be provided by the interviews to create complete themes out of these. As such, the framework is useful nonetheless as a guide for other potential MSD prevention and management strategies, although with the caveat that the effect of the intervention in a South African context is, as yet, unknown.

The second objective of Phase 2 was to gain insights into the framework's design and layout. Themes from the interviews identified the visual representation of the levels of ergonomics interventions as useful when planning interventions and acted as a reminder for a multimodal approach to intervention. Stakeholders did highlight the need for full access to the articles cited in the framework to save even more time navigating the MSD literature. The interviews also identified concerns about whom the framework was designed for. The interviewees suggested clarification of the target audience in the introduction of the framework to reduce the likelihood of confusion and misuse.

5.2 Limitations

Some limits and challenges were found during the duration of the study. However, no changes to the study design or interpretation of the results were required to account for them.

5.2.1. Keyword Identification and Literature Search

The scoping review of the study was conducted using keywords identified during the narrative review of the literature. As the initial literature review was based on a search of international journals, the scoping review made use of keywords commonly encountered in a variety of contexts rather than only a South African one.

5.4.1. Sampling

The use of a purposive sampling technique in this study meant that only key stakeholders identified by the researcher were included in the sample. This was largely overcome by the inclusion criteria and a limited number of CPEs and CEAs that were available in South Africa at the time of the study. However, some stakeholders with potentially valuable experience may have been omitted. It is not required that all ergonomists need to be certified, and some certifications may have lapsed during the time of the study. It is also important to note that other occupations also deal with MSDs (such as occupational doctors, occupational hygienists, engineers etc.) that have different and valuable knowledge on the state of MSD intervention in South Africa.

Furthermore, the sample size of Phase 2 of the study was small; only 5 participants were interviewed, therefore grossly limiting the number of themes identified and the strengths of the themes identified during this phase. The distribution of CPEs (4) to CEAs (1) could also have been improved. However, this was a product of the recruitment design, whereby CEAs were only contacted after not enough CPEs were recruited. The low response rate (29%) to the recruitment call may be explained by the limited number of registered ergonomists in South Africa, only 27 at the time of testing. Recruitment of more CPEs and CEAs would have been preferred to strengthen existing themes and identify new ones.

5.4.2. Participant engagement

It was evident from the interviews that the pre-interview engagement from participants with the framework varied greatly. Some participants had prepared thoroughly, while others only briefly read over the document before the interview. This may have led to interventions being mislabelled and understood by participants during the interviews. The number of interventions listed in the framework meant that it was also likely that some interventions were unfamiliar to the participants, thus indicating that recommendations could have been made based on the potential of the intervention rather than the practical experience they have with using or implementing them.

5.3 Recommendations for Future Studies

Both the narrative and the scoping reviews indicate that further research into MSD prevention and management strategies in South Africa is needed. As the ergonomics discipline in the country continues to grow and evolve, the demands placed on a limited number of ergonomists in the country to combat MSDs will increase. As such, if one aspect of their work can be made more accessible, such as the intervention framework presented in this thesis, pressure on ergonomics practitioners due to high workloads will be reduced, thus allowing for growth in other areas of the discipline. Future studies into creating a framework for MSD intervention or improving the current one may therefore involve:

- Making use of a Delphi approach, where experts are involved in multiple feedback loops, to identify effective MSD practices. This would also allow for the framework to be updated and changes implemented based on the expert's opinions as part of the research method until a final version is produced.

- Involving content experts outside of ergonomists (e.g., engineers, occupational health and safety experts, occupational medical practitioners, etc.) to add a multi-disciplinary aspect to the final product, where another stakeholder may be involved in the implementation of interventions adds value.

- Researching the prevalence and causality of MSDs across different sectors of South Africa. It is challenging to identify appropriate intervention techniques when the number of MSDs and their risk factors are largely unknown in the country. More knowledge on the burden of MSDs in South Africa may also increase attention from organisations and businesses, thus increasing the attention and resources allocated to combating MSDs.

- The creation of more guiding documents and frameworks to assist ergonomists in other aspects of the discipline. MSDs only make up a small portion of the responsibilities of ergonomists, and as such more guidance and assistance to solve other risks plaguing the workplace may be beneficial (such as fatigue, vigilance, psychological and physiological stress etc.)

- Research into the nature and characteristics of the South Africa working context, especially on the barriers and enablers to reporting of different cultural, ethnic, and socio-economic groups. Understanding these would provide better clarity on why certain intervention approaches are more successful than others.

REFERENCES

Abbafati, C., Abbas, K. M., Abbasi-Kangevari, M., Abd-Allah, F., Abdelalim, A., Abdollahi, M., Abdollahpour, I., Abegaz, K. H., Abolhassani, H., Aboyans, V., Abreu, L. G., Abrigo, M. R. M., Abualhasan, A., Abu-Raddad, L. J., Abushouk, A. I., Adabi, M., Adekanmbi, V., Adeoye, A. M., Adetokunboh, O. O., … Amini, S. (2020). Global burden of 369 diseases and injuries in 204 countries and territories, 1990–2019: a systematic analysis for the Global Burden of Disease Study 2019. *The Lancet*, *396*(10258), 1204–1222. https://doi.org/10.1016/S0140-6736(20)30925-9

Abdollahi, T., Pedram Razi, S., Pahlevan, D., Yekaninejad, M. S., Amaniyan, S., Leibold Sieloff, C., & Vaismoradi, M. (2020). Effect of an Ergonomics Educational Program on Musculoskeletal Disorders in Nursing Staff Working in the Operating Room: A Quasi-Randomized Controlled Clinical Trial. *International Journal of Environmental Research and Public Health*, *17*(19), 7333. https://doi.org/10.3390/ijerph17197333

Alias, A. N., Karuppiah, K., How, V., & Perumal, V. (2020). Prevalence of musculoskeletal disorders (MSDS) among primary school female teachers in Terengganu, Malaysia. *International Journal of Industrial Ergonomics*, *77*(May), 102957. https://doi.org/10.1016/j.ergon.2020.102957

Amell, T., & Kumar, S. (2001). Work-related musculoskeletal disorders: design as a prevention strategy. A review. *Journal of Occupational Rehabilitation*, *11*(4), 255–265. https://doi.org/10.1023/a:1013344508217

American Academy of Orthopedic Surgeons. (2008). *United States Bone and Joint Decade: The Burden of Musculoskeletal Diseases in the United States*. Bone and Joint Decade 2002-2011.

Andersen, L. B., Mota, J., & Di Pietro, L. (2016). Update on the global pandemic of physical inactivity. *The Lancet*, *388*(10051), 1255–1256. https://doi.org/10.1016/S0140-6736(16)30960-6

Andrén, D., & Svensson, M. (2012). Part-Time Sick Leave as a Treatment Method for Individuals with Musculoskeletal Disorders. *Journal of Occupational Rehabilitation*, *22*(3), 418–426. https://doi.org/10.1007/s10926-011-9348-7

Aptel, M., Aublet-Cuvelier, A., & Cnockaert, J. C. (2002). Work-related musculoskeletal disorders of the upper limb. *Revue Du Rhumatisme (Edition Francaise)*, *69*(12), 1181–1190. https://doi.org/10.1016/S1169-8330(02)00438-6

Aptel, M., Cail, F., Gerling, A., & Louis, O. (2008). Proposal of parameters to implement a workstation rotation system to protect against MSDs. *International Journal of Industrial Ergonomics*, *38*(11–12), 900–909. https://doi.org/10.1016/j.ergon.2008.02.006

Armstrong, T. J., Buckle, P., Fine, J. F., Hagberg, M., Jonsson, B., Kilbom, A., Kuorinka, I. A. A., Silverstein, B. A., Sjogaard, G., & Viikari-Juntura, E. R. (1993). A conceptual model for work-related neck and upper-limb musculoskeletal disorders. *Scandinavian Journal of Work, Environment and Health*, *19*(2), 73–84. https://doi.org/10.5271/sjweh.1494

Asensio-Cuesta, S., Diego-Mas, J. A., Canós-Darós, L., & Andrés-Romano, C. (2012). A genetic algorithm for the design of job rotation schedules considering ergonomic and competence criteria. *The International Journal of Advanced Manufacturing Technology*, *60*(9–12), 1161–1174. https://doi.org/10.1007/s00170-011-3672-0

Barredo, R. D. V., & Mahon, K. (2007). The Effects of Exercise and Rest Breaks on Musculoskeletal Discomfort during Computer Tasks: An Evidence-Based Perspective. *Journal of Physical Therapy Science*, *19*(2), 151–163. https://doi.org/10.1589/jpts.19.151

Bolton, G. C., & Cox, D. L. (2015). Survey of UK sonographers on the prevention of work related muscular-skeletal disorder (WRMSD). *Journal of Clinical Ultrasound*, *43*(3), 145–152. https://doi.org/10.1002/jcu.22216

Bonini-Rocha, A. C., de Oliveira, R. A. C., Bashash, M., do Couto Machado, G., & Cruvinel, V. R. N. (2021). Prevalence of musculoskeletal disorders and risk factors in recyclable material waste pickers from the dump of the structural city in Brasília, Brazil. *Waste Management*, *125*, 98–102. https://doi.org/10.1016/j.wasman.2021.02.018

Boocock, M. G., McNair, P. J., Larmer, P. J., Armstrong, B., Collier, J., Simmonds, M., & Garrett, N. (2007). Interventions for the prevention and management of

neck/upper extremity musculoskeletal conditions: A systematic review. *Occupational and Environmental Medicine*, *64*(5), 291–303. https://doi.org/10.1136/oem.2005.025593

Bornhöft, L., Thorn, J., Svensson, M., Nordeman, L., Eggertsen, R., & Larsson, M. E. H. (2019). More cost-effective management of patients with musculoskeletal disorders in primary care after direct triaging to physiotherapists for initial assessment compared to initial general practitioner assessment. *BMC Musculoskeletal Disorders*, *20*(1), 186. https://doi.org/10.1186/s12891-019-2553-9

Botha, P. J., Chikte, U., Barrie, R., & Esterhuizen, T. M. (2014). Self-reported musculoskeletal pain among dentists in South Africa: A 12-month prevalence study. *SADJ : Journal of the South African Dental Association = Tydskrif van Die Suid-Afrikaanse Tandheelkundige Vereniging*, *69*(5), 208, 210–213. https://hdl.handle.net/10520/EJC154823

Bouffard, J., Durand, M.-J., & Coutu, M.-F. (2019). Adaptation of a Guide to Equip Employers to Manage the Gradual Return to Work of Individuals with a Musculoskeletal Disorder. *Journal of Occupational Rehabilitation*, *29*(3), 625–635. https://doi.org/10.1007/s10926-019-09827-4

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

Breloff, S. P., Sinsel, E. W., Dutta, A., Carey, R. E., Warren, C. M., Dai, F., Ning, S., & Wu, J. Z. (2019). Are knee savers and knee pads a viable intervention to reduce lower extremity musculoskeletal disorder risk in residential roofers? *International Journal of Industrial Ergonomics*, *74*(October), 102868. https://doi.org/10.1016/j.ergon.2019.102868

Briggs, A. M., Hoy, D. G., Blyth, F. M., Schneider, C. H., & March, L. M. (2018). The Global Burden of Musculoskeletal Pain—Where to From Here? *American Journal of Public Health*, *109*(1), 35–40. https://doi.org/10.2105/ajph.2018.304747

Broday, E. E. (2021). Participatory Ergonomics in the context of Industry 4.0: a

literature review. *Theoretical Issues in Ergonomics Science*, *22*(2), 237–250. https://doi.org/10.1080/1463922X.2020.1801886

Bryman, A. (2012). Part Three. In *Social Research Methods* (4th ed., Vol. 4, pp. 377–429). Oxford University Press.

Buckle, P. W., & Devereux, J. J. (2002). Work-Related Neck and Upper Limb Musculoskeletal Disorders disorders. *Applied Ergonomics*, *33*, 207–217. https://doi.org/10.1016/S0003-6870(02)00014-5

Butwin, A. N., Evans, K. D., Klatt, M., & Sommerich, C. M. (2017). Teaching a Series of Mind-Body Techniques to Address the Risk of Work-Related Musculoskeletal Disorders Among Sonography Students: A Pilot Study. *Journal of Diagnostic Medical Sonography*, *33*(5), 392–403. https://doi.org/10.1177/8756479317720657

By, R. T. (2005). Organisational change management: A critical review. Journal of Change Management, 5(4), 369–380. https://doi.org/10.1080/14697010500359250

Caplan, N., Robson, H., Robson, A., Barry, G., & Wilkes, G. (2017). Associations between community-based physiotherapy for musculoskeletal injury and health related quality of life (EQ-5D): a multi-centre retrospective analysis. *Health and Quality of Life Outcomes*, *15*(1), 212. https://doi.org/10.1186/s12955-017-0789-3

Caple, D. C. (2012). A toolkit for MSDs prevention - WHO and IEA context. *Work*, *41*(SUPPL.1), 3930–3932. https://doi.org/10.3233/WOR-2012-0688-3930

Capodaglio, E. M. (2022). Participatory ergonomics for the reduction of musculoskeletal exposure of maintenance workers. *International Journal of Occupational Safety and Ergonomics*, *28*(1), 376–386. https://doi.org/10.1080/10803548.2020.1761670

Carayon, P., Hancock, P., Leveson, N., Noy, I., Sznelwar, L., & van Hootegem, G. (2015). Advancing a sociotechnical systems approach to workplace safety – developing the conceptual framework. *Ergonomics*, *58*(4), 548–564. https://doi.org/10.1080/00140139.2015.1015623

Carayon, P., Smith, M. J., & Haims, M. C. (1999). Work Organization, Job Stress, and Work-Related Musculoskeletal Disorders. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, *41*(4), 644–663. https://doi.org/10.1518/001872099779656743

Caroly, S., Coutarel, F., Landry, A., & Mary-Cheray, I. (2010). Sustainable MSD prevention: Management for continuous improvement between prevention and production. Ergonomic intervention in two assembly line companies. *Applied Ergonomics*, *41*(4), 591–599. https://doi.org/10.1016/j.apergo.2009.12.016

Catchpole, K., & Alfred, M. (2018). Industrial Conceptualization of Health Care Versus the Naturalistic Decision-Making Paradigm: Work as Imagined Versus Work as Done. *Journal of Cognitive Engineering and Decision Making*, *12*(3), 222–226. https://doi.org/10.1177/1555343418774661

Cheung, Z. (Cal/OSHA C. S., Feletto, M. (Cal/OSHA C. S., Galante, J. (EASE C., & Waters, T. (NIOSH). (2007). Ergonomic guidelines for manual material handling. *DHHS (NIOSH) Publication*, 131. https://doi.org/10.1017/CBO9781107415324.004

Chim, J. (2006). Ergonomics workload analysis for the prevention of musculoskeletal disorders in food services in the health sector. *Proceedings: 42nd Annual Human Factors and Ergonomics Society of Australia Conference 2006, HFESA 2006*, 197–205.

Choi, S. D., & Woletz, T. (2010). Do Stretching Programs Prevent Work-related Musculoskeletal Disorders? *Journal of Safety, Health and Environmental Research*, *6*(2), 1–18.

Cieza, A., Causey, K., Kamenov, K., Hanson, S. W., Chatterji, S., & Vos, T. (2020). Global estimates of the need for rehabilitation based on the Global Burden of Disease study 2019: a systematic analysis for the Global Burden of Disease Study 2019. *The Lancet*, *396*(10267), 2006–2017. https://doi.org/10.1016/S0140-6736(20)32340-0

Cochrane, A., Higgins, N. M., FitzGerald, O., Gallagher, P., Ashton, J., Corcoran, O., & Desmond, D. (2017). Early interventions to promote work participation in people with regional musculoskeletal pain: a systematic review and meta-

analysis. *Clinical Rehabilitation*, *31*(11), 1466–1481. https://doi.org/10.1177/0269215517699976

Colombini, D., & Occhipinti, E. (2006). Preventing upper limb work-related musculoskeletal disorders (UL-WMSDS): New approaches in job (re)design and current trends in standardization. *Applied Ergonomics*, *37*(4), 441–450. https://doi.org/10.1016/j.apergo.2006.04.008

Comper, M. L. C., Dennerlein, J. T., Evangelista, G. D. S., Rodrigues Da Silva, P., & Padula, R. S. (2017). Effectiveness of job rotation for preventing work-related musculoskeletal diseases: A cluster randomised controlled trial. *Occupational and Environmental Medicine*, *74*(8), 545–552. https://doi.org/10.1136/oemed-2016-104077

Coskun Beyan, A., Dilek, B., & Demiral, Y. (2020). The Effects of Multifaceted Ergonomic Interventions on Musculoskeletal Complaints in Intensive Care Units. *International Journal of Environmental Research and Public Health*, *17*(10), 3719. https://doi.org/10.3390/ijerph17103719

Crawford, J. O., Berkovic, D., Erwin, J., Copsey, S. M., Davis, A., Giagloglou, E., Yazdani, A., Hartvigsen, J., Graveling, R., & Woolf, A. (2020). Musculoskeletal health in the workplace. *Best Practice & Research Clinical Rheumatology*, *34*(5), 101558. https://doi.org/10.1016/j.berh.2020.101558

Cullen, K. L., Irvin, E., Collie, A., Clay, F., Gensby, U., Jennings, P. A., Hogg-Johnson, S., Kristman, V., Laberge, M., McKenzie, D., Newnam, S., Palagyi, A., Ruseckaite, R., Sheppard, D. M., Shourie, S., Steenstra, I., Van Eerd, D., & Amick, B. C. (2018). Effectiveness of Workplace Interventions in Return-to-Work for Musculoskeletal, Pain-Related and Mental Health Conditions: An Update of the Evidence and Messages for Practitioners. *Journal of Occupational Rehabilitation*, *28*(1), 1–15. https://doi.org/10.1007/s10926-016-9690-x

Davis, K. G., & Marras, W. S. (2000). The effects of motion on trunk biomechanics. *Clinical Biomechanics*, *15*(10), 703–717. https://doi.org/10.1016/S0268-0033(00)00035-8

de Bruyn, E. (2019). Identifying Barriers and Enablers to Musculoskeletal Disorder Reporting in the Service Sector: A Pilot Study. Unpublished Honours Research Project, Rhodes University, Makhanda, South Africa.

de Castro, A. B. (Butch). (2003). 'Hierarchy of Controls.' *AJN, American Journal of Nursing*, *103*(12), 104. https://doi.org/10.1097/00000446-200312000-00030

de Oliveira Sato, T., & Cote Gil Coury, H. J. (2009). Evaluation of musculoskeletal health outcomes in the context of job rotation and multifunctional jobs. *Applied Ergonomics*, *40*(4), 707–712. https://doi.org/10.1016/j.apergo.2008.06.005

Decker, M., Gomas, K. A., Narvy, S. J., & Vangsness, C. T. (2016). The influence of a dynamic elastic garment on musculoskeletal and respiratory wellness in computer users. *International Journal of Occupational Safety and Ergonomics*, *22*(4), 550–556. https://doi.org/10.1080/10803548.2016.1182321

Denis, D., St-Vincent, M., Imbeau, D., Jetté, C., & Nastasia, I. (2008). Intervention practices in musculoskeletal disorder prevention: A critical literature review. *Applied Ergonomics*, *39*(1), 1–14. https://doi.org/10.1016/j.apergo.2007.02.002

Denyer, D., & Tranfield, D. (2009). Producing a Systematic Review. In D. A. Buchanan & A. Bryman (Eds.), *The Sage Handbook of organisational Research Methods* (Issue 1, pp. 671–689). SAGE Publications Ltd.

Department of Employment and Labour. (2019). *Ergonomics Regulations 2019*. http://www.labour.gov.za/ergonomics-regulation-2019

Desmeules, F., Roy, J.-S., MacDermid, J. C., Champagne, F., Hinse, O., & Woodhouse, L. J. (2012). Advanced practice physiotherapy in patients with musculoskeletal disorders: a systematic review. *BMC Musculoskeletal Disorders*, *13*(1), 107. https://doi.org/10.1186/1471-2474-13-107

Donovan, M., Khan, A., & Johnston, V. (2017). The Effect of a Workplace-Based Early Intervention Program on Work-Related Musculoskeletal Compensation Outcomes at a Poultry Meat Processing Plant. *Journal of Occupational Rehabilitation*, *27*(1), 24–34. https://doi.org/10.1007/s10926-016-9628-3

Du, J., Zhang, L., Xu, C., & Qiao, J. (2021). Relationship Between the Exposure to Occupation-related Psychosocial and Physical Exertion and Upper Body

Musculoskeletal Diseases in Hospital Nurses: A Systematic Review and Meta-analysis. *Asian Nursing Research*, *15*(3), 163–173. https://doi.org/10.1016/j.anr.2021.03.003

Eggers, L. (2016). *Prevalence and Selected Risk Factors for Neck, Shoulder, and Low Back Pain Among Primary School Teachers in the Central Durban Area*. Unpublished Master's thesis, Durban University of Technology.

Entzel, P., Albers, J., & Welch, L. (2007). Best practices for preventing musculoskeletal disorders in masonry: Stakeholder perspectives. *Applied Ergonomics*, *38*(5), 557–566. https://doi.org/10.1016/j.apergo.2006.08.004

Ergonomics Society of South Africa. (2022a). *CEA & CPE Contact List*. https://ergonomicssa.com/cea-cpe/ (Last Accessed: 20 April 2022)

Ergonomics Society of South Africa. (2022b). *Our History*. https://ergonomicssa.com/our-history/ (Last Accessed: 20 April 2022)

Erick, P. N., & Smith, D. R. (2015). Musculoskeletal disorders in the teaching profession: an emerging workplace hazard with significant repercussions for developing countries. *Industrial Health*, *53*(4), 385–386. https://doi.org/10.2486/indhealth.2014-0218

Farham, B. (2020). Vulnerability to disease: Look to the future. *South African Medical Journal*, *110*(11), 1058. https://doi.org/10.7196/SAMJ.2020.v110i11.15365

Ferreira, E. J., & Strydom, E. A. (2016). Managing work-related musculoskeletal disorders in the virtual office. *Journal of Contemporary Management*, *13*, 117–143. https://doi.org/doi/10.10520/EJC185648

Fleishman, E. A., Quaintance, M. K., & Broedling, L. A. (1984). *Taxonomies of human performance: The description of human tasks.* Academic Press.

Francis, D., & Webster, E. (2019). Poverty and inequality in South Africa: critical reflections. Development Southern Africa, 36(6), 788–802. https://doi.org/10.1080/0376835X.2019.1666703

Gangopadhyay, S., & Dev, S. (2014). Design and Evaluation of Ergonomic Interventions for the Prevention of Musculoskeletal Disorders in India. *Annals of*

Occupational and Environmental Medicine, *26*(1), 18. https://doi.org/10.1186/2052-4374-26-18

Garber, C. E., Blissmer, B., Deschenes, M. R., Franklin, B. A., Lamonte, M. J., Lee, I.-M. M., Nieman, D. C., & Swain, D. P. (2011). Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: Guidance for prescribing exercise. *Medicine & Science in Sports & Exercise*, *43*(7), 1334–1359. https://doi.org/10.1249/MSS.0b013e318213fefb

Garg, A., & Kapellusch, J. M. (2009). Applications of biomechanics for prevention of work-related musculoskeletal disorders. *Ergonomics*, *52*(1), 36–59. https://doi.org/10.1080/00140130802480794

Gcelu, A., & Kalla, A. A. (2015). Musculoskeletal disorders – Disease burden and challenges in the developing world. *South African Medical Journal*, *105*(12), 1070–1071. https://doi.org/10.7196/SAMJ.2015.v105i12.10260

Gerr, F. (2005). A randomised controlled trial of postural interventions for prevention of musculoskeletal symptoms among computer users. *Occupational and Environmental Medicine*, *62*(7), 478–487. https://doi.org/10.1136/oem.2004.015792

González, A. G., Barrios-Muriel, J., Romero-Sánchez, F., Salgado, D. R., & Alonso, F. J. (2020). Ergonomic assessment of a new hand tool design for laparoscopic surgery based on surgeons' muscular activity. *Applied Ergonomics*, *88*(May), 103161. https://doi.org/10.1016/j.apergo.2020.103161

Grayson, D., Dale, A. M., Bohr, P., Wolf, L., & Evanoff, B. (2005). Ergonomic Evaluation: Part of a Treatment Protocol for Musculoskeletal Injuries. *AAOHN Journal*, *53*(10), 450–457. https://doi.org/10.1177/216507990505301006

Hay, S. I., Abajobir, A. A., Abate, K. H., Abbafati, C., Abbas, K. M., Abd-Allah, F., Abdulkader, R. S., Abdulle, A. M., Abebo, T. A., Abera, S. F., Aboyans, V., Abu-Raddad, L. J., Ackerman, I. N., Adedeji, I. A., Adetokunboh, O., Afshin, A., Aggarwal, R., Agrawal, S., Agrawal, A., … Murray, C. J. L. (2017). Global, regional, and national disability-adjusted life-years (DALYs) for 333 diseases and injuries and healthy life expectancy (HALE) for 195 countries and territories,

1990–2016: a systematic analysis for the Global Burden of Disease Study 2016. *The Lancet*, *390*(10100), 1260–1344. https://doi.org/10.1016/S0140-6736(17)32130-X

Hochdörffer, J., Hedler, M., & Lanza, G. (2018). Staff scheduling in job rotation environments considering ergonomic aspects and preservation of qualifications. *Journal of Manufacturing Systems*, *46*, 103–114. https://doi.org/10.1016/j.jmsy.2017.11.005

Holtermann, A., Jørgensen, M. B., Gram, B., Christensen, J. R., Faber, A., Overgaard, K., Ektor-Andersen, J., Mortensen, O. S., Sjøgaard, G., & Søgaard, K. (2010). Worksite interventions for preventing physical deterioration among employees in job-groups with high physical work demands: Background, design and conceptual model of FINALE. *BMC Public Health*, *10*(1), 120. https://doi.org/10.1186/1471-2458-10-120

Howarth, S. J., Grondin, D. E., La Delfa, N. J., Cox, J., & Potvin, J. R. (2016). Working position influences the biomechanical demands on the lower back during dental hygiene. *Ergonomics*, *59*(4), 545–555. https://doi.org/10.1080/00140139.2015.1077274

HSENI, & HSA. (2013). *Guidance on the Prevention and Management of Musculoskeletal Disorders (MSDs) in the Workplace* (1st ed.). Health and Safety Authority.

Hu, H., Yang, W., Zeng, Q., Chen, W., Zhu, Y., Liu, W., Wang, S., Wang, B., Shao, Z., & Zhang, Y. (2020). Promising application of Pulsed Electromagnetic Fields (PEMFs) in musculoskeletal disorders. *Biomedicine & Pharmacotherapy*, *131*, 110767. https://doi.org/10.1016/j.biopha.2020.110767

Huang, G. D., & Feuerstein, M. (2004). Identifying Work Organization Targets for a Work-Related Musculoskeletal Symptom Prevention Program. *Journal of Occupational Rehabilitation*, *14*(1), 13–30. https://doi.org/10.1023/B:JOOR.0000015008.25177.8b

Huang, G. D., Feuerstein, M., & Sauter, S. L. (2002). Occupational stress and work-related upper extremity disorders: Concepts and models. *American Journal of Industrial Medicine*, *41*(5), 298–314. https://doi.org/10.1002/ajim.10045

Hutting, N., Johnston, V., Staal, J. B., & Heerkens, Y. F. (2019). Promoting the Use of Self-management Strategies for People With Persistent Musculoskeletal Disorders: The Role of Physical Therapists. *Journal of Orthopaedic & Sports Physical Therapy*, *49*(4), 212–215. https://doi.org/10.2519/jospt.2019.0605

Imenda, S. (2014). Is There a Conceptual Difference between Theoretical and Conceptual Frameworks? *Journal of Social Sciences*, *38*(2), 185–195. https://doi.org/10.1080/09718923.2014.11893249

Jabareen, Y. (2009). Building a Conceptual Framework: Philosophy, Definitions, and Procedure. *International Journal of Qualitative Methods*, *8*(4), 49–62. https://doi.org/10.1177/160940690900800406

Jakobsen, M. D., Sundstrup, E., Brandt, M., & Andersen, L. L. (2018). Effect of physical exercise on musculoskeletal pain in multiple body regions among healthcare workers: Secondary analysis of a cluster randomized controlled trial. *Musculoskeletal Science and Practice*, *34*(January), 89–96. https://doi.org/10.1016/j.msksp.2018.01.006

Jakobsen, M. D., Sundstrup, E., Brandt, M., Jay, K., Aagaard, P., & Andersen, L. L. (2015). Effect of workplace- versus home-based physical exercise on musculoskeletal pain among healthcare workers: a cluster randomized controlled trial. *Scandinavian Journal of Work, Environment & Health*, *41*(2), 153–163. https://doi.org/10.5271/sjweh.3479

Jay, K., Brandt, M., Jakobsen, M. D., Sundstrup, E., Berthelsen, K. G., Schraefel, M., Sjøgaard, G., & Andersen, L. L. (2016). Ten weeks of physical-cognitive-mindfulness training reduces fear-avoidance beliefs about work-related activity. *Medicine*, *95*(34), e3945. https://doi.org/10.1097/MD.0000000000003945

Jorgensen, M., Davis, K., Kotowski, S., Aedla, P., & Dunning, K. (2005). Characteristics of job rotation in the Midwest US manufacturing sector. *Ergonomics*, *48*(15), 1721–1733. https://doi.org/10.1080/00140130500247545

Karsh, B.-T. (2006). Theories of work-related musculoskeletal disorders: Implications for ergonomic interventions. *Theoretical Issues in Ergonomics Science*, *7*(1), 71–88. https://doi.org/10.1080/14639220512331335160

Karsh, B.-T., Moro, F. B. P., & Smith, M. J. (2001). The efficacy of workplace ergonomic interventions to control musculoskeletal disorders: A critical analysis of the peer-reviewed literature. *Theoretical Issues in Ergonomics Science*, *2*(1), 23–96. https://doi.org/10.1080/14639220152644533

Karsh, B. T., Waterson, P., & Holden, R. J. (2014). Crossing levels in systems ergonomics: A framework to support “mesoergonomic” inquiry. *Applied Ergonomics*, *45*(1), 45–54. https://doi.org/10.1016/j.apergo.2013.04.021

Kennedy, C. A., Amick III, B. C., Dennerlein, J. T., Brewer, S., Catli, S., Williams, R., Serra, C., Gerr, F., Irvin, E., Mahood, Q., Franzblau, A., Van Eerd, D., Evanoff, B., & Rempel, D. (2010). Systematic Review of the Role of Occupational Health and Safety Interventions in the Prevention of Upper Extremity Musculoskeletal Symptoms, Signs, Disorders, Injuries, Claims and Lost Time. *Journal of Occupational Rehabilitation*, *20*(2), 127–162. https://doi.org/10.1007/s10926-009-9211-2

Kleiner, B. M. (2006). Macroergonomics: Analysis and design of work systems. *Applied Ergonomics*, *37*(1 SPEC. ISS.), 81–89. https://doi.org/10.1016/j.apergo.2005.07.006

Kogi, K., Kawakami, T., Itani, T., & Batino, J. M. (2003). Low-cost work improvements that can reduce the risk of musculoskeletal disorders. *International Journal of Industrial Ergonomics*, *31*(3), 179–184. https://doi.org/10.1016/S0169-8141(02)00195-6

Kosterec, M. (2016). Methods of conceptual analysis. *Filozofia*, *71*(3), 220–230.

Kuijer, P. P. F. M., Van Der Beek, A. J., Van Dieën, J. H., Visser, B., & Frings-Dresen, M. H. W. (2005). Effect of job rotation on need for recovery, musculoskeletal complaints, and sick leave due to musculoskeletal complaints: A prospective study among refuse collectors. *American Journal of Industrial Medicine*, *47*(5), 394–402. https://doi.org/10.1002/ajim.20159

Kumar, S. (2001). Theories of musculoskeletal injury causation. *Ergonomics*, *44*(1), 17–47. https://doi.org/10.1080/00140130120716

Lanfranchi, J. B., & Duveau, A. (2008). Explicative models of musculoskeletal

disorders (MSD): From biomechanical and psychosocial factors to clinical analysis of ergonomics. *Revue Europeenne de Psychologie Appliquee*, *58*(4), 201–213. https://doi.org/10.1016/j.erap.2008.09.004

Larson, N. L. J. (2012). Corporate Ergonomics. *Ergonomics in Design: The Quarterly of Human Factors Applications*, *20*(4), 29–33. https://doi.org/10.1177/1064804612457674

Legge, J., Burgess-Limerick, R., & Peeters, G. (2013). A New Pre-employment Functional Capacity Evaluation Predicts Longer-Term Risk of Musculoskeletal Injury in Healthy Workers. *Spine*, *38*(25), 2208–2215. https://doi.org/10.1097/BRS.0000000000000013

Leider, P. C., Boschman, J. S., Frings-Dresen, M. H. W., & van der Molen, H. F. (2015). Effects of job rotation on musculoskeletal complaints and related work exposures: a systematic literature review. *Ergonomics*, *58*(1), 18–32. https://doi.org/10.1080/00140139.2014.961566

Lima, T. M., & Coelho, D. A. (2011). Prevention of musculoskeletal disorders (MSDs) in office work: A case study. *Work*, *39*(4), 397–408. https://doi.org/10.3233/WOR-2011-1190

Lincoln, A. E., Vernick, J. S., Ogaitis, S., Smith, G. S., Mitchell, C. S., & Agnew, J. (2000). Interventions for the primary prevention of work-related carpal tunnel syndrome. *American Journal of Preventive Medicine*, *18*(4), 37–50. https://doi.org/10.1016/S0749-3797(00)00140-9

Lloyd, C., Waghorn, G., & McHugh, C. (2008). Musculoskeletal disorders and comorbid depression: Implications for practice. *Australian Occupational Therapy Journal*, *55*(1), 23–29. https://doi.org/10.1111/j.1440-1630.2006.00624.x

Macdonald, W. (2012). Conceptual framework for development of a toolkit for prevention of work-related musculoskeletal disorders. *Work*, *41*(SUPPL.1), 3933–3936. https://doi.org/10.3233/WOR-2012-0689-3933

Macdonald, W., & Oakman, J. (2015). Requirements for more effective prevention of work-related musculoskeletal disorders. *BMC Musculoskeletal Disorders*, *16*(1), 1–9. https://doi.org/10.1186/s12891-015-0750-8

Madiba, S., Hoque, M. E., & Rakgase, R. (2013). Musculoskeletal disorders among nurses in high acuity areas in a tertiary hospital in South Africa. *Occupational Health Southern Africa*, *19*(1), 20–23.

Mansi, S., Milosavljevic, S., Baxter, G. D., Tumilty, S., & Hendrick, P. (2014). A systematic review of studies using pedometers as an intervention for musculoskeletal diseases. *BMC Musculoskeletal Disorders*, *15*(1), 231. https://doi.org/10.1186/1471-2474-15-231

Marinho, O. D. S., & Pereira, A. (2020). Clinical Efficacy and Safety Profile of Topical Etofenamate in the Treatment of Patients with Musculoskeletal Disorders: A Systematic Review. *Pain and Therapy*, *9*(2), 393–410. https://doi.org/10.1007/s40122-020-00177-1

Marras, W. S. (2012). The complex spine: The multidimensional system of causal pathways for low-back disorders. *Human Factors*, *54*(6), 881–889. https://doi.org/10.1177/0018720812452129

Marras, W. S., Davis, K. G., Kirking, B. C., & Bertsche, P. K. (1999). A comprehensive analysis of low-back disorder risk and spinal loading during the transferring and repositioning of patients using different techniques. *Ergonomics*, *42*(7), 904–926. https://doi.org/10.1080/001401399185207

Marras, W. S., & Hancock, P. A. (2014). Putting mind and body back together: A human-systems approach to the integration of the physical and cognitive dimensions of task design and operations. *Applied Ergonomics*, *45*(1), 55–60. https://doi.org/10.1016/j.apergo.2013.03.025

Marras, W. S., Walter, B. A., Purmessur, D., Mageswaran, P., & Wiet, M. G. (2016). The contribution of biomechanical-biological interactions of the spine to low back pain. *Human Factors*, *58*(7), 965–975. https://doi.org/10.1177/0018720816657235

Masiero, S., Pignataro, A., Piran, G., Duso, M., Mimche, P., Ermani, M., & Del Felice, A. (2020). Short-wave diathermy in the clinical management of musculoskeletal disorders: a pilot observational study. *International Journal of Biometeorology*, *64*(6), 981–988. https://doi.org/10.1007/s00484-019-01806-x

Mattison, M. C., & Goebel, M. (2007). A conceptual approach for matching individuals with reduced physical capacities to work. *10th Conference of the Ergonomics Society of South Africa, Durban, 21-2 June*.

Mehrparvar, A. H., Heydari, M., Mirmohammadi, S. J., Mostaghaci, M., Davari, M. H., & Taheri, M. (2014). Ergonomic intervention, workplace exercises and musculoskeletal complaints: a comparative study. *Medical Journal of the Islamic Republic of Iran*, *28*(69), 69.

Melhorn, J. M., Wilkinson, L. K., & Dean O'Malley, M. (2001). Successful Management of Musculoskeletal Disorders. *Human and Ecological Risk Assessment: An International Journal*, *7*(7), 1801–1810. https://doi.org/10.1080/20018091095401

Melo, R., & Costa, D. (2020, January 14). Reducing the gap between work as done and work as imagined on construction safety supported by UAS. *Proceedings: 8th REA Symposium on Resilience Engineering: Scaling up and Speeding up Linnaeus Univerity, Kalmar, Sweden, 24th-27th June 2019*. https://doi.org/10.15626/rea8.02

Menta, R., Randhawa, K., Côté, P., Wong, J. J., Yu, H., Sutton, D., Varatharajan, S., Southerst, D., Angelo, K., Cox, J., Brown, C., Dion, S., Mior, S., Stupar, M., Shearer, H. M., Lindsay, G. M., Jacobs, C., & Taylor-Vaisey, A. (2015). The effectiveness of exercise for the management of musculoskeletal disorders and injuries of the elbow, forearm, wrist, and hand: A systematic review by the Ontario Protocol for Traffic Injury Management (OPTIMa) Collaboration. *Journal of Manipulative and Physiological Therapeutics*, *38*(7), 507–520. https://doi.org/10.1016/j.jmpt.2015.06.002

Mody, G. M., & Brooks, P. M. (2012). Improving musculoskeletal health: Global issues. *Best Practice & Research Clinical Rheumatology*, *26*(2), 237–249. https://doi.org/10.1016/j.berh.2012.03.002

Moodley, R., Naidoo, S., & van Wyk, J. (2018). The prevalence of occupational health-related problems in dentistry: A review of the literature. *Journal of Occupational Health*, *60*(2), 111–125. https://doi.org/10.1539/joh.17-0188-RA

Moom, R. K., Singb, L. P., & Moom, N. (2015). Prevalence of Musculoskeletal

Disorder among Computer Bank Office Employees in Punjab (India): A Case Study. *Proceedings: 6th International Conference on Applied Human Factors and Ergonomics (AHFE 2015) and the Affiliated Conferences, AHFE 2015*, *3*(Ahfe), 6624–6631. https://doi.org/10.1016/j.promfg.2015.11.002

Moore, D., Tappin, D., & Ashby, L. (2006). *Musculoskeletal Disorders in Seafood Processing: A review of the literature for the New Zealand seafood processing industry* (Vol. 7, Issue 2). https://www.scionresearch.com/__data/assets/pdf_file/0020/16094/COHFE-MSDinSeafoodProcessing.pdf

Moradi-Lakeh, M., Forouzanfar, M. H., Vollset, S. E., El Bcheraoui, C., Daoud, F., Afshin, A., Charara, R., Khalil, I., Higashi, H., Abd El Razek, M. M., Kiadaliri, A. A., Alam, K., Akseer, N., Al-Hamad, N., Ali, R., Almazroa, M. A., Alomari, M. A., Al-Rabeeah, A. A., Alsharif, U., … Mokdad, A. H. (2017). Burden of musculoskeletal disorders in the Eastern Mediterranean Region, 1990-2013: Findings from the Global Burden of Disease Study 2013. In *Annals of the Rheumatic Diseases* (Vol. 76, Issue 8, pp. 1365–1373). https://doi.org/10.1136/annrheumdis-2016-210146

Morse, T., Dillon, C., Weber, J., Warren, N., Bruneau, H., & Fu, R. (2004). Prevalence and Reporting of Occupational Illness by Company Size: Population Trends and Regulatory Implications. *American Journal of Industrial Medicine*, *45*(4), 361–370. https://doi.org/10.1002/ajim.10354

Munn, Z., Peters, M. D. J., Stern, C., Tufanaru, C., McArthur, A., & Aromataris, E. (2018). Systematic review or scoping review? Guidance for authors when choosing between a systematic or scoping review approach. *BMC Medical Research Methodology*, *18*(1), 1–7. https://doi.org/10.1186/s12874-018-0611-x

Noonan, J., & Wagner, S. L. (2010). A biopsychosocial perspective on the management of work-related musculoskeletal disorders. *AAOHN Journal : Official Journal of the American Association of Occupational Health Nurses*, *58*(3), 105–114. https://doi.org/10.3928/08910162-20100224-01

Norval, M., Zare, M., Brunet, R., Coutarel, F., & Roquelaure, Y. (2019). Operational leeway in work situations: do ergonomic risk assessment tools consider

operational leeway for job analysis? *International Journal of Occupational Safety and Ergonomics*, *25*(3), 429–442. https://doi.org/10.1080/10803548.2017.1387392

Novak, C. B. (2004). Upper extremity work-related musculoskeletal disorders: A treatment perspective. *Journal of Orthopaedic and Sports Physical Therapy*, *34*(10), 628–637. https://doi.org/10.2519/jospt.2004.34.10.628

Nunes, I. L. (2009). FAST ERGO_X – A tool for ergonomic auditing and work-related musculoskeletal disorders prevention. *Work*, *34*(2), 133–148. https://doi.org/10.3233/WOR-2009-0912

Nuopponen, A. (2010). Methods of concept analysis – Towards systematic concept analysis. *LSP Journal*, *1*(2), 5–14.

Nyantumbu-Mkhize, B. (2017). Musculoskeletal Disorders and Associated Factors in Nurses and Bank Workers in South Africa. Unpublished Doctor of Philosophy thesis , University of Witwatersrand http://www.nioh.ac.za/?page=ergonomicsa&id=146

Nyawose, Z. Z., & Naidoo, R. (2019). Prevalence of shoulder musculoskeletal disorders among school teachers: A systematic review. *South African Journal for Research in Sport, Physical Education and Recreation*, *41*(3), 51–61.

O'Sullivan, P. (2012). It's time for change with the management of non-specific chronic low back pain. *British Journal of Sports Medicine*, *46*(4), 224–227. https://doi.org/10.1136/bjsm.2010.081638

O'Sullivan, P., Caneiro, J. P., O'Keeffe, M., & O'Sullivan, K. (2016). Unraveling the complexity of low back pain. *Journal of Orthopaedic and Sports Physical Therapy*, *46*(11), 932–937. https://doi.org/10.2519/jospt.2016.0609

Oakland, J. S., & Tanner, S. (2007). Successful Change Management. Total Quality Management & Business Excellence, 18(1–2), 1–19. https://doi.org/10.1080/14783360601042890

Oakman, J., & Bartram, T. (2017). Occupational health and safety management practices and musculoskeletal disorders in aged care. *Journal of Health*

Organization and Management, *31*(3), 331–346. https://doi.org/10.1108/JHOM-03-2017-0061

Oakman, J., & Chan, S. (2015). Risk management: Where should we target strategies to reduce work-related musculoskeletal disorders? *Safety Science*, *73*, 99–105. https://doi.org/10.1016/j.ssci.2014.11.026

Oakman, J., Macdonald, W., Bartram, T., Keegel, T., & Kinsman, N. (2018). Workplace risk management practices to prevent musculoskeletal and mental health disorders: What are the gaps? *Safety Science*, *101*(December 2016), 220–230. https://doi.org/10.1016/j.ssci.2017.09.004

Oakman, J., Macdonald, W., & Kinsman, N. (2019). Barriers to more effective prevention of work-related musculoskeletal and mental health disorders. *Applied Ergonomics*, *75*(February 2018), 184–192. https://doi.org/10.1016/j.apergo.2018.10.007

Oakman, J., Weale, V., Kinsman, N., Nguyen, H., & Stuckey, R. (2022). Workplace physical and psychosocial hazards: A systematic review of evidence informed hazard identification tools. *Applied Ergonomics*, *100*(June 2021), 103614. https://doi.org/10.1016/j.apergo.2021.103614

Oh, I. H., Yoon, S. J., Seo, H. Y., Kim, E. J., & Kim, Y. A. (2011). The economic burden of musculoskeletal disease in Korea: A cross sectional study. *BMC Musculoskeletal Disorders*, *12*. https://doi.org/10.1186/1471-2474-12-157

Oranye, N. O., Wallis, B., Ahmad, N., & Aguilar, Z. (2017). Workers' experience with work-related musculoskeletal disorder and worker's perception of organisational policies and practices. *International Journal of Workplace Health Management*, *10*(1), 69–83. https://doi.org/10.1108/IJWHM-03-2016-0015

Otto, A., & Battaïa, O. (2017). Reducing physical ergonomic risks at assembly lines by line balancing and job rotation: A survey. *Computers and Industrial Engineering*, *111*, 467–480. https://doi.org/10.1016/j.cie.2017.04.011

Ouellet, S., & Vézina, N. (2014). Work training and MSDs prevention: Contribution of ergonomics. *International Journal of Industrial Ergonomics*, *44*(1), 24–31. https://doi.org/10.1016/j.ergon.2013.08.008

Padula, R. S., Comper, M. L. C., Sparer, E. H., & Dennerlein, J. T. (2017). Job rotation designed to prevent musculoskeletal disorders and control risk in manufacturing industries: A systematic review. *Applied Ergonomics*, *58*, 386–397. https://doi.org/10.1016/j.apergo.2016.07.018

Panel on Musculoskeletal Disorders and the Workplace. (2001). Musculoskeletal disorders and the workplace: Low back and upper extremities - Executive Summary. *Theoretical Issues in Ergonomics Science*, *2*(2), 142–152. https://doi.org/10.1080/14639220110102035

Pascual, S. A., & Naqvi, S. (2008). An Investigation of Ergonomics Analysis Tools Used in Industry in the Identification of Work-Related Musculoskeletal Disorders. *International Journal of Occupational Safety and Ergonomics*, *14*(2), 237–245. https://doi.org/10.1080/10803548.2008.11076755

Pavlovic-Veselinovic, S., Hedge, A., & Veselinovic, M. (2016). An ergonomic expert system for risk assessment of work-related musculo-skeletal disorders. *International Journal of Industrial Ergonomics*, *53*, 130–139. https://doi.org/10.1016/j.ergon.2015.11.008

Piligian, G., Herbert, R., Hearns, M., Dropkin, J., Landsbergis, P., & Cherniack, M. (2000). Evaluation and management of chronic work-related musculoskeletal disorders of the distal upper extremity. *American Journal of Industrial Medicine*, *37*(1), 75–93. https://doi.org/10.1002/(SICI)1097-0274(200001)37:1<75::AID-AJIM7>3.0.CO;2-4

Pintakham, K., & Siriwong, W. (2016). Effectiveness of the multidimensional ergonomic intervention model to reduce musculoskeletal discomfort among street sweepers in Chiang Rai Province, Thailand. *Risk Management and Healthcare Policy*, *Volume 9*, 275–283. https://doi.org/10.2147/RMHP.S110864

Prall, J., & Ross, M. (2019). The management of work-related musculoskeletal injuries in an occupational health setting: the role of the physical therapist. *Journal of Exercise Rehabilitation*, *15*(2), 193–199. https://doi.org/10.12965/jer.1836636.318

Pransky, G., Snyder, T., Dembe, A., & Himmelstein, J. (1999). Under-reporting of work-related disorders in the workplace: A case study and review of the

literature. *Ergonomics*, *42*(1), 171–182. https://doi.org/10.1080/001401399185874

Punnett, L. (2000). The Costs of Work-Related Musculoskeletal Disorders in Automotive Manufacturing. *NEW SOLUTIONS: A Journal of Environmental and Occupational Health Policy*, *9*(4), 403–426. https://doi.org/10.2190/Y93Q-DEAQ-FEU2-8B26

Punnett, L., Cherniack, M., Henning, R., Morse, T., & Faghri, P. (2009). A Conceptual Framework for Integrating Workplace Health Promotion and Occupational Ergonomics Programs. *Public Health Reports*, *124*(4_suppl1), 16–25. https://doi.org/10.1177/00333549091244S103

Punnett, L., & Wegman, D. H. (2004). Work-related musculoskeletal disorders: The epidemiologic evidence and the debate. *Journal of Electromyography and Kinesiology*, *14*(1), 13–23. https://doi.org/10.1016/j.jelekin.2003.09.015

Purnomo, H., Giyono, E., & Apsari, A. E. (2017). THE USE OF MACRO-ERGONOMIC WORK SYSTEM DESIGNS TO REDUCE MUSCULOSKELETAL DISORDERS AND INJURY RISK IN TRAINING. *South African Journal of Industrial Engineering*, *28*(1), 47–56. https://doi.org/10.7166/28-1-1600

Radwin, R. G., Marras, W. S., & Lavender, S. A. (2001). Biomechanical aspects of work-related musculoskeletal disorders. *Theoretical Issues in Ergonomics Science*, *2*(2), 153–217. https://doi.org/10.1080/14639220110102044

Randhawa, K., Côté, P., Gross, D. P., Wong, J. J., Yu, H., Sutton, D., Southerst, D., Varatharajan, S., Mior, S., Stupar, M., Shearer, H. M., Lindsay, G. M., Jacobs, C., & Taylor-Vaisey, A. (2015). The effectiveness of structured patient education for the management of musculoskeletal disorders and injuries of the extremities: A systematic review by the Ontario Protocol for Traffic Injury Management (OPTIMa) Collaboration. *Journal of the Canadian Chiropractic Association*, *59*(4), 349–362.

Rasmussen, J. (1997). Risk management in a dynamic society: A modelling problem. *Safety Science*, *27*(2–3), 183–213. https://doi.org/10.1016/S0925-7535(97)00052-0

Richardson, A., McNoe, B., Derrett, S., & Harcombe, H. (2018). Interventions to prevent and reduce the impact of musculoskeletal injuries among nurses: A systematic review. *International Journal of Nursing Studies*, *82*(December 2017), 58–67. https://doi.org/10.1016/j.ijnurstu.2018.03.018

Rissén, D., Melin, B., Sandsjö, L., Dohns, I., & Lundberg, U. (2002). Psychophysiological stress reactions, trapezius muscle activity, and neck and shoulder pain among female cashiers before and after introduction of job rotation. *Work and Stress*, *16*(2), 127–137. https://doi.org/10.1080/02678370210141530

Rivera-Rodriguez, A. J., McGuire, K., Carayon, P., Kleiner, B., Wears, R., Robertson, M., Holden, R., & Waterson, P. (2013). Multi-Level Ergonomics. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, *57*(1), 1104–1108. https://doi.org/10.1177/1541931213571246

Rocco, S. T., & Plakhotnik, S. M. (2009). Literature reviews, conceptual frameworks, and theoretical frameworks: Terms, functions, and distinctions. *Human Resource Development Review*, *8*(1), 120–130. https://doi.org/10.1177/1534484309332617

Rodrigues, V., & Rocha, R. (2022). Participatory ergonomics approaches to design and intervention in workspaces: a literature review. *Theoretical Issues in Ergonomics Science*, *0*(0), 1–16. https://doi.org/10.1080/1463922X.2022.2095457

Rose, L. M., Eklund, J., Nord Nilsson, L., Barman, L., & Lind, C. M. (2020). The RAMP package for MSD risk management in manual handling – A freely accessible tool, with website and training courses. *Applied Ergonomics*, *86*(March), 103101. https://doi.org/10.1016/j.apergo.2020.103101

Rostykus, W., Ip, W., & Mallon, J. (2013). Five Common Management Approaches. *Professional Safety*, *58*(December), 35–42.

Rostykus, W., & Mallon, J. (2017). Leading Measures Preventing MSDs and Driving Ergonomic Improvements. *Professional Safety*, *62*(09), 37–42.

Sauter, S. L., & Swanson, N. G. (1996). An ecological model of musculoskeletal

disorders in office work. In *Beyond biomechanics psychosocial aspects of musculoskeletal disorders in office work* (pp. 3–21). CRC Press. https://doi.org/10.1201/9781482272680-11

Schakenraad, C. H. A., Vendrig, L., Sluiter, J. K., Veenstra, W., & Frings-Dresen, M. H. W. (2004). Evaluation of a multidisciplinary treatment for patients with chronic non-specific upper-limb musculoskeletal disorders: A pilot study. *Occupational Medicine*, *54*(8), 576–578. https://doi.org/10.1093/occmed/kqh105

Schroeder, G. P. (2005). Work-Related Musculoskeletal Prevention : a Case Study of an Industrial Msd Prevention Program. *Orthopaedic Practice*, *21*(1), 48–51.

Shariat, A., Cleland, J. A., Danaee, M., Kargarfard, M., Sangelaji, B., & Tamrin, S. B. M. (2018). Effects of stretching exercise training and ergonomic modifications on musculoskeletal discomforts of office workers: a randomized controlled trial. *Brazilian Journal of Physical Therapy*, *22*(2), 144–153. https://doi.org/10.1016/j.bjpt.2017.09.003

Sherrod, C. W., Casey, G., Dubro, R. E., & Johnson, D. F. (2013). The modulation of upper extremity musculoskeletal disorders for a knowledge worker with chiropractic care and applied ergonomics: A case study. *Journal of Chiropractic Medicine*, *12*(1), 45–54. https://doi.org/10.1016/j.jcm.2013.02.002

Shoaf, C., Genaidy, A., Haartz, J., Karwowski, W., Shell, R., Hancock, P. A., & Huston, R. (2000). An adaptive control model for assessment of work-related musculoskeletal hazards and risks. *Theoretical Issues in Ergonomics Science*, *1*(1), 34–61. https://doi.org/10.1080/146392200308462

Siddharthan, K., Hodgson, M., Rosenberg, D., Haiduven, D., & Nelson, A. (2006). Under-reporting of work-related musculoskeletal disorders in the Veterans Administration. *International Journal of Health Care Quality Assurance Incorporating Leadership in Health Services*, *19*(6–7), 463–476. https://doi.org/10.1108/09526860610686971

Sirkin, H. L., Keenan, P., & Jackson, A. (2005). The Hard Side of Change Management. In Harvard Business Review (Vol. 83, Issue 10, pp. 108–158). (Last Accessed: 18 September 2023)

Smith-Young, J., Solberg, S., & Gaudine, A. (2014). Constant negotiating: Managing work-related musculoskeletal disorders while remaining at the workplace. *Qualitative Health Research*, *24*(2), 217–231. https://doi.org/10.1177/1049732313519868

Smith, T. O., Purdy, R., Latham, S. K., Kingsbury, S. R., Mulley, G., & Conaghan, P. G. (2016). The prevalence, impact and management of musculoskeletal disorders in older people living in care homes: a systematic review. *Rheumatology International*, *36*(1), 55–64. https://doi.org/10.1007/s00296-015-3322-1

South African Reserve Bank. (2022). Full Quarterly Bulletin – No 306 – December 2022. https://www.resbank.co.za/en/home/publications/publication-detail-pages/quarterly-bulletins/quarterly-bulletin-publications/2022/full-quarterly-bulletin---no-306---december-2022

Southerst, D., Marchand, A. A., Côté, P., Shearer, H. M., Wong, J. J., Varatharajan, S., Randhawa, K., Sutton, D., Yu, H., Gross, D. P., Jacobs, C., Goldgrub, R., Stupar, M., Mior, S., Carroll, L. J., & Taylor-Vaisey, A. (2015). The effectiveness of noninvasive interventions for musculoskeletal thoracic spine and chest wall pain: A systematic review by the Ontario protocol for traffic injury management (OPTIMa) Collaboration. *Journal of Manipulative and Physiological Therapeutics*, *38*(7), 521–531. https://doi.org/10.1016/j.jmpt.2015.06.001

Stanos, S. P. (2007). Topical Agents for the Management of Musculoskeletal Pain. *Journal of Pain and Symptom Management*, *33*(3), 342–355. https://doi.org/10.1016/j.jpainsymman.2006.11.005

Strazdins, L., & Bammer, G. (2004). Women, work and musculoskeletal health. *Social Science and Medicine*, *58*(6), 997–1005. https://doi.org/10.1016/S0277-9536(03)00260-0

Stubbs, B., Koyanagi, A., Thompson, T., Veronese, N., Carvalho, A. F., Solomi, M., Mugisha, J., Schofield, P., Cosco, T., Wilson, N., & Vancampfort, D. (2016). The epidemiology of back pain and its relationship with depression, psychosis, anxiety, sleep disturbances, and stress sensitivity: Data from 43 low- and middle-income countries. *General Hospital Psychiatry*, *43*, 63–70.

https://doi.org/10.1016/j.genhosppsych.2016.09.008

Summers, K., Jinnett, K., & Bevan, S. (2015). Musculoskeletal Disorders, Workforce Health and Productivity in the United States [White paper]. In *The center for workforced health and performance. London: Lancaster university* (Issue June, pp. 1–41). https://pdfs.semanticscholar.org/99e7/db4d88d398a612aa4d16fb0fd16425a86560.pdf?_ga=2.50245743.895633849.1584971278-1374044221.1584971278

Tähtinen, J., & Havila, V. (2019). Conceptually confused, but on a field level? A method for conceptual analysis and its application. *Marketing Theory*, *19*(4), 533–557. https://doi.org/10.1177/1470593118796677

Thatcher, A., & Yeow, P. H. P. (2016). A sustainable system of systems approach: a new HFE paradigm. *Ergonomics*, *59*(2), 167–178. https://doi.org/10.1080/00140139.2015.1066876

Thinkhamrop, W., Sawaengdee, K., Tangcharoensathien, V., Theerawit, T., Laohasiriwong, W., Saengsuwan, J., & Hurst, C. P. (2017). Burden of musculoskeletal disorders among registered nurses: Evidence from the Thai nurse cohort study. *BMC Nursing*, *16*(1), 1–9. https://doi.org/10.1186/s12912-017-0263-x

Thomson, K., de Chernatony, L., Arganbright, L., & Khan, S. (1999). The Buy-in Benchmark: How Staff Understanding and Commitment Impact Brand and Business Performance. *Journal of Marketing Management*, *15*(8), 819–835. https://doi.org/10.1362/026725799784772684

Tsertsvadze, A., Clar, C., Court, R., Clarke, A., Mistry, H., & Sutcliffe, P. (2014). Cost-effectiveness of manual therapy for the management of musculoskeletal conditions: A systematic review and narrative synthesis of evidence from randomized controlled trials. *Journal of Manipulative and Physiological Therapeutics*, *37*(6), 343–362. https://doi.org/10.1016/j.jmpt.2014.05.001

van Niekerk, S.-M., Louw, Q. A., & Hillier, S. (2012). The effectiveness of a chair intervention in the workplace to reduce musculoskeletal symptoms. A systematic review. *BMC Musculoskeletal Disorders*, *13*(1), 145. https://doi.org/10.1186/1471-2474-13-145

Vargas, C., Bilbeny, N., Balmaceda, C., Rodríguez, F., Zitko, P., Rub´, R., Rojas, R., Eberhard, E., Ahumada, M., & Espinoza, M. A. (2018). *Pain Around the World Costs and consequences of chronic pain due to musculoskeletal disorders from a health system perspective in Chile*. https://doi.org/10.1097/PR9.0000000000000656

Vermeulen, S. J., Anema, J. R., Schellart, A. J. M., Van Mechelen, W., & Van Der Beek, A. J. (2009). Intervention mapping for development of a participatory return-to-work intervention for temporary agency workers and unemployed workers sick-listed due to musculoskeletal disorders. *BMC Public Health*, *9*(1), 216. https://doi.org/10.1186/1471-2458-9-216

Viikari-Juntura, E., Kausto, J., Shiri, R., Kaila-Kangas, L., Takala, E. P., Karppinen, J., Miranda, H., Luukkonen, R., & Martimo, K. P. (2012). Return to work after early part-time sick leave due to musculoskeletal disorders: A randomized controlled trial. *Scandinavian Journal of Work, Environment and Health*, *38*(2), 134–143. https://doi.org/10.5271/sjweh.3258

Vink, P., Peeters, M., Gründemann, R. W. M., Smulders, P. G. W., Kompier, M. A. J., & Dul, J. (1995). A participatory ergonomics approach to reduce mental and physical workload. *International Journal of Industrial Ergonomics*, *15*(5), 389–396. https://doi.org/10.1016/0169-8141(94)00085-H

Waddell, G. (2006). Preventing incapacity in people with musculoskeletal disorders. *British Medical Bulletin*, *77–78*(1), 55–69. https://doi.org/10.1093/bmb/ldl008

Walker-Bone, K., Doherty, E., Sanyal, K., & Churchill, D. (2017). Assessment and management of musculoskeletal disorders among patients living with HIV. *Rheumatology (United Kingdom)*, *56*(10), 1648–1661. https://doi.org/10.1093/rheumatology/kew418

Waterson, P., Eason, K., & Karsh, B. T. (2009). Crossing the macro-micro divide in systems ergonomics. *Proceedings: 17th World Congress on Ergonomics*.

Weale, V., Stuckey, R., Kinsman, N., & Oakman, J. (2022). Workplace musculoskeletal disorders: A systematic review and key stakeholder interviews on the use of comprehensive risk management approaches. *International Journal of Industrial Ergonomics*, *91*(June), 103338.

https://doi.org/10.1016/j.ergon.2022.103338

Wells, R. (2009). Why have we not solved the MSD problem? *Work*, *34*(1), 117–121. https://doi.org/10.3233/WOR-2009-0937

Whittaker, J. L., McKay, C. D., & Batt, M. E. (2019). Prevention, management and long-term consequences of sport and exercise-related musculoskeletal disorders. *Best Practice & Research Clinical Rheumatology*, *33*(1), 1–2. https://doi.org/10.1016/j.berh.2019.101432

WHO Scientific Group on the Burden of Musculoskeletal Conditions at the Start of the New Millennium. (2003). The burden of musculoskeletal conditions at the start of the new millennium. In *World Health Organization technical report series* (Vol. 919, Issue 44). http://www.ncbi.nlm.nih.gov/pubmed/14679827

Wilson, J. R. (2014). Fundamentals of systems ergonomics/human factors. *Applied Ergonomics*, *45*(1), 5–13. https://doi.org/10.1016/j.apergo.2013.03.021

Winnemuller, L. L., Spielholz, P. O., Daniell, W. E., & Kaufman, J. D. (2004). Comparison of ergonomist, supervisor, and worker assessments of work-related musculoskeletal risk factors. *Journal of Occupational and Environmental Hygiene*, *1*(6), 414–422. https://doi.org/10.1080/15459620490453409

Woods, D. D., & Cook, R. I. (2002). Nine Steps to Move Forward from Error. *Cognition, Technology & Work*, *4*(2), 137–144. https://doi.org/10.1007/s101110200012

Woolf, A. D., Brooks, P., Åkesson, K., & Mody, G. M. (2008). Prevention of musculoskeletal conditions in the developing world. *Best Practice and Research: Clinical Rheumatology*, *22*(4), 759–772. https://doi.org/10.1016/j.berh.2008.07.003

Woolf, A. D., & Pfleger, B. (2003). Burden of major musculoskeletal conditions. Bulletin of the World Health Organisation. *Bulletin of the World Health Organisation*, *9*(03), 2003. https://doi.org/10.1590/S0042-96862003000900007

Yan, X., Li, H., Li, A. R., & Zhang, H. (2017). Wearable IMU-based real-time motion warning system for construction workers' musculoskeletal disorders prevention. *Automation in Construction*, *74*, 2–11.

https://doi.org/10.1016/j.autcon.2016.11.007

Yazdani, A., Hilbrecht, M., Imbeau, D., Bigelow, P., Patrick Neumann, W., Pagell, M., & Wells, R. (2018). Integration of musculoskeletal disorders prevention into management systems: A qualitative study of key informants' perspectives. *Safety Science*, *104*(January), 110–118. https://doi.org/10.1016/j.ssci.2018.01.004

Yazdani, A., Neumann, W. P., Imbeau, D., Bigelow, P., Pagell, M., & Wells, R. (2015). Prevention of musculoskeletal disorders within management systems: A scoping review of practices, approaches, and techniques. *Applied Ergonomics*, *51*, 255–262. https://doi.org/10.1016/j.apergo.2015.05.006

Yazdani, A., Sawicki, B., Schwenck, G., & Wells, R. (2019). Awareness of Musculoskeletal Disorders Hazards and Controls in Micro and Small Businesses in Ontario, Canada. *IISE Transactions on Occupational Ergonomics and Human Factors*, *7*(1), 59–68. https://doi.org/10.1080/24725838.2019.1565870

Yazdani, A., & Wells, R. (2018). Barriers for implementation of successful change to prevent musculoskeletal disorders and how to systematically address them. *Applied Ergonomics*, *73*(May), 122–140. https://doi.org/10.1016/j.apergo.2018.05.004

Yu, W., Yu, I. T. S., Wang, X., Li, Z., Wan, S., Qiu, H., Lin, H., Xie, S., & Sun, T. (2013). Effectiveness of participatory training for prevention of musculoskeletal disorders: A randomized controlled trial. *International Archives of Occupational and Environmental Health*, *86*(4), 431–440. https://doi.org/10.1007/s00420-012-0775-3

Ziam, S., Laroche, E., Lakhal, S., Alderson, M., & Gagné, C. (2020). Application of MSD prevention practices by nursing staff working in healthcare settings. *International Journal of Industrial Ergonomics*, *77*(March). https://doi.org/10.1016/j.ergon.2020.102959

Draft Framework for Musculoskeletal Disorder Prevention and Management

1. Purpose of the Draft Framework

This framework aims to provide a concise, evidence-based document to use in the process of preventing and/or managing Musculoskeletal Disorders (MSDs). Through the use of this draft framework, ergonomist or professionals performing ergonomics-based work can navigate the vast amount of literature that surrounds MSDs prevention and management. By the categorizing prevention and management strategies into different hierarchical levels, and with the help of a navigation tool, the draft framework should allow professionals to quickly navigate to the type of the intervention strategy that best suits their context. The draft framework aims to a starting point to navigating the MSD literature when deciding which intervention best suits the organisation's needs. Please take care that this is not a diagnostic tool, nor does it work as a substitute for a qualified professional in combatting MSDs.

This draft framework consists of three sections, 1) draft framework description, 2) how to use the framework, and 3) MSD intervention literature guides.

Section 1: *Draft Framework Description* consists of a brief description on why MSDs intervention can be difficult, the draft framework (Figure 1), as well as how this draft framework attempts to support practitioners in dealing with this issue.

Having said that*, this does not mean that* one intervention is superior to another; sometimes, an intervention at a micro level, such as changing an individual's tools, may be more effective in resolving the problem than, for example, altering the policies surrounding tool usage in an international organisation. The cost, duration of implementation and level of expertise associated with the MSD being targeted should all be considered.

Section 2: How to use the Draft Framework, presents a document navigation tool (Figure 3), and step-by-step instructions on how to use it using visual aids (Figure 2).

Section 3: *MSD Intervention Strategy Literature Guides*, consisting of two tables (Table I: MSD Prevention and Table II: MSD Management) for the names, descriptions, and references of different MSD intervention strategies.

Section 1: Draft Framework Description

MSDs are multifactorial in nature, meaning there are many different factors that all collectively contribute to the development of these disorders. Considering the vast number of industries and types of work in South Africa and the great variety of working demands and exposures, it quickly becomes evident that not all treatment strategies will suit all contexts. It is therefore essential to first identify which level of the work system the intervention should be aimed at.

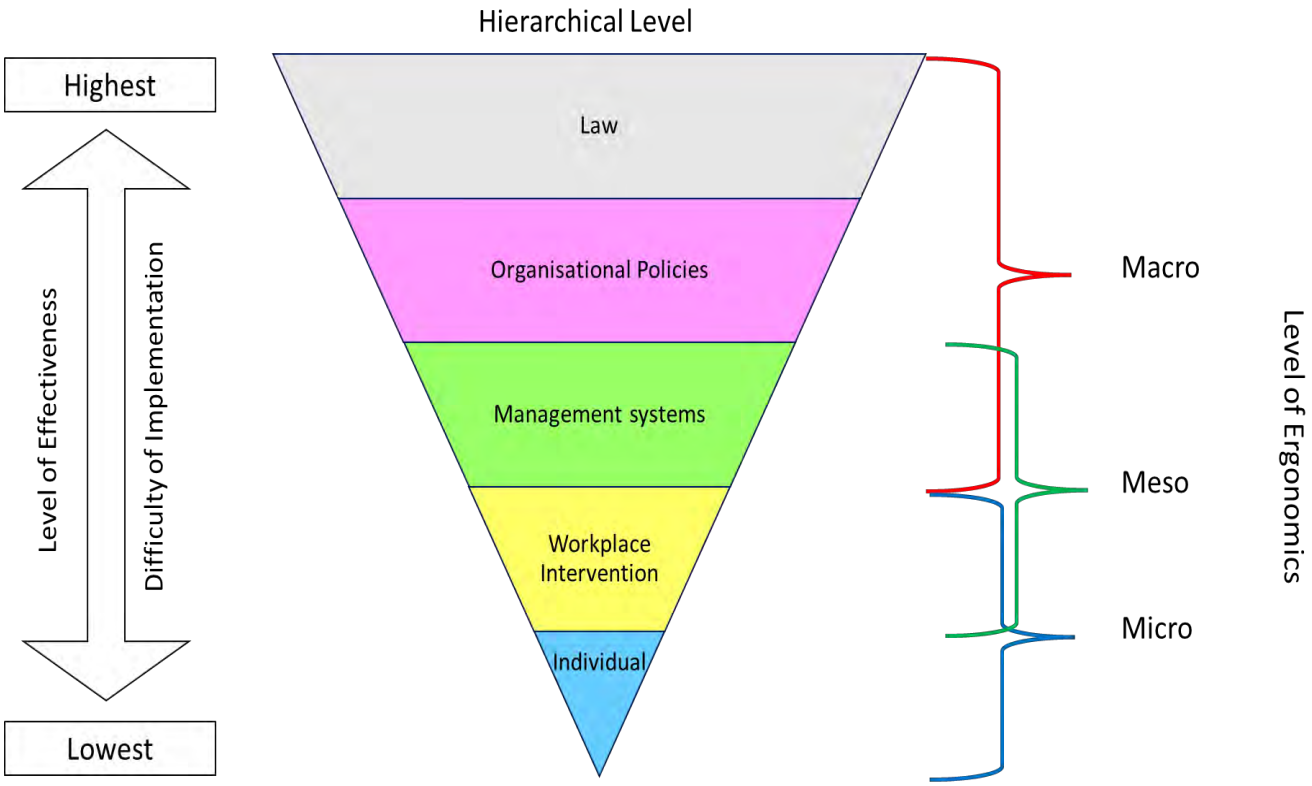

Figure 1: Conceptual Model for the usage of the MSD intervention framework

Figure 1 shows a conceptual model of the draft framework, which is accompanied by Tables I and II under Section 3. There are multiple levels of interventions to reduce the burden of MSDs, ranging from the Law (uppermost/macro level) to the individual with the disorder at the micro level. The framework also indicates that interventions at the higher levels are the most effective, since the effects 'trickle down' to all lower levels, resulting in an overall reduction in the burden of MSDs. However, implementation of higher hierarchical level interventions requires a lot of time and have a higher initial cost. More extensive interventions also need more qualified personnel to implement. Interventions at a microlevel,

on the other hand, are the least effective, as they are generally limited to managing the symptoms of MSDs in an individual or a small group of individuals, leaving the root cause of the problem unattended. However, they are generally faster and cheaper to implement. Microergonomic interventions therefore often require multiple interventions to be implemented simultaneously to be effective.

Having said that, this does not mean that one intervention is superior to another; sometimes, an intervention at a micro level, such as changing an individual's tools, may be more effective in resolving the problem than, for example, altering the policies surrounding tool usage in an international organisation. The cost, duration of implementation and level of expertise associated with the MSD being targeted should all be considered.

Section 2: How to use the Draft Framework

This section explains how to best use the framework and easily navigate Table I and Table II to find the strategy best suited for the context.

Below are step-by-step instructions as well as a visual representation of the steps to follow (Figure 2). This is followed by Figure 3, a navigation tool with the hierarchical sub-levels to allow for quick navigation to the relevant Hierarchical Levels and Sub-levels. **Please read all the steps before using Figure 3 to avoid confusion**

Step 1: Identify whether an MSD prevention strategy or an MSD management strategy best suits the context. In Figure 3, prevention strategies are presented to the left of the "Hierarchical Levels" and management strategies are to the right of the inverted triangle.

Step 2: Identify the "Hierarchical Level" of intervention (i.e., "Law", "Organisational Policies", "Management Systems", Workplace Interventions" or "Individuals"). Consider here the time, finances, and level of expertise available.

Step 3: For MSD **prevention:** click on the **left** side of the inverted triangle.on Figure 3 under the specific "Hierarchical Level" to jump to the relevant section in Table I. To jump to a specific "Prevention Hierarchical Sub-level", you can also click on the appropriate box to the **left** Figure 3.

For MSD **management**: repeat Step 3 on the **right** side of the inverted triangle.or under the "Management Hierarchical Sub-level". This will take you to relevant references in Table II.

Step 4: Once at the appropriate table, use the "Hierarchical Sub-level" to identify the appropriate strategy name. A brief description of the Sub-level is presented in italics underneath each Sub-level name.

Step 5: Move to the "References" and "Article Notes" columns to find the tool or strategy in the literature that best matches the desired context of the MSD.

Step 6: Find and read the article and related content on how best to use that strategy.

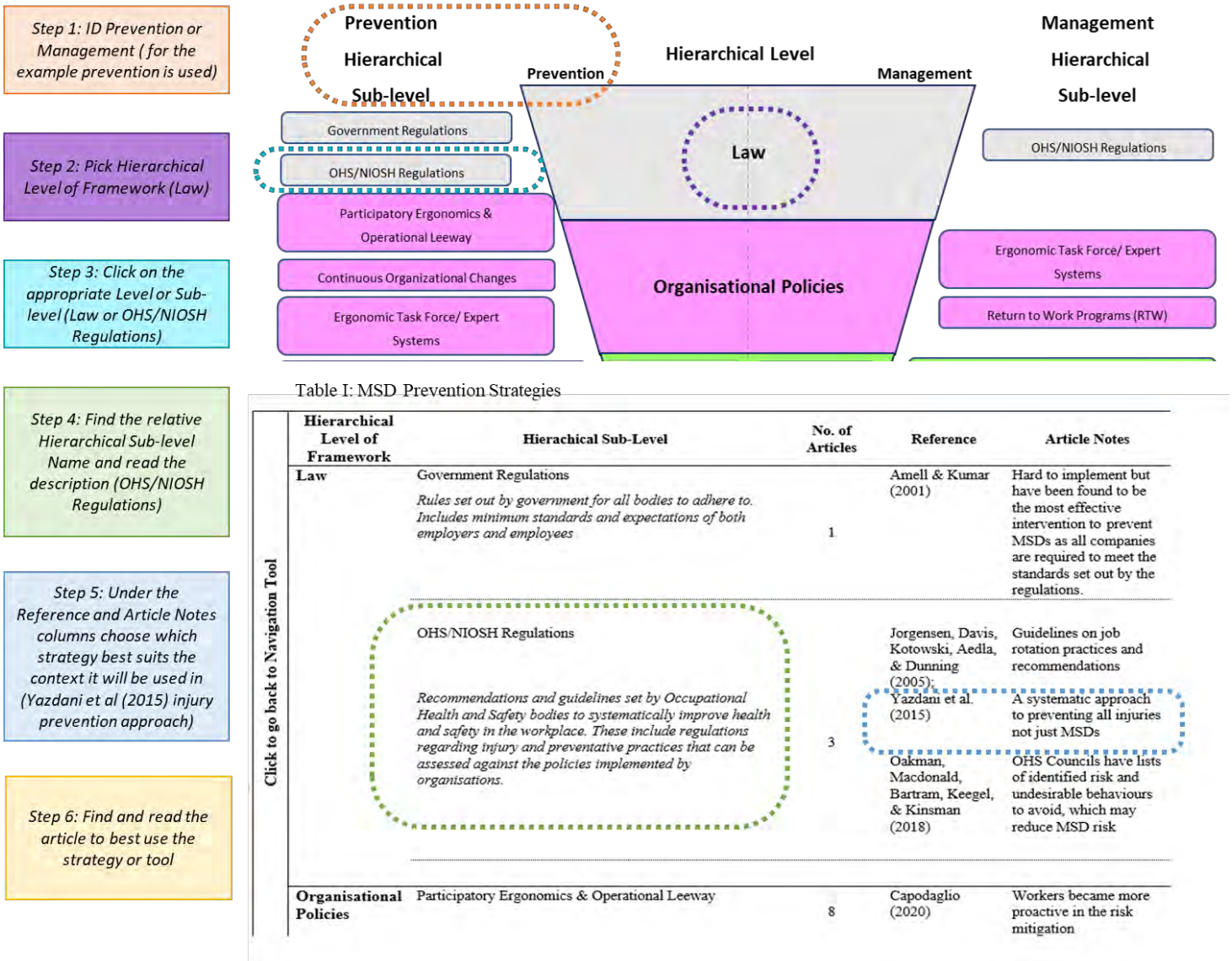

Table I: MSD Prevention Strategies

Click to go back to Navigation Tool

Hierarchical Level of Framework	Hierachical Sub-Level	No. of Articles	Reference	Article Notes
Law	Government Regulations *Rules set out by government for all bodies to adhere to. Includes minimum standards and expectations of both employers and employees*	1	Amell & Kumar (2001)	Hard to implement but have been found to be the most effective intervention to prevent MSDs as all companies are required to meet the standards set out by the regulations.
	OHS/NIOSH Regulations *Recommendations and guidelines set by Occupational Health and Safety bodies to systematically improve health and safety in the workplace. These include regulations regarding injury and preventative practices that can be assessed against the policies implemented by organisations.*	3	Jorgensen, Davis, Kotowski, Aedla, & Dunning (2005); Yazdani et al. (2015) Oakman, Macdonald, Bartram, Keegel, & Kinsman (2018)	Guidelines on job rotation practices and recommendations A systematic approach to preventing all injuries not just MSDs OHS Councils have lists of identified risk and undesirable behaviours to avoid, which may reduce MSD risk
Organisational Policies	Participatory Ergonomics & Operational Leeway	8	Capodaglio (2020)	Workers became more proactive in the risk mitigation

Figure 2: Step-by-step visual aid

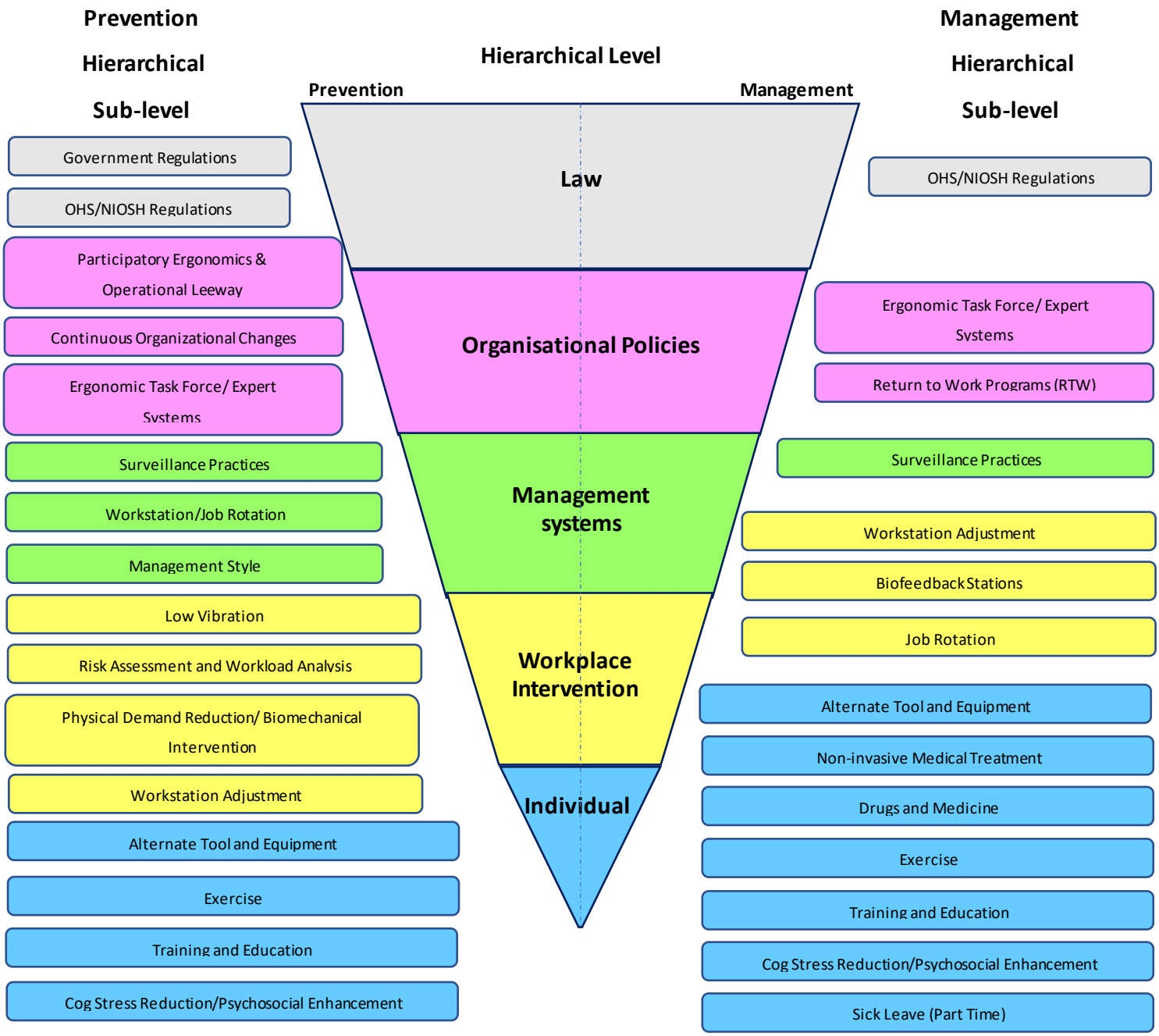

Figure 3: Framework Navigation Tool

Section 3: MSD Intervention Strategy Literature Guides

Table I: MSD Prevention Strategies

Hierarchical Level of Framework	Hierachical Sub-Level	No. of Articles	Reference	Article Notes
Law	Government Regulations *Rules set out by government for all bodies to adhere to. Includes minimum standards and expectations of both employers and employees*	1	Amell & Kumar (2001)	Hard to implement but have been found to be the most effective intervention to prevent MSDs as all companies are required to meet the standards set out by the regulations.
	OHS/NIOSH Regulations *Recommendations and guidelines set by Occupational Health and Safety bodies to systematically improve health and safety in the workplace. These include regulations regarding injury and preventative practices that can be assessed against the policies implemented by organisations.*	3	Jorgensen, Davis, Kotowski, Aedla, & Dunning (2005); Yazdani et al. (2015) Oakman, Macdonald, Bartram, Keegel, & Kinsman (2018)	Guidelines on job rotation practices and recommendations A systematic approach to preventing all injuries not just MSDs OHS Councils have lists of identified risks and undesirable behaviours to avoid, which may reduce MSD risk.

Organisational Policies	Participatory Ergonomics & Operational Leeway	8	Capodaglio (2020)	Workers became more proactive in the risk mitigation
	Policy whereby the workers are involved in the development of the intervention, using their knowledge of the workplace alongside expert knowledge to create a suitable preventative approach. *Examples of participatory ergonomics include using training surrounding risk and ergonomics awareness of MSDs and MSD prevention, and collecting feedback from workers to then incorporate changes into the organisation's prevention plan.*		Caroly, Coutarel, Landry, & Mary-Cheray (2010)	Continuous improvement and efficiency of workstations and tools used in the prevention of the MSDs
			Norval, Zare, Brunet, Coutarel, & Roquelaure (2019)	Evidence for increased accuracy of MSD risk identification
			Yazdani et al. (2015)	Increased acceptance of interventions by workers
			Yazdani & Wells (2018)	Effective for the prevention of MSDs in an isolated part of the business without affecting the whole business.
			Yu et al. (2013)	Reduced occurrence of lower extremity MSDs
			Caroly, Coutarel, Landry, & Mary-Cheray (2010)	Participatory ergonomics lead to new innovation of MSD risk assessment

Continuous Organisational Changes *Systematic changes to the current policy or intervention strategy in an organisation to increase the scope of the intervention practices over time. This in turn allows for multiple level interventions to be implemented as the ergonomist or team conduct risk assessments and various intervention strategies form a policy that best fits the particular organisation within which it is implemented* in.	4	Caroly, Coutarel, Landry, & Mary-Cheray (2010)	Incentive for reduced risk movements with active worker involvement
		Denis, St-Vincent, Imbeau, Jetté, & Nastasia (2008)	Continuous change works best with an Ergonomic Task Force to lead the changes.
		Yazdani et al. (2015)	Feedback from workers is vital to enusre that the changes are not negatively affecting another part of the system
		Yazdani et al. (2018)	The implementation of "end users" feedback is key for long term effective intervention
Ergonomic Task Force/Expert Systems *A task force or program responsible for evaluating tasks, assessing risk and making informed decisions on how to intervene to prevent MSDs, using evidence based off the initial assessment. The process is then repeated with the new interventions*	6	Nunes (2009)	FAST ERGO-X tool for MSD prevention. User input is tested against historical correlations and know causes of MSDs to produce an evaluation and recommendation to reduce risk
		Padula, Comper, Sparer, & Dennerlein (2017)	Task force used to effectively design job rotation schedules

			Pavlovic-Veselinovic, Hedge, & Veselinovic (2016)	SONEX computer expert system tool used to replicate human problem-solving abilities
			Yazdani & Wells (2018)	The use of ergonomists throughout design increased effectiveness of MSD prevention
			Schroeder (2005)	Ergonomics program successfuly identified and managed risks for MSDs, thus preventing future MSD occurrence
			Choi & Woletz (2010)	Effective programs reduce ergonomics risks using multiple interventions
Management systems	Surveillance Practices *Programs for the screening of employees over the course of employment*	1	Amell & Kumar (2001)	Part of a secondary prevention strategy, for early detection and treatment of symptoms prior to MSD development

Workstation/Job Rotation *The systematic rotation of employees from one task to another after a set amount of time to reduce repetitive movements and overuse of particular body parts, in an effort to lower risk and increase rest*	10	Aptel, Cail, Gerling, & Louis (2008)	Effectively reduced psychosocial strain but had limited effect mitigating biomechanical risk
		Asensio-Cuesta, Diego-Mas, Canós-Darós, & Andrés-Romano (2012)	Creating job rotation schedules using the ECRot algorithm tool has shown effective MSD prevention
		Comper, Dennerlein, Evangelista, Rodrigues Da Silva, & Padula (2017)	Lead to a decrease in wrist and hand MSD symptoms*
		Denis, St-Vincent, Imbeau, Jetté, & Nastasia (2008)	Resulted in a more complete intervention *
		Hochdörffer, Hedler, & Lanza (2018)	Creating long term job rotation schedules using the BEQR method has shown reduction in MSD risk
		Jorgensen, Davis, Kotowski, Aedla, & Dunning (2005)	Effective in medium term (5-8 years) MSD prevention with increase productivity, but only when assigned correctly.

			Incorrect job assignment could increase cumulative biomechanical exposure and risk of MSD development.
		Kuijer, Van Der Beek, Van Dieën, Visser, & Frings-Dresen (2005)	Reduces peak biomechanical load. Incorrect job assignment could increase cumulative biomechanical exposure and risk of MSD development.
		Leider, Boschman, Frings-Dresen, & van der Molen (2015)	Beneficial if job demands are matched to workers' capabilities, e.g., rotation occurs between a high demand and a low demand task
		Otto & Battaïa (2017)	Reduced cumulative biomechanical load under a balanced schedule
		Rissén, Melin, Sandsjö, Dohns, & Lundberg (2002)	Resulted in a decrease in awkward postures
Management Style *The ability for employees to provide feedback to managers or supervisors about potential risks, safety concerns or ideas promoting safety*	1	Huang & Feuerstein (2004)	May reduce the psychosocial component of MSD formation.

Workplace Intervention	Low Vibration *Reduction in vibration-based tasks*	1	Amell & Kumar (2001)	Reduced biomechanical risk when doing tasks*
	Risk Assessment and Workload Analysis	12	Amell & Kumar (2001)	Reduction in MSD risk when correct intervention practices were used *
	The use of appropriate ergonomic risk assessment tools to identify both potential and current medium and high-risk tasks/workstations and application of interventions to mitigate the risk prior to MSD development.		Aptel, Cail, Gerling, & Louis (2008)	Key in describing and identifying areas of risk for workplace modifications, both psychosocially and biomechanically *
			Choi & Woletz (2010)	Important step in ergonomic program, prior to any intervention
			Denis, St-Vincent, Imbeau, Jetté, & Nastasia (2008)	Key part of identifying the potential risk that may lead to MSDs, however only when combined with effective interventions*
			Huang & Feuerstein (2004)	Showed that high risk job categories can be easily identified through specific risk assessment throughout an organisation*

Norval, Zare, Brunet, Coutarel, & Roquelaure (2019)	First step in identifying where and what potential risks of MSD are in the workplace
Yazdani et al. (2015)	Multiple asssesments are crucial in the intial risk identification process, especially in an ergonomics program.*
Winnemuller, Spielholz, Daniell, & Kaufman (2004)	The use of non-ergonomic specialist to do the initial check was suitable; however more detailed examination of tasks required an ergonomist's input.
Shoaf et al. (2000)	Provides a systematic approach to assessing risk. Notes that accurate descriptions of risks and hazards can lead to more effective MSD prevention.
Chim (2006)	Suggested a multi-modal assessment to test multiple components that contribute to a single task's workload

		Colombini & Occhipinti (2006)	Important in risk assessment programs*
		de Oliveira Sato & Cote Gil Coury (2009)	Ergonomic Workplace Analysis (EWA) used to evaluate the workplace, tasks and biomechanical risk
Physical Demand Reduction/Biomechanical intervention	4	Choi & Woletz (2010)	This was found to be effective as part of an ergonomic program*
Interventions to reduce the effect of vibrations, high loads, awkward postures and other biomechanical hazards		Garg & Kapellusch (2009)	Reduced biomechanical load to match tissue capabilities of workers decreases MSD risk
		Huang & Feuerstein (2004)	Reduction in biomechanical risk as part of a job redesign intervention mitigated risk*
		Use of low-cost micro ergonomic interventions to decrease MSD risk	Use of low cost micro ergonomic interventions to decrease MSD risk

	Workstation Adjustment	6	Boocock et al. (2007)	Evidence for reduced upper extremity risk of MSDs
	Changes to the physical workstation to meet the needs of the user, including layout, equipment set up and tool usage.		Denis, St-Vincent, Imbeau, Jetté, & Nastasia (2008)	Allowed for prescribed and individual adjustments to be made after training*
			Kennedy et al. (2010)	Positive effect on MSD reduction only when paired with ergonomic training *
			Gerr et al. (2005)	Not effective alone*
			Lima & Coelho (2011)	After installing ergonomic equipment for correct usage
			Colombini & Occhipinti (2006)	Increased need for collaboration between ergonomists and manufactures to reduce MSD risk
Individual	Alternate Tool and Equipment	9	Amell & Kumar (2001)	Tool that meets the limitations of the user*
	Tools that are ergonomically designed to reduce awkward postures, strains, vibrations, and high loads, thus reducing the risk of MSD formation, especially in high repetition tasks		Boocock et al. (2007)	Reduced some risk in upper extremity MSDs*

de Oliveira Sato & Cote Gil Coury (2009)	Use of RPE scales in measuring exertion to prevent overuse, alongside an ergonomic task force*
Denis, St-Vincent, Imbeau, Jetté, & Nastasia (2008)	Changes/adaptations to standard tool design as well as purchasing more ergonomically designed tools where benneftil in risk reduction *
Gangopadhyay & Dev (2014)	Found using alternative tools to be effective as part of a complete ergonomics intervention program
Kogi, Kawakami, Itani, & Batino (2003)	Low-cost tools decreased tissue loads
Lima & Coelho (2011)	Effective when the proper training to use the equipment was administered*
Yan, Li, Li, & Zhang (2017)	Use of PPE increased self managemt of risk during task performamnce

		Lincoln et al. (2000)	Positive short-term reduction in MSD risk
Exercise	4	Boocock et al. (2007)	Strength and flexibility training was found to be effective in combination with multiple other individual category interventions *
Stretching, at home or on-the- job strength and conditioning programs or physical activity.		Choi & Woletz (2010)	On-the-job stretching was found to be effective in combination with multiple other individual category interventions*
		Holtermann et al. (2010)	Resulted in increased tissue capacity which lowers MSD risk*
		May be effective in reducing MSD risk when combined with ergonomics training	May be effective in reducing MSD risk when combined with ergonomics training

Training and Education	7	Capodaglio (2020)	As part of a participatory ergonomics program
Programs or courses that teach the basic principles of ergonomics, risk and hazards to workers. This allows for the assessment and mitigation of risks and hazards to prevent MSDs		Denis, St-Vincent, Imbeau, Jetté, & Nastasia (2008)	Training could be effective when the broader context of the workplace is taken into consideration*
		Kennedy et al. (2010)	May reduce MSD risk*
		Lincoln et al. (2000)	Training with new equipment or tools is important
		Oakman, Macdonald, Bartram, Keegel, & Kinsman (2018)	Can be useful especial when introducing new tools or equipment Training workers to identify potential risk to MSD can also lead to increased early intervention*
		Ziam, Laroche, Lakhal, Alderson, & Gagné (2020)	On the job, context specific training is more benefitial, especial when a participatory ergonomics appraoch is taken

		Ouellet & Vézina (2014)	Taining allne is not effective, however when paired with learing conditions, it may result in reduced MSD risk *
Cognitive Stress Reduction/Psychosocial Enhancement	2	Huang & Feuerstein (2004)	Important factor which may decrease tolerance of individuals, leading to greater risk of MSDs.
Training, support, and educational practices that are aimed at decreasing the psychosocial risk of MSD development		Oakman, Macdonald, Bartram, Keegel, & Kinsman (2018)	Largely ignored in the assessment process and thus no interventions occurred. May reduce MSD risk

** Denotes ineffective intervention when implemented on its own*

Table II: MSD Management Strategies

Hierarchical Level of Framework	Hierachical Sub-Level	No. of Articles	Reference	Article Notes
Law	Ocupational Health and Safety (OHS)/National Institute for Occupational Safety and Health (NIOSH) Regulations		Oakman & Bartram (2017)	Aligned with organisational policies, results in better MSD management
	Recommendations and guidelines set by Occupational Health and Safety bodies to systematically improve health and safety in the workplace. These include regulations surrounding rehabilitation, return-to-work practices and decrease in symptoms, that can be assessed against the policies implemented by organisations.	2	Moore, Tappin, & Ashby (2006)	Addressing existing, previously identified hazards by increasing the effectiveness of MSD management techniques
Organisational Policies	Ergonomic Task Force/Expert Systems		Beyan, Dilek, & Demiral (2020)	Encompassing multimodal interventions has been effective
	A task force or program responsible for evaluating tasks, assessing risk and making informed decisions on how to intervene to reduce MSD symptoms and reoccurrence, using evidence based on the initial assessment. The process is then repeated with the new interventions	10	Oakman & Bartram (2017)	Programs addressing the OHS mandate showed a decrease in psychosocial and physiological risk of MSD and decrease MSD symptoms
			Grayson et al. (2004)	Conducting ergonomic evaluations to perform risk assessments on the individuals, specific tasks and thee worker capabilities to promote return to work

Melhorn, Wilkinson, & O'Malley (2001)	Comprehensive ergonomic program creates opportunity for better MSD management
Pintakham & Siriwong (2016)	Multimodal approach showed a reduction in MSD symptoms
Purnomo, Giyono, & Apsari (2017)	Macro Ergonomic Analysis Design (MEAD) decreased the risk of MSD reoccurrence and reduced symptoms
Moore, Tappin, & Ashby (2006)	Reduced severity in symptoms, with specific ergonomics interventions
Southerst et al. (2015)	Multimodal intervention increased self-reported improvement
Larson (2012)	Macro-level interventions led to decreased MSD symptoms and related costs
Donovan, Khan, & Johnston (2017)	Decrease the delay between diagnosis and interventions thus decreasing the severity of MSD symptoms (early recognition is key). Also led to a reduction in treatment cost due to MSDs*

Return to Work Programs (RTW) *Organisational programs that promote and facilitate the return to work of an employee after a period of rest or absenteeism due to injury or chronic disorders, such as MSDs. These programs include rehabilitation practices, monitoring, workstation interventions, training and exercise techniques to facilitate a speedy recovery, while not putting the individual at further risk.*	8	Bouffard, Durand, & Coutu (2019)	Gradual RTW programs with MM (margin of manoeuvre) allows for a decrease in MSD symptoms as workers have latitude to complete a task using their own method. It may decrease psychosocial factors of MSDs and reduce the risk of catastrophizing
		Cochrane et al. (2017)	RTW programs with Part-time sick leave has resulted in reduced symptoms and increase
		Hoosain et al. (2018)	Decreased RTW time and symptoms with multiple interventions especially CBT*
		Waddell (2006)	Promoting positive attitude towards RTW and rehabilitation; decreased time of MSD-induced sick leave
		Viikari-Juntura et al. (2012)	Early part-time sick leave decreased RTW time and increased full recoveries of MSDs *
		Schakenraad, Vendrig, Sluiter, Veenstra, & Frings-Dresen (2004)	Decreased upper limb MSD symptoms when a multidisciplinary approach was taken*

			Vermeulen, et al. (2009)	Participatory approach to designing RTW program using the Intervention Mapping protocol, decreased MSD symptoms and increased faster RTW
			Oranye, Wallis, Ahmad, & Aguilar (2017)	A safety-first approach to RTW led to reduced sick leave
Management systems	Surveillance Practices *Programs for the screening of employees over the course of employment including risk assessments and medical analysis*	8	Bornhöft et al. (2019)	Triage employees as they report MSDs to keep track of the severity of the disorder
			Donovan, Khan, & Johnston (2017)	Used as part of and initial prevalence survey to intervene early in MSD onset and decrease compensation claims
			Legge, Burgess-Limerick, & Peeters (2013)	Pre-employment screening to match worker capacity to the demands of the task assigned to them
			Rose, Eklund, Nord Nilsson, Barman, & Lind (2020)	As part of the Risk Assessment and Management tool for manual handling Proactively (RAMP) to manage and reduce MSDs

			Waddell (2006)	Screening with work modifications decreased MSDs
			Melhorn, Wilkinson, & O'Malley (2001)	Screened workers pre-employment to monitor potential MSD risk
			Moore, Tappin, & Ashby (2006)	Early risk detection and intervention after early reporting of MSDs
			Rostykus & Mallon (2017)	Assessment of risk allows for early interventions to reduce risk and MSD prevelance
Workplace Intervention	Workstation Adjustments		Boocock et al. (2007)	Decreased the risk of worsening MSD symptoms
	Changes to the physical workstation or task design to meet the needs of the user, including layout, equipment set up and tool usage; thus, decreasing the demands of the task	7	Waddell (2006)	Changes based on post-screening recommendations may decrease symptoms
			Viikari-Juntura et al. (2012)	As a part of part-time sick leave by reducing the time spent performing the task*
			Sherrod, Casey, Dubro, & Johnson (2013)	With proper training may lead to long term reductions in MSD symptoms. *
			Shariat et al. (2018)	With exercise they may reduce pain in the long term *

			Mehrparvar et al. (2014)	Decreased MSD complaints and symptoms
			van Niekerk, Louw & Hillier (2012)	With training they may reduce MSD symptoms*
	Biofeedback Stations *Garments and techniques used to remind the worker to correct their posture thus reducing the risk of MSDs due to awkward postures*	2	Decker, Gomas, Narvy, & Vangsness (2016)	Novel elastic garment that may reduce MSD symptoms and risk
			Butwin, Evans, Klatt, & Sommerich (2017)	Biofeedback training with appropriate education decreased MSD symptoms*
	Job Rotation *The systematic rotation of employees from one task to another after a set amount of time to reduce repetitive movements and overuse of particular body parts, in an effort to lower risk and increase rest*	1	Kuijer, Van Der Beek, Van Dieën, Visser, & Frings-Dresen (2005)	Decreased cumulative load exposure in workers and decreased MSD symptoms and future risk
Individual	Alternate Tool and Equipment *Tools that are ergonomically designed to reduce awkward postures, strains, vibrations, and high loads, thus decreasing the risk of MSD formation, especially in high repetition tasks*	4	Breloff et al. (2019)	Decreased biomechanical load and risk of aggravation to the disorder, if used correctly*
			Melhorn, Wilkinson, & O'Malley (2001)	Decreased severity of MSD symptoms*
			Pascual & Naqvi (2008)	Effective with training on how to properly use the tools*
			Moore, Tappin, & Ashby (2006)	Tools suited to the task being performed and that were

			properly maintained reduced MSDs*
Non-invasive Medical Treatment	11	Andrén & Svensson (2012)	OH Physician have better evaluation of RTW schedule than GP for workers with MSDs, reducing sick-leave time and worker turnover*
Diagnosis and rehabilitation practices from physical therapist, physiotherapist and occupational health care physicians to reduce symptoms and severity of MSDs and improve RTW time.		Bolton & Cox (2015)	Rehabilitation with strength and conditioning programs can decrease MSD symptoms and increase RTW
		Bornhöft et al. (2019)	Physiotherapy lead to decreased sick leave and MSD symptoms. Physiotherapy also had a lower cost than a GP for similar results
		Caplan, Robson, Robson, Barry, & Wilkes (2017)	A decrease in MSD symptoms with physiotherapy*
		Cochrane et al. (2017)	Early intervention and rehabilitation decreased RTW of MSD patients*
		Desmeules et al. (2012)	Physiotherapy decreased MSD symptoms and RTW time*
		Hu et al. (2020)	Novel treatment using Pulsed Electromagnetic Fields (PEMFs) may decrease MSD symptoms in selected cases

		Tsertsvadze et al. (2014)	Manual therapy decreased some MSD symptoms. * Could decrease the cost of treatment when aligned with GP recommendations*
		Hutting, Johnston, Staal, & Heerkens (2019)	Along with self-management practices these led to long term reductions in MSD symptoms
		Sherrod, Casey, Dubro, & Johnson (2013)	Decreased MSD associated pain.
		Masiero et al. (2020)	Short Wave Diathermy (SWD) reduced pain in MSD patients
Drugs and Medicine		Marinho & Pereira (2020)	Nonsteroidal Anti-Inflammatory Drugs (NSAID) decreased the pain and symptoms of MSDs
Medication to relieve the pain and symptoms induced by MSDs	3	Stanos (2007)	Topical NSAID decreases the local pain associated with MSDs
		Randhawa et al. (2015)	Corticosteroid injections provide short term pain relief
Exercise	11	Beyan, Dilek, & Demiral (2020)	Decrease in MSD symptoms*
		Bolton & Cox (2015)	Prescribed exercise decreased MSD symptoms*

Stretching, at home or on-the- job strength and conditioning programs or physical activity.		Boocock et al. (2007)	Decreased MSD symptoms and associated pain* with multiple interventions
		Barredo & Mahon (2007)	Moderately decreased MSD symptoms*
		Jakobsen, Sundstrup, Brandt, & Andersen (2018)	Workplace-based exercise with ergonomics training reduced MSD related pain
		Mansi, Milosavljevic, Baxter, Tumilty, & Hendrick (2014)	Pedometer usage increased physical activity and functionality in lower limb MSDs. It also reduced MSD-related pain
		Prall & Ross (2019)	Stretching and strengthening exercises decreased pain and increased RTW success when done
		Menta et al. (2015)	Only effective in multimodal interventions *
		Shariat et al. (2018)	Reduced pain
		Mehrparvar et al. (2014)	Reduced MSD symptoms
		Randhawa et al. (2015)	Only effective in multimodal interventions *
Training and Education	8	Abdollahi et al. (2020)	Decreases prevalence and risk of MSDs

Programs or courses that teach the basic principles of ergonomics, risk and hazards to workers. This allows for the assessment and mitigation of risks and hazards to prevent MSDs		Beyan, Dilek, & Demiral (2020)	Only effective in multimodal interventions *
		Bolton & Cox (2015)	Positive effect on risk and symptom management
		Butwin, Evans, Klatt, & Sommerich (2017)	Decreased symptoms with biofeedback*
		Jakobsen et al. (2015)	Appropriate ergonomic training with exercise reduce MSDs and risk of MSDS*
		Hutting, Johnston, Staal, & Heerkens (2019)	Used to increase independent self-management of symptoms and pain
		Prall & Ross (2019)	Increased the RTW effectiveness and reduced pain
		Randhawa et al. (2015)	Long-term solution to MSD management
Cognitive Stress Reduction/Psychosocial Enhancement		Butwin, Evans, Klatt, & Sommerich (2017)	Mindfulness training decreased the risk of aggravation and reduced MSD symptoms
	6		
Training, support, and educational practices that are aimed at decreasing the psychosocial risk of MSD development		Lloyd, Waghorn, & Mchugh (2008)	Increased the effect of RTW program and prescribed treatment

		Waddell (2006)	Used the biopsychosocial model to address MSDs, resulting in a decrease in MSD symptoms and a reduction in the catastrophising of existing disorders. Increase the effectiveness of RTW programs
		Smith et al. (2016)	Helped decrease pain
		Smith-Young, Solberg, & Gaudine (2014)	Used as a coping mechanism in patients with severe pain. Reduced the time taken to RTW
		Hoosain et al. (2018)	Cognitive Behavioral Training led to decreased RTW time for MSD patients
Sick Leave (Part Time)		Andrén & Svensson (2012)	Increased likelihood to recover from MSDs and RTW in less time
Either a reduction in number of hours worked or time off of less than six months allowing for the rest and recovery of MSDs	3	Cochrane et al. (2017)	Reduced severity of MSD with early RTW*
		Viikari-Juntura et al. (2012)	Along with an effective RTW program decreased MSDs and may prove to be more sustainable as workers can continue to work.

** Denotes ineffective intervention when implemented on its own*

Click to go back to Navigation Tool

Appendix B: Interview Schedule and Questions

RHODES UNIVERSITY
Grahamstown • 6140 • South Africa

DEPARTMENT OF HUMAN KINETICS AND ERGONOMICS

INTERVIEW QUESTIONS

---

1 Consent
   i. Thank you for your participation in my master's research. Your participation in this study will remain anonymous, and all the answers you give will be used purely for the purposes mentioned in the Participant Information Letter. You have the right not to answer questions or stop at any time if you so choose. By doing so, you would remove your consent from participation and inclusion in this study. Do you consent to the involvement in this study?
   ii. Do you consent to the recording of this interview for academic purposes (transcription post-interview)?

2 Framework Recap
   i. A quick run-through of how the framework is designed to work to ensure all participants understand.

3 Participant information
   i. Are you a CPE or CEA?
   ii. Which sector or industry do you conduct the majority of your work in?
   iii. Do you hold a permanent position in a company or work as a consultant?
   iv. Which province do you conduct the majority of your work in?
   v. What educational background in ergonomics do you have?
   vi. How many years of experience in ergonomics do you have overall?
   vii. How many years of experience practising ergonomics do you have?
   viii. How often do you deal with musculoskeletal disorders in your work?

4 Prevention of MSDs
The following questions are in reference to your own opinion/practice:
   i. Do you perceive prevention as a priority in MSD intervention?
   ii. In your opinion, what does MSD prevention entail?
   iii. What guidelines do you use in MSD prevention activities?

With reference to the draft framework developed for this study which was sent to you prior to the interview…
   i. Which strategies/interventions did you find most effective? Why?
   ii. Which strategies/interventions did you find least effective? Why?
   iii. Are there any strategies/interventions that you have found beneficial in MSD prevention not present in the framework?

5 Management of MSDs

The following questions are in reference to your own opinion/practice:

i. Do you perceive the management of existing MSD conditions as a priority in MSD intervention?
ii. In your opinion, what does MSD management entail?
iii. What guidelines do you use in MSD management activities?

With reference to the draft framework developed for this study which was sent to you prior to the interview...

i. Which strategies/interventions did you find most effective? Why?
ii. Which strategies/interventions did you find least effective? Why?
iii. Are there any strategies/interventions that you have found beneficial in MSD prevention not present in the framework?

6 Ease of Framework use

i. What did you think of the framework design and layout?
ii. Did it convey the importance of multiple levels of interventions?
iii. Were the steps on how to use the draft framework clear?

7 Closing Comments

i. In your opinion, is there a need for a framework or guideline like this in MSD intervention?
ii. What would you like to see going forward in this regard?
iii. Any last comments?
iv. Would you like to receive any feedback from the study?

Appendix C: Ethics documents

C1. Ethics Approval Letter

RHODES UNIVERSITY
Where leaders learn

Rhodes University Human Ethics Committee
PO Box 94, Makhanda, 6140, South Africa
t: +27 (0) 46 603 7727
f: +27 (0) 46 603 8822
e: s.mariqele@ru.ac.za
NHREC Registration number: RC-241114-045

https://www.ru.ac.za/researchgateway/ethics/

18/10/2021

Elrico de Bruyn

Email: g16d0163@campus.ru.ac.za

Review Reference: 2021-5206-6364

Dear Mrs Miriam Mattison

Title: Developing an Evidence-Based Framework for the Prevention and Management of Musculoskeletal Disorders in South Africa

Principal Investigator: Mrs Miriam Mattison

Collaborators: Mr Elrico de Bruyn

This letter confirms that the above research proposal has been reviewed and **APPROVED** by the Rhodes University Human Ethics Committee (RU-HEC). Your Approval number is: 2021-5206-6364

Approval has been granted for 1 year. An annual progress report will be required in order to renew approval for an additional period. You will receive an email notifying you when the annual report is due.

Please ensure that the ethical standards committee is notified should any substantive change(s) be made, for whatever reason, during the research process. This includes changes in investigators. Please also ensure that a brief report is submitted to the ethics committee on the completion of the research. The purpose of this report is to indicate whether the research was conducted successfully, if any aspects could not be completed, or if any problems arose that the ethical standards committee should be aware of. If a thesis or dissertation arising from this research is submitted to the library's electronic theses and dissertations (ETD) repository, please notify the committee of the date of submission and/or any reference or cataloguing number allocated.

Sincerely,

Prof Arthur Webb

Chair: Rhodes University Human Ethics Committee, RU-HEC

cc: Ms Danielle de Vos - Ethics Coordinator

Page 1 of 1

RHODES UNIVERSITY

DEPARTMENT OF HUMAN KINETICS AND ERGONOMICS

LETTER OF INFORMATION TO PARTICIPANTS

Dear_____,

Thank you for your interest in my study provisionally titled *"Developing an Evidence-Based Framework for the Prevention and Management of Musculoskeletal Disorders in South Africa"*

BACKGROUND AND AIM OF THE STUDY

My name is Elrico de Bruyn, and I am a student in the Department of Human Kinetics and Ergonomics, Rhodes University. I am currently in the process of completing my Master of Science degree under the supervision of Mrs Miriam Mattison.

Musculoskeletal Disorders are a wide-spread problem among all industries around the world, yet despite years of research into this issue, there is no comprehensive evidence-based framework on how to effectively prevent or manage these disorders This lack of guidance can make it hard to prevent and manage MSDs, as the literature surrounding MSD interventions is vast. It can therefore be confusing and even overwhelming when searching for effective solutions to the problem. To reduce the burden these disorders have in the workplace, there is a need for a comprehensive "one-stop guide" to assist particularly practitioners to prevent MSDs from occurring or to manage them once they have been diagnosed. I have conducted a scoping review, and based on this, created such a framework with a model of use, which now needs to be evaluated by professionals in the field of ergonomics.

The purpose of this study is to collect feedback on the draft framework I have created, identify themes and integrate the feedback into the framework for a more complete guide to MSD prevention and management.

PARTICIPANT CHARACTERISTICS

To participate in this study, you should be working as a practicing ergonomist for at least 4 years and have an educational background in ergonomics

PROCEDURES

This study and its procedures have been reviewed and approved by the Rhodes University Ethical Standards Committee (RUESC tracking number: 5206). The testing procedure will consist of participants being sent a draft framework and explanation on how it works prior to taking part in once-off interview relating to the framework design and contents for MSD prevention and management intervention tactics. The interview will be conducted via an online platform such as Zoom and is anticipated to last approximately 45 minutes to 1 hour. You will be asked 28 demographic and topic-specific questions relating to this framework based on your experienced as practicing ergonomist.

The interview will be recorded and transcribed after which a thematic analysis will be conducted. The results of the analysis will be integrated into the framework and a copy of the results will be sent back to participants who opt for feedback.

RHODES UNIVERSITY

OTHER RIGHTS AND RESPONSIBILITIES

Anonymity: No personal identifying information will be obtained of you during the interview. Although the recording of the interview will not show your face, it will contain your voice, which poses a risk to your anonymity. However, this risk is minimized by securely storing the data on the password secured HKE drive and by transcribing the interview. The raw data will remain in the possession of the HKE Department and will only be used to inform my study and for no other purpose. There is a potential risk of emotional discomfort or embarrassment if you are unable or unwilling to answer a question, however, you may opt to skip a question or ask for the question to be rephrased to avoid such situations.

Finally, be aware that you have the right to withdraw from the study at any point in time, without any negative consequences to you. Your withdrawal will not negatively influence your relationship with any person in the HKE Department.

Please take a moment to consider whether you want to participate in my study. Feel free to contact me if you are unsure about any of the above information or the reasoning behind them or address any concern to my supervisor Mrs Miriam Mattison (m.mattison@ru.ac.za; 046-603 8468), or the Rhodes University Ethical Standards Committee's ethics coordinator (ethics-committee@ru.ac.za; 046 603 7727).

Yours sincerely,

Elrico de Bruyn

Cell: 073 668 3890

Email: elricodebruyn@outlook.com

C3. Participant Informed Consent Letter

RHODES UNIVERSITY
Grahamstown • 6140 • South Africa

DEPARTMENT OF HUMAN KINETICS AND ERGONOMICS

PARTICIPANT INFORMED CONSENT DECLARATION

(To be signed by research participants)

Research Project Title: *"Developing an Evidence-Based Framework for the Prevention and Management of Musculoskeletal Disorders in South Africa".*

Elrico de Bruyn from the Department of Human Kinetics and Ergonomics, Rhodes University, has requested my permission to participate in the above-mentioned research project.

The nature and the purpose of the research project and of this informed consent declaration have been explained to me in a language that I understand.

I am aware that:

1. The purpose of the research project is to collect feedback on a draft framework for MSD prevention and management, identify themes and integrate the input into the framework for a complete guide to MSD prevention and management in a South African Context.

2. Rhodes University has given ethical clearance to this research project (RUESC tracking number: 5206). I have seen/may request to see the clearance certificate by contacting the Ethics Coordinator (ethics-committee@ru.ac.za).

3. By participating in this research project, I will be contributing towards the improvement of musculoskeletal disorder interventions laid out in the framework developed by the researcher. My expert opinion will be fed back into the framework, which in turn can be used as a guide to reduce the cost and burden that MSDs have on both organisations and individuals, particularly in South Africa

4. I will participate in the project through a face-to-face interview where safe and possible or an online interview.

5. My participation is entirely voluntary, and should I at any stage wish to withdraw from participating further, I may do so without any negative consequences.

6. I will not be compensated for participating in the research.

Rhodes University, Research Office, Ethics
Ethics Coordinator: ethics-commitee@ru.ac.za
t: +27 (0) 46 603 7727 f: +27 (0) 86 616 7707
Room 204, Main Admin Building, Drostdy Road, Grahamstown, 6139

7. The following risks are associated with my participation: a potential risk of emotional discomfort or embarrassment. If I am unable or unwilling to answer a question, I understand that I may opt to skip a question or ask for the question to be rephrased

8. The Researcher intends to publish the research results in the form of a Masters of Science thesis. However, confidentiality and anonymity of records will be maintained, and my name and identity will not be revealed to anyone who has not been involved in conducting the research, *unless I indicate to the contrary/recognise that as a public figure, my identity will inevitably be/become known in which case I agree to and accept the loss of confidentiality.*

9. In terms of the Protection of Personal Information Act, it remains my right to request the Researcher to provide me with a detailed explanation of exactly how confidentiality and anonymity will be achieved. I may request to know how my personal information will be stored securely, for how long it will be stored, and whether it is likely to be used again in further research.

10. In terms of the Protection of Personal Information Act, I possess the right to receive feedback about this research. This will take the form of a written report regarding the results obtained during the study, *unless I elect not to receive feedback.*

11. Any further questions that I might have regarding the research or my participation will be answered by Elrico de Bruyn (elricodebruyn@outlook.com; or g16d0163@ru.ac.za; 073 668 3890).

12. By signing this informed consent declaration, I am not waiving any legal claims, rights or remedies.

13. A copy of this informed consent declaration will be given to me, and the original will be kept on record.

I, ..., have read the above information / confirm that the above information has been explained to me in a language that I understand and I am aware of this document's contents. I have asked all the questions that I wished to ask and these have been answered to my satisfaction. I fully understand what is expected of me during the research.

I have not been pressurised in any way and I voluntarily agree to participate in the above-mentioned project.

Rhodes University, Research Office, Ethics
Ethics Coordinator: ethics-commitee@ru.ac.za
t: +27 (0) 46 603 7727 f: +27 (0) 86 616 7707
Room 204, Main Admin Building, Drostdy Road, Grahamstown, 6139

I **agree/disagree** (SELECT APPLICABLE) to the Researcher's request to take photographs and/or videos of me as part of this research project, recognising that agreement here is likely to raise the risk of compromising my anonymity and that steps will be taken to ensure this does not happen if my approval is granted.

I **agree/disagree** to the Researcher's request to voice record my comments and opinions during interviews, the purpose of which is to ensure the accurate recording of my views. Furthermore, I have the right to request a copy of interview transcriptions to confirm that my opinions are accurately recorded

....

Participants signature **Date**

Rhodes University, Research Office, Ethics
Ethics Coordinator: ethics-commitee@ru.ac.za
t: +27 (0) 46 603 7727 f: +27 (0) 86 616 7707
Room 204, Main Admin Building, Drostdy Road, Grahamstown, 6139