

**APPROPRIATE INTEGRATION OF WORKERS WITH
PHYSICAL LIMITATIONS INTO A MANUAL
WORKPLACE – DEVELOPMENT OF AN
ASSESSMENT TOOL**

by

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ABSTRACT

Background: People with physical limitations can contribute significantly to society and the economy, however, barriers to full and effective participation in the labour market often hinder decent employment. In light of this, placement decisions of impaired workers should be based on detailed information of the nature of the jobs available, as well as individual capabilities of the worker. An ergonomics approach to design attempts to achieve an appropriate balance between the capabilities of the worker and the requirements of the task and uses this balance to improve productivity and encourage physical and mental well-being, job satisfaction and safety.

A specific analysis tool which can be applied to various workplaces and jobs, and provide information for decisions regarding placement of physically limited workers, will help to increase the percentage of correct placement in an appropriate workplace, resulting in optimum productivity and worker safety.

Methods: An assessment tool which allows matching of job requirements and worker capabilities was developed based on a theoretical framework from Mattison and Goebel (2007), as well as principles defined by Almgren and Schaurig (2012) and Demura & Nakada (2010). The tool assesses range of motion, force and time components of the physical requirements of different tasks involved in the job, as well as movement capabilities and limitations of the worker. The tool was pilot tested in a case study with an above the knee amputee working at a research facility.

Results: The tool successfully provided information regarding the matching of the work to the identified job. The output of the tool highlighted two tasks which would place the worker at risk due to physical requirements of the tasks being greater than movement capabilities of the worker. These tasks need to be further investigated to determine if accommodations can be made to assist the worker in safely performing the task, or if the job is not suitable for the worker.

Conclusions: The tool developed was useful in providing information to inform appropriate placement of the physically limited worker. Further research needs to be done to validate and determine reliability of the tool.

Key words: physical impairment, injured worker, job analysis, functional capacity evaluation

TABLE OF CONTENTS

Abstract	II
Table of contents.....	III
List of figures.....	VI
List of tables.....	VII
Acknowledgements	VIII
Chapter 1 - Introduction.....	1
Statement of the problem and benefits of this study	1
Research aim	2
Overview of this paper.....	2
2.1 Physical limitation in the workplace	4
2.1.1 Prevalence	5
2.1.2 Theories of the development of physical limitations in the workplace	6
2.2 Effects of physical limitations.....	8
2.2.1 Worker	8
2.2.2 Organisation.....	9
2.2.3 Society	9
2.3 Return to work	9
2.3.1 Defining return to work.....	10
2.3.2 Benefits of returning workers to the workplace	10
2.4 Job accommodation for injured workers	11
2.4.1 Legal requirements for job accommodation	12
2.5 Analyses to inform appropriate placement of physically limited workers ...	13
2.5.1 Task demands	13
2.5.2 Worker capabilities.....	13
2.6 Matching worker capabilities to task demands	14
2.6.1 Challenges to appropriate matching of worker capabilities and task demands	15
Chapter 3 – Development of the tool.....	16
3.1 Theoretical Framework.....	16
3.2 The interaction of force, task duration and posture involved in task performance by the worker	19
3.3 Process of developing the tool	21

3.3.1	Compile a list of physical task demands which may be encountered in the workplace.....	21
3.3.2	Compile a list of all possible anatomical movements necessary to perform tasks in manual work	23
3.3.3	Describe physical task demands by the movements necessary to perform the demands.....	24
3.3.4	Describe movements by the physical task demands which require those movements.....	26
3.3.5	Range of motion and posture.....	27
	Task demands	27
	Worker capabilities.....	28
3.3.6	Force.....	29
3.3.7	Time on task	30
	Task demands	31
	Worker capabilities.....	32
Chapter 4 – Case study.....		34
4.1	Procedure.....	34
4.1.1	Ethical considerations.....	34
4.1.2	Sampling.....	35
4.1.3	Assessment	36
4.1.4	Feedback and reporting	38
4.2	Results	38
4.2.1	Task analysis	39
4.2.2	Worker analysis	44
	Using the assessment tool developed to compare task and worker ..	46
	Force.....	47
	Time.....	48
	Ergonomic assessment.....	49
Chapter 5 – Discussion		51
5.1	Lessons learnt during application of the tool	51
	Limitations of the case study.....	52
5.2	Considerations and necessary adaptations to the tool.....	52
	Delimitations	52

Limitations of the tool	53
5.3 Addition to knowledge	54
Chapter 6 – Conclusions and recommendations.....	57
6.1 Summary of developing and testing the tool.....	57
6.2 Conclusions.....	58
6.3 Recommendations for further research	59
References.....	61
Appendices	66
Appendix 1: Example of common job analysis tool – Rapid Entire Body Analysis (REBA)	66
Appendix 2: Example of a commonly used Functional Capacity Evaluation – Nordic Questionnaire	67
Appendix 3: Full list of task demands.....	68
Appendix 4: Goniometry guidelines.....	69
Appendix 5 – Ethical clearance.....	72
Appendix 6: Information to the organisation	74

LIST OF FIGURES

Figure 1: Integrated model of the development of WRMSDs	7
Figure 2: Schematic of matching worker capabilities and task demands (Adapted from Mattison & Goebel, 2007).....	17
Figure 3: Schematic illustration of the information sources available when making placement decisions for physically impaired workers (Red circle illustrates the focus of this research, which is to bridge the gap between information relating to the worker and the task)	19
Figure 4: The cube-model of the three variables that can be used to describe physical ergonomics (Almgren & Schaurig, 2012).....	20
Figure 5: Anatomical demands of sitting upright on a chair (Body Literate, 2016)...	24
Figure 6: Some of the physical task demands which involve hip flexion.....	26
Figure 7: Measuring range of motion of trunk flexion when standing stooped over a) starting position b) stooped posture with angle of trunk flexion shown.....	28
Figure 8: Relationship between force levels and endurance time (Demura & Nakada, 2010)	32
Figure 9: Relationship between force levels and endurance time (Demura & Nakada, 2010) (Red line shows interpolation of time from force capabilities of the worker. ...	48
Figure 10: a) Measurement of hip flexion from leg vertical (162.7degrees), b) Measurement of back flexion from trunk vertical (73.5 degrees), c) Measurement of trunk rotation from trunk horizontal (32.3 degrees), d) Measurement of trunk lateral flexion from trunk vertical (11.1 degrees), e) Measurement of trunk extension from trunk vertical (6.2 degrees).....	88

LIST OF TABLES

Table 1: a) Categories of task demands included in assessment tool b) Example of components in body posture category.....	22
Table 2: Movements of joints with most prevalent injury rates	23
Table 3: Example of description of joint movements involved in adopting and maintaining a posture, and returning to neutral anatomical position	25
Table 4: Example of task demands described as movements involved in adopting, maintaining and returning from the posture (repeated movements only listed once)25	
Table 5: Examples of task demands which involve hip flexion.....	26
Table 6: Template data collection sheet for worker capabilities – Range of Motion. 37	
Table 7: Summary of activities performed during testing	38
Table 8: Tasks performed by the 'apparently healthy' workers	39
Table 9: Records of task demands and accompanying attributes (force, frequency and duration).....	42
Table 10: Frequency Scale	44
Table 11: Maximum range of motion (in degrees) requirements for the tasks	44
Table 12: Tasks performed by the worker assessed	45
Table 13: Range of motion for physically limited worker	46
Table 14: Output from assessment tool showing maximum range of motion values for each task (Values highlighted in red represent those which are greater than the minimum range of motion capabilities of the worker)	46
Table 15: REBA scores for the different components	50
Table 16: Range of motion (ROM) of the hips and back.....	86

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CHAPTER 1 - INTRODUCTION

Active involvement and participation of workers from all aspects of society is important in the South African context as this allows a diverse and holistic contribution to the work force, as well as financial and psychological independence of workers who are physically able to work, even with some limitations. People with physical limitations can contribute significantly to society and the economy, however, barriers to full and effective participation in the labour market often hinder decent employment (Merrill, n.d.). Individuals with limited physical ability, but with full mental capacity, often find themselves in situations where their limitations disadvantage them in the workplace. These disadvantages often have huge psychological affects resulting in them feeling inferior and financially dependent. Similarly, organisations are disadvantaged by loss of skill, as well as financial and time loss when recruiting and training new workers. Families, and even society as a whole, are affected by the financial strain of the worker needing health care, and not being able to contribute to the earnings, as well as the psychological effects of the worker not being productive, and sometimes not being able to work at all.

STATEMENT OF THE PROBLEM AND BENEFITS OF THIS STUDY

There are high levels of workplace injuries in the working population in industrially developed countries (Legge, Burgess-Limerick & Peeters, 2013; Panel on Musculoskeletal Disorders and the Workplace, 2001; Takala, 1998; United States Department of Labor Bureau of Labor Statistics, 2003). However, according to the United Nations Development Program, eighty per cent of people with disabilities live in developing countries (Disabled World, 2016). Since South Africa is considered a developing country, and still has a large population of manual workers, it is likely that there will be a large number of physically limited workers due to injuries or impairments from high workloads and poor workspace designs. There are a number of legislative acts (Merrill, n.d.; Sieberhagen, Torhmann, & Pienaar, 2009) which govern the working conditions and accommodation of physically limited workers, but it is still difficult to apply this practically in the workplace.

Thus, the output of this study will be a useful assessment tool to ensure appropriate placement of workers in manual workplaces, which will result in optimal productivity, while ensuring worker safety and reduced risk of further injury or re-injury.

RESEARCH AIM

To use a theoretical framework which focuses on the physical abilities and limitations of the worker, as well as the environment in which they work, to develop an analysis tool which will allow appropriate job assignment of physically limited workers. To achieve this aim, the following questions need to be addressed:

1. What are the important considerations for assessment and appropriate placement of physically limited workers in a manual workplace?
2. Can an analysis tool which considers a specific physical limitation, and specific task demands, be used to appropriately place a physically limited worker in a manual workplace?

OVERVIEW OF THIS PAPER

Chapter 2 presents existing literature pertaining to the development and prevalence of musculoskeletal disorders in the workplace. Evidence of the effects of physical limitations on the worker, the organisation and society at large is provided. Common assessment tools used to determine the placement of workers are presented. Finally, the importance, difficulties, and proposed ways to achieve appropriate matching of workers and tasks are outlined and discussed.

In Chapter 3, the knowledge gained from reviewing the literature is applied to development of an assessment tool, which considers the physical limitations of the worker, as well as the demands of the tasks which need to be performed. The methods and considerations for developing the tool are outlined and the final tool presented. Some potential future considerations and additions that may need to be made to the tool are proposed. Following development of the tool, the methods and results from a case study pilot testing of the tool are detailed in Chapter 4.

Since the tool was developed based on the limited existing literature, the lessons learnt from actual application of the tool are discussed in Chapter 5. Suggestions are made for adaptations which may improve usefulness of the tool. Lastly, limitations of

applicability of the tool are presented, and suggestions are given for adaptations to overcome these limitations.

Chapter 6 summarises the process and outcomes of developing and testing the tool, final conclusions are drawn and recommendations for further research are given.

CHAPTER 2 - LITERATURE REVIEW

This chapter sets the scene for the research by highlighting the prevalence and theories of development of Musculoskeletal Disorders (MSDs) in the workplace. The effects that MSDs have on the worker, as well as the organisation and society at large are briefly described. Next, the idea of return to work is introduced and defined and common benefits associated with return to work are highlighted. The concept of job accommodation for workers with physical limitations is presented, as well as the legal expectations on organisations to accommodate physically limited workers.

Following on from the presentation of the theories of occurrence of MSDs and ways to accommodate physical limitations, the process of assessing task demands placed on the worker, and the worker's capabilities to perform at work is described. The importance of performing these assessments in order to appropriately match a worker and a task is emphasised, then some potential challenges to this matching are highlighted. Finally, in light of the evidence presented, the relevance and scope of this research is proposed.

2.1 PHYSICAL LIMITATION IN THE WORKPLACE

There are a number of different terms used in literature relating to altered physical capability. The most common terms include injuries, impairments, musculoskeletal disorders and disabilities, although these terms are not always clearly defined or differentiated from each other. The United States Department of Labor Bureau of Labor Statistics (2016) defines an injury as any wound or damage to the body resulting from an event which occurs while functioning in a particular environment. Physical impairment is defined as limitations in mobility performance (Janssen, Heymsfield, & Ross, 2002).

The Occupational Safety and Health Administration (2016) defines musculoskeletal disorders as a condition affecting functionality of the muscles, nerves, tendons, ligaments, joints, cartilage and blood vessels associated with exposure to risk factors. These conditions may include muscle strains and tears, ligament sprains, joint and tendon inflammation, pinched nerves, spinal disc degeneration and medical conditions such as low back pain, tension neck syndromes (Occupational Safety and Health Administration, 2016). The World Health Organisation describes musculoskeletal

disorders related to the working context as ‘work-related’ conditions since they can be caused by work exposures, as well as factors outside of the work environment (WHO, 1985). Some of the factors associated with these disorders include physical, organisational and social aspects of the work itself and the workplace; physical and social aspects of life outside the workplace; and physical and psychological characteristics of the individual (Panel on Musculoskeletal Disorders and the Workplace, 2001). Physical disability can be defined as having difficulty performing activities of daily living (Janssen et al., 2002). The World Health Organisation (2016) considers physical disability an overarching term which includes physical impairments, limitations in performing a task or action, and restrictions to participating in life situations.

In this paper, the terms Musculoskeletal Disorders and physical disabilities are used interchangeably since the definitions for each (as presented above) are very similar and are most inclusive of the common presentations seen in a work environment. The use of the term injury generally refers to the actual incident which caused the MSD or disability and the subsequent physical limitations experienced by the worker. The term ‘physical limitations’ is used to infer that the worker has experienced a form of injury which has resulted in an MSD or disability, and aims to include all cases and severities of altered physical capability.

2.1.1 Prevalence

This sub-section, presents evidence of the need to explore important considerations for assessment and appropriate placement of physically limited workers in a manual workplace.

Occupational injuries are estimated to kill more than 300 000 workers a year worldwide, and cause many more cases of disability (Takala, 1998, cited in Concha-barrientos, Nelson, Fingerhut, Driscoll, & Leigh, 2005). According to these authors, mortality due to physical injury tends to be higher in developing countries due to a number and variety of hazards (both in the workplace and elsewhere), as well as limited resources for injury prevention, treatment and rehabilitation following an injury.

Unfortunately, there is a lack of data on work-related musculoskeletal disorders in developing countries such as South Africa (Concha-barrientos et al., 2005). This

makes it difficult to quantify the magnitude of the problem that occupational physical disorders pose to the health sector in South Africa. Thus, the following statistics are based on countries where these data are available.

The United States Department of Labor Bureau of Labor Statistics, (2003) recorded approximately 4.7million injuries and illnesses in private industry in 2002, with almost 94% of these being injuries. Similarly, the Panel on Musculoskeletal Disorders and the Workplace, (2001) reported that musculoskeletal disorders account for approximately 130million health care encounters annually in the United States, including outpatient care, hospital and emergency room visits.

Legge, Burgess-Limerick, and Peeters (2013) performed a study using Australian coal miners in which injury data was coded from company records for body part, mechanism, and severity. Based on this data, back and trunk regions showed the highest injury rate by body location (43 per 1000 person years), while manual handling tasks showed the highest injury rate by mechanism of injury (46 per 1000 person years). Back and trunk injuries associated with manual handling represented the largest subgroup of injuries (22 per 1000 person years) (Legge et al., 2013).

2.1.2 Theories of the development of physical limitations in the workplace

There are many theories related to development of MSDs in the workplace which result in physical limitations. Different theories describe a relationship between exposures, doses, capacity and response (Dose-response model); a relationship between psychological and biomechanical strain (Ecological model); and even a relationship between work factors, external loads, organisational factors, social context, individual characteristics and physical outcomes on the worker (Biomechanical model) (Karsh, 2006). In order to deal with the variety of explanations and factors affecting development of Work-Related Musculoskeletal Disorders (WRMSDs), Karsh described an integrated model (see Figure 1) which accounts for various possible mechanisms and pathways of development. One such pathway highlights the direct impact of physical work demands on work strain through overexertion, cumulative loading and differential fatigue (red arrow in Figure 1) (Kumar, 2001). In addition to the many theories of development of MSDs, the sources of evidence to describe the MSD varies widely from signs and symptoms reported by

the worker, to functional and structural abnormalities observed during evaluations or analyses done by a practitioner (Aptel, Aublet-Cuvelier, & Cnockaert, 2002).

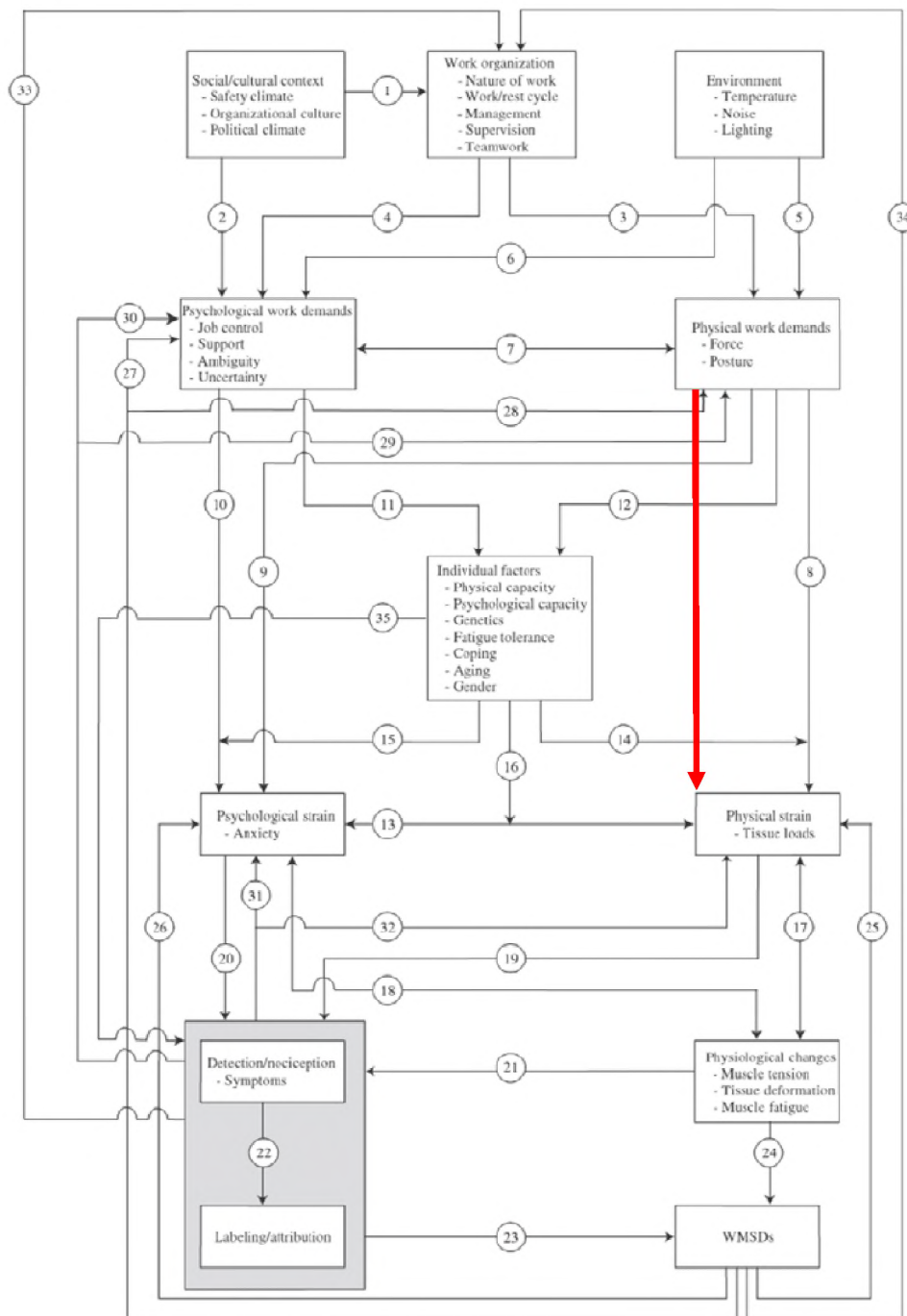


Figure 1: Integrated model of the development of WRMSDs*

*Red arrow indicates the direct impact of physical work demands on work strain through overexertion, cumulative loading and differential fatigue (adapted from Karsh, 2006 Pg. 83)

Biomechanical stressors such as repetitive motion and extreme joint positions, in work-related and non-work related situations, have consistently been found in cases where workers have developed MSDs of the upper limbs (Aptel et al., 2002). Similarly, Jezukaitis & Kapur, (2011) list physical factors including ergonomic load, manual handling and the physical work environment as being associated with risk of WRMSDs. In addition, inadequate posture from poorly designed workstations can result in static muscle efforts (Das & Sengupta, 1996) and discomfort or even injury. Aptel et al. (2002) go on to postulate that inadequate job training, poorly designed tools and production requirements that exceed workers' functional capacities can add to the biomechanical stress exposure and increase the risk of developing WRMSDs. This suggests that an analysis tool needs to consider various aspects of the individual's specific physical impairment, and the task demands to ensure appropriate placement in a manual workplace.

2.2 EFFECTS OF PHYSICAL LIMITATIONS

Physical limitations primarily affect the worker, but the consequences go further than the worker. With this in mind, and given the evidence regarding the high prevalence of work place injuries, it is vital that a suitable analysis tool which can appropriately place individual impaired workers, be developed. In the sections below, consequences of physical limitations in the workplace will be discussed briefly.

2.2.1 Worker

Physically limited employees in many workplaces, particularly in the manufacturing field, often experience discrimination because colleagues and supervisors assume that their work performance will be affected by their limitations (Chi, Pan, Liu, & Jang, 2004). Additionally, some compensation systems do not encourage permanently restricted workers affected by work-related injuries to return to work. This discrimination and encouragement to stay off work may result in financial loss, reduced feelings of productivity and self-confidence (Helm, Powell, & Nieuwenhuijsen, 1999), as well as reduced opportunity within the job market. Quaigrain, Winter, and Issa (2014) suggest that analysis of the employee's residual skills and capabilities may allow appropriate placement, modification of the original job, or identification of alternate jobs that are more suited to the worker's functionality.

2.2.2 Organisation

A summary by the Panel on Musculoskeletal Disorders and the Workplace (2001) showed that limited physical capacity can result in loss of skill in the workplace, as well as a need for training of replacement workers and alteration of the work flow to accommodate new and potentially unexperienced workers (Panel on Musculoskeletal Disorders and the Workplace, 2001).

The Panel on Musculoskeletal Disorders and the Workplace (2001) reported that MSDs in the United States account for approximately \$130 million in total healthcare consultations annually, including outpatient care, hospital and emergency room visits. In addition to this, compensation costs, lost wages and lost productivity totalled between \$45 and \$54 billion annually. Similarly, in France in 1990 the total cost of low back pain alone was approximately 1.3 billion Euros (Panel on Musculoskeletal Disorders and the Workplace, 2001).

2.2.3 Society

Society is also affected by worker physical limitations since the workers sometimes have to be reassigned and thus feel less productive. Furthermore, state and federal financial resources are spent to support the limited individual if they are not able to fully support themselves or their families (Helm et al., 1999). Similarly, Krause, Dasinger, Deegan, Rudolph, and Brand (2001) suggest that returning physically limited workers to work helps to improve social support of the worker.

In light of this, the aim of project was to demonstrate the usefulness of an analysis tool which can assess physical impairments and ensure correct placement of workers resulting in positive implications for the worker, the organisation, society, and beyond.

2.3 RETURN TO WORK

Following an injury, it is important for the worker to be able to return to work in order to maintain productivity and financial independence. However, it is also important to ensure protection from re-injury or further injury. Without an effective method or analysis tool to ensure this, workplace injury statistics will continue to be very high as outlined in the section 2.1.1 (Prevalence of MSDs) and 2.1.2 (Theories of development of physical limitations in the workplace) above.

2.3.1 Defining return to work

Return to work management programs aim to help physically impaired workers to improve performance, regain functionality and enhance work capacity (Kong et al., 2012). However, return to work does not necessarily mean the worker has completely recovered from the musculoskeletal disorder that kept them off work (Bültmann et al., 2007). Many workers who return to work may still have health problems and find it difficult to meet work and task demands (Bültmann et al., 2007). However, successful return to work has been shown to be significantly associated with job satisfaction before the incident, as well as the severity of the injury and physical functionality of the worker (Pransky, Benjamin, Savageau, Currivan, & Fletcher, 2005). According to Kong et al., (2012) successful return to work strategies include ergonomic intervention, workplace assessment, clinical interviews and analyses of physical capacity of the worker. An analysis tool specifically designed to ensure this will likely result in a higher percentage of correct placement post-injury and a reduction in some of the negative consequences outlined in sections 2.2.1 (Effects of physical limitations on the worker) and 2.2.2 (Effects of physical limitations on the organisation).

2.3.2 Benefits of returning workers to the workplace

Fenner (2013) states that a rapid, but safe return to work process following injury can benefit both the worker and the employer. Fenner (2013) suggests that the return to work plan should enable the impaired worker to perform as many of their usual tasks as possible, in order to allow their knowledge and experience to be utilised in the work setting. Appropriate job placement has also been shown to result in feelings of independence and usefulness, improved self-respect and confidence, and better financial security since they can return to a productive work role and provide financially for themselves and their families (Helm et al., 1999).

For the employer, appropriate return to work can result in reduced cost of wage replacement, increased productivity for wages paid, and reduced training and personnel costs for replacement or recruitment of new workers (Snook, 1988 as cited in Krause et al., 2001). In order to achieve these benefits for both the worker and the employer, appropriate accommodations may be necessary to reduce exposure to tasks or sub-tasks which may aggravate the disorder, while ensuring optimal

performance and job productivity. The use of an assessment process, which considers individual injuries, impairments and task demands would help to achieve this and result in appropriate placement of the worker.

2.4 JOB ACCOMMODATION FOR INJURED WORKERS

Evan Terry Associates (1993, cited in Chi, 1999) describe job accommodation as providing or modifying devices or facilities, or changing practices and procedures in order to match a particular person with a particular program or activity. In addition to changing or modifying the workplace or job demands, Chi et al. (2004) suggest that job assignment, work instruction and work training can also be used to accommodate impaired workers. Thornton, (1998) extends the definition of adaptations or accommodations by saying that they need to be more than a change to the technical system or equipment used by impaired workers, instead they should be specifically produced to prevent, compensate for, reduce or neutralise the impairment. This strongly supports the need to develop a specific analysis tool, which will provide specific data of the individual's physical capabilities and the workplace requirements they face.

Chi et al., (2004) detail three approaches to accommodations that can adopt ergonomic principles to widen the job range available to impaired workers, as well as improving working conditions. These approaches include selecting a suitable workplace to accommodate the workers abilities and limitations, work instruction and training if a new position has to be taken up, and finally adequate workspace design to create an appropriate environment for the worker, as well as providing sufficient equipment and procedural modifications to accommodate the worker's capabilities (Chi et al., 2004). Cleveland et al., (1997) describe five different types of accommodation; worksite changes such as changing layout of the production line, workstation changes such as changing the layout of the specific working area, work environment alteration such as changing lighting and visibility, job restructuring such as changing the order of procedures, and modification of work activities such as changing the way of performing the task itself.

The accommodation process may allow physically impaired workers, who were previously unqualified, to fill a position due to physical limitations to return to work

(Helm et al., 1999). Cleveland et al. (1997) also reason that reasonable accommodations allow qualified individuals with physical impairments to fairly compete in the job market, and enjoy equal benefits and privileges as their able counterparts.

2.4.1 Legal requirements for job accommodation

There have been a number of legal acts passed in various countries to ensure appropriate accommodation of disabled workers to allow them to continue to actively participate in the workforce. One such act is The Americans with Disabilities Act, which states that companies are required to provide reasonable accommodations for qualified individuals, with disabilities, to allow the workers to compete fairly in the workplace, perform essential functions of the job and enjoy equal benefits and privileges to able workers (Cleveland et al., 1997).

In South Africa, the Employment Equity Act states that employers are expected to identify and reduce barriers to employment of physically impaired workers, and provide reasonable accommodation to overcome these barriers (Merrill, n.d.). In addition, the Code of Good Practice on Key Aspects of Disability in the Workplace purports that reasonable accommodation should be considered if requirements of a job change in a way which creates barriers for an employee, or if a person acquires an injury at work which results in barriers to work performance (Merrill, n.d.).

Cleveland, Barnes-Farrell, and Ratz (1997) suggest that the implementation of legal requirements to accommodate physically impaired workers has likely shifted the focus from average or above average workers, to those with limited physical functionality. Similarly, the legal implementations have shifted the goal of workspace layout and job organisation from maximum performance to meeting minimum essential job functions (Cleveland et al., 1997). Whilst these legal shifts in focus are likely to ensure compliance for a better fit between physically impaired workers and the workplace, a specific analysis tool which allows individualised assessment of impaired workers' limitations and altered capabilities, as well as specific job demands, will result in appropriate placement for each worker based on their particular situation.

2.5 ANALYSES TO INFORM APPROPRIATE PLACEMENT OF PHYSICALLY LIMITED WORKERS

Currently there is no generally accepted procedure which applies to all workplaces to aid in the appropriate placement of an impaired worker upon returning to work. In order to facilitate the return to work process, companies use various methods of task demand analysis and functional assessment of worker capabilities to determine the most appropriate fit between worker and task. These approaches are described below.

2.5.1 Task demands

Job analyses are conducted to determine essential functions, necessary skills, physical and mental requirements, production expectations and qualifications necessary for the job at hand (Helm et al., 1999). In addition to this, these authors suggest that a job analysis can provide information regarding movements, basic postures and motions involved in the task being performed. Postural job demands commonly included in functional evaluations include forward reach, above shoulder reach, stooping, squatting and stair climbing (Legge et al., 2013).

Commonly used job analyses include the Ovako Working posture Assessment System (OWAS), the Rapid Entire Body Assessment (REBA), the National Institute of Safety and Health (NIOSH) lifting equation, and the Liberty Mutual Manual Material Handling Tables (see Appendix 1: Example of common job analysis tool – Rapid Entire Body Analysis).

2.5.2 Worker capabilities

Despite the wide range of assessment tools available, the existing tools are based on assumptions of health and lack of injury and thus do not take into consideration potential physical limitations resulting from injury. Thus, it appears that there is a need for an analysis tool which considers specific physical characteristics of the worker in order to accurately describe capabilities and limitations.

It is important for the worker's physical capabilities, and subsequent limitations, to be assessed prior to job allocation to allow safe and productive work placement. Functional capacity evaluations (FCEs) are commonly used to assess fitness for work and to inform the return to work process for physically impaired workers (King,

Tuckwell, & Barrett, 1998). FCEs can be broad and only assess baseline performance (Hart, Isernhagen, & Matheson, 1993), or they can be formulated to identify the specific abilities necessary to meet specific work demands, as well as the restrictions specific to the work environment (Helm et al., 1999) (see Appendix 2: Example of a commonly used Functional Capacity Evaluation – Nordic Questionnaire).

Although a more specific FCE provides more detailed information and a more accurate match to a specific workplace, a broad assessment is practically more feasible since it considers a large variety of workspaces and tasks (Mattison & Goebel, 2007). Despite the availability of assessment tools which allow adequate assessment of the fit between the worker and the task, no single assessment can cover all of the parameters influencing the worker-task relationship in every work environment (King et al., 1998). This makes it difficult to directly measure the worker's ability to perform and sustain a specific job.

2.6 MATCHING WORKER CAPABILITIES TO TASK DEMANDS

Even in a simple work system various components interact either directly or indirectly (Bridger, 2009). Bridger proposes that these components may include the worker, machines used to execute the task, and the environment in which the task is performed. Compatibility within the system needs to be achieved at a number of levels, namely biomechanical, anatomical, physiological, behavioural and cognitive levels (Bridger, 2009) to ensure productivity, as well as safety for the worker. Bridger suggests that, in order to achieve compatibility, the demands from the technological and environmental systems need to be weighed against the capabilities of the user. Physical strain and injuries may result if there are imbalances between the worker's capacities and work demands (Johns, Bloswick, Elegante, & Colledge, 1994).

Das & Sengupta (1996) suggest that an ergonomics approach to design attempts to achieve an appropriate balance between the capabilities of the worker and the requirements of the task and uses this balance to improve productivity and encourage physical and mental well-being, job satisfaction and safety. Applying ergonomics principles to workstation layout uses a compromise between the operators physical capabilities and tolerances and the physical requirements of the task at hand (Das & Sengupta, 1996).

Helm et al. (1999) propose that matching the individual's qualifications and capabilities to a suitable position should pay particular attention to essential functions of the job to ensure that the worker can perform the task as required, with or without suitable accommodations. Similarly, Chi (1999) proposes that placement decisions of impaired workers should be based on detailed information of the nature of the jobs available, as well as individual capabilities assessed through physical evaluations. When dealing with impaired workers, it is important to consider reduced movement capabilities, as well as limited functionality in order to effectively and safely match the worker with the task.

2.6.1 Challenges to appropriate matching of worker capabilities and task demands

Das & Sengupta (1996) suggest that a major obstacle to implementing ergonomic recommendations is human variability in size and capabilities. Developing basic predictors of physical limitations resulting from various disabling conditions across generic job demands is not comprehensive enough, since these profiles indicate only possible areas of consideration and cannot encompass all possible presentations of physical disorders in all job settings (Chi, 1999). Similarly, these authors state that physical limitations vary between people, even if they have the same classification of disability or disability in the same bodily area. Thus, an analysis tool which considers individual workers' physical impairments is necessary to accommodate the specific limitations experienced by the worker.

On the other hand, there are numerous job stations in any one workplace, which in turn have their own specific demands and requirements. Two workstations may produce the same output, but the process involved to reach that outcome may be different and require different worker capabilities. Furthermore, the social and cultural context of the workplace can have a direct impact on the physical and psychological demands of the work (Karsh, 2006). Thus, even if there are two identical workstations in two different workplaces, there will be different demands placed on the worker due to different social and cultural influences. This further adds to the complexity of defining job demands to match to worker capabilities. A specific analysis tool which can be applied to various workplaces and jobs will help to increase the percentage of correct placement in an appropriate workplace, resulting in optimum productivity.

CHAPTER 3 – DEVELOPMENT OF THE TOOL

This chapter describes the development of the assessment tool, which will be applied in the case study described in Chapter 4. The theoretical framework used to influence the development of the tool is described in subsection 3. Factors which influence worker capability to perform optimally are briefly discussed in subsection 3.2, before detailing the methods involved in the development of the tool in subsection 3.3.

3.1 THEORETICAL FRAMEWORK

The literature presented (See section 2.5 – Analyses to inform appropriate placement of physically limited workers) shows that there are many job profiles and job assessments used in industry to determine task demands (Helm et al., 1999; Legge et al., 2013). There are also functional evaluations and medical records generated when a worker is injured, be it doctor's records, observations by an occupational health and safety officer, or assessments done by another professional involved with worker safety and well-being. It is not always possible to accurately match the information gained from the job assessments to that collected in the functional evaluations or medical records. As described in section 2.1 (Physical limitations in the workplace) inaccurate matching may lead to physical strain and potentially injury, and thus expose the worker to effects such as financial loss, reduced feelings of productivity and self-confidence (Helm et al., 1999). The organisation is also impacted in areas such as loss of skills and time invested in training replacement workers (Panel on Musculoskeletal Disorders and the Workplace, 2001) (see section 2.2 - Effects of physical limitation).

The principle of matching task demands to worker capabilities is central to the field of ergonomics (Mattison & Goebel, 2007) and is vitally important when placing injured workers in manual workplaces. Effective assessment and placement ensures safety and reduces the risk of further impairment. Although ergonomic design recommendations or accommodations are based on norms and standards, implementation of these principles is still extremely complex due to human variability (Chi, 1999; Das & Sengupta, 1996). Add to this the highly individualistic nature of injuries and subsequent impairments, and it becomes even more difficult to match the worker to the workplace.

Mattison and Goebel (2007) propose a way to deal with the large number of variable factors and the immense variation associated with both worker capabilities and task demands. These authors suggest that the main limiting factors of the worker's capabilities and the demands of the task be identified in order to account for the complexity of these two components and allow an optimal match of worker to the task. Chi (1999) recommends that the limiting factors of the job be identified by dividing the job into critical factors and comparing these demands with the limitations of the worker obtained through physical assessment of the worker. This process of determining the main limiting factors of the task demands and the worker capabilities may allow better comparison and matching (depicted by the red line in Figure 2) of the information pertaining to task characteristics and worker abilities (Mattison & Goebel, 2007).

Some important considerations for determining worker capabilities and limitations are presented by Mattison and Goebel (2007). These considerations have been grouped into different categories of resources in the human body, namely musculoskeletal, cardiovascular, respiratory and cognitive abilities (see Figure 2). The assumption made by Mattison and Goebel (2007) is that the principles applied to assessing physical limitations and capabilities can be applied to other resources in the body, and that the different resources can be assessed independent of each other (Mattison & Goebel, 2007).

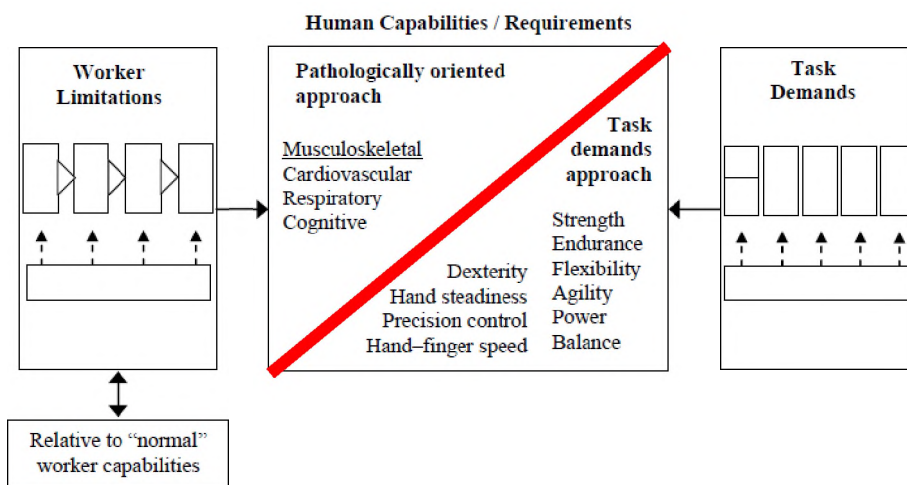


Figure 2: Schematic of matching worker capabilities and task demands (Adapted from Mattison & Goebel, 2007)

The theoretical framework described by Mattison and Goebel (2007) provided the outline for development of an analysis tool which considers specific physical limitations, as well as specific task demands in order to appropriately place physically impaired workers in a manual workplace.

Whilst the research conducted by Mattison and Goebel (2007) is comprehensive, it is important to note that they make a few major assumptions, which affect the interpretation and application of the theoretical framework for matching workers and tasks. One such assumption is that task demands can be split up into sub-tasks which will be consistent throughout similar tasks and jobs. However, Mattison and Goebel (2007) point out that there is difficulty in analysing physical tasks because there are varying numbers and combinations of sub-tasks which can make up any one task. For example, when assembling the body of a car, one model may require five sub-tasks while another model requires ten sub-tasks to achieve complete assembly. The task is the same for both models, namely assembling the car body, but the sub-tasks are different in number and maybe even nature. In addition to this, the context in which the task is performed will influence the nature of the task, as well as the impact the task demands have on the worker (Mattison & Goebel, 2007).

Ergonomic evaluation methods tend to assess job requirements and then use population normative values to categorise physical risk to the individual (Mattison & Goebel, 2007). These authors highlight the fact that workers with physical limitations have very specific capabilities and needs when being reintroduced into the workplace and thus commonly used risk categorization is not likely to be accurate. In light of this, it is essential to develop a new assessment tool which considers both the demands of the task, and the specific capabilities and requirements of the physically limited worker (as shown in Figure 3 below).

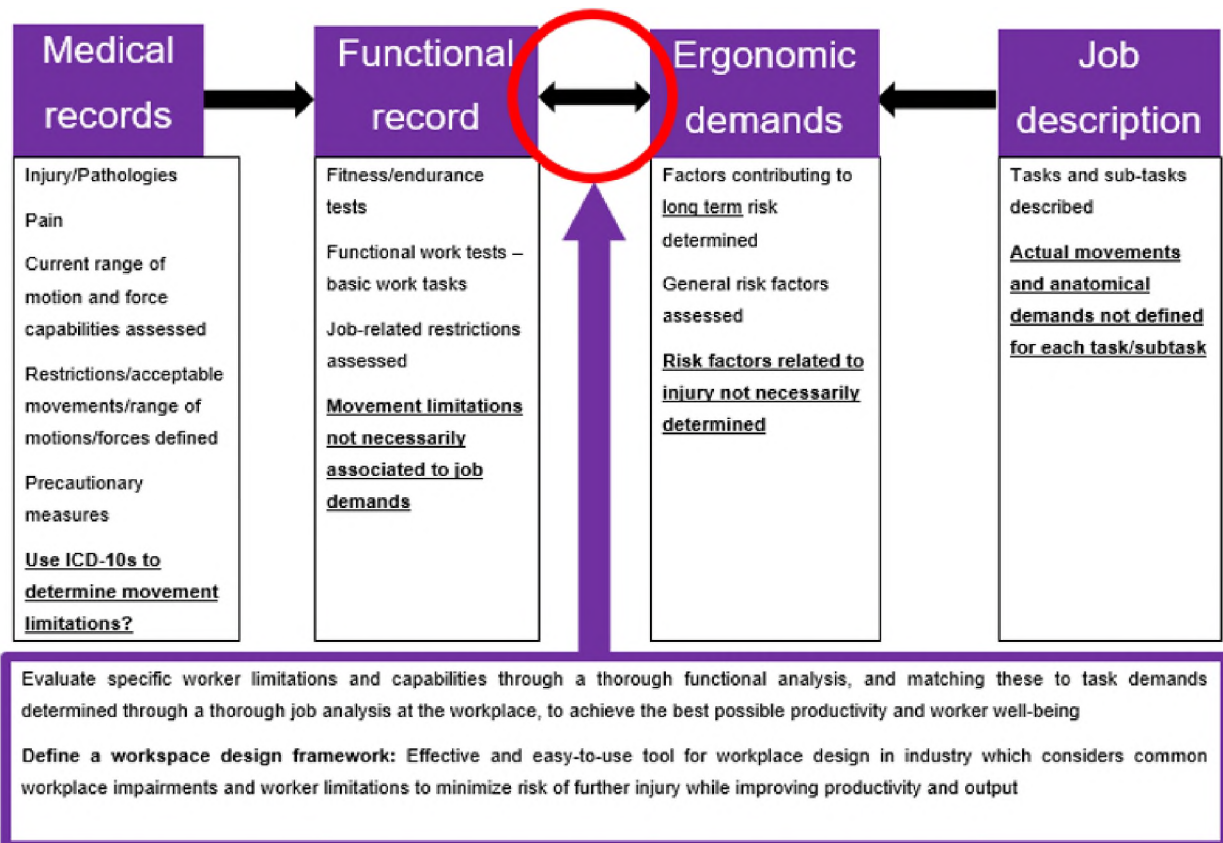


Figure 3: Schematic illustration of the information sources available when making placement decisions for physically impaired workers (Red circle illustrates the focus of this research, which is to bridge the gap between information relating to the worker and the task)

3.2 THE INTERACTION OF FORCE, TASK DURATION AND POSTURE INVOLVED IN TASK PERFORMANCE BY THE WORKER

Research conducted by Almgren and Schaurig (2012) describes physical ergonomics as consisting of a combination of three factors, namely time, force, and posture as illustrated in Figure 4. These authors claim that these three aspects cannot be separated since they interact and all contribute to the demands of ergonomic situations.

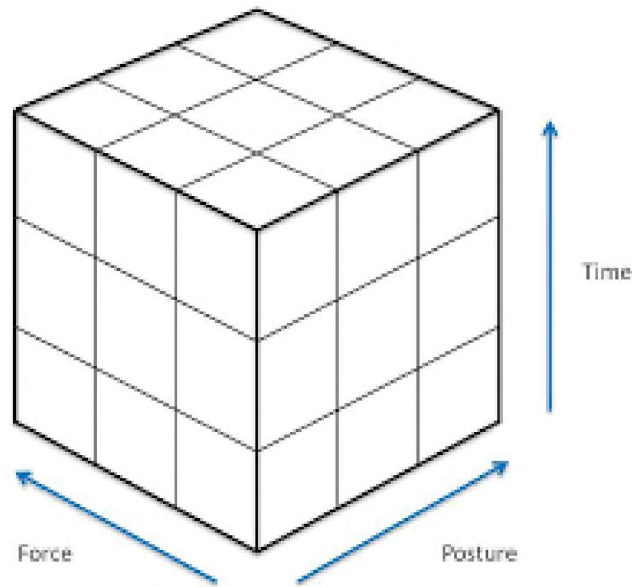


Figure 4: The cube-model of the three variables that can be used to describe physical ergonomics (Almgren & Schaurig, 2012)

This model described by Almgren and Schaurig (2012) suggests that it was not sufficient to just identify the movements involved in performing a task. Range of motion and posture capabilities and demands of the particular movements need to be defined to determine whether the worker can achieve the required posture, both in a static position and during dynamic movements. In addition to this, movements are rarely performed once off, thus time on task is important since increased time on task will increase the load placed on the body. Furthermore, it is not safe for a worker to exert maximal force capacity repeatedly throughout the day, because if the load is too large, there will be immediate damage to the musculoskeletal system (Almgren & Schaurig, 2012).

In order to minimise risk of further injury, it is necessary to assess both the task and the worker effectively to allow accurate matching of the task and the worker. Similarly, posture, force and time components need to be assessed for both the task and the worker. The processes of assessing each factor for both the task requirements and the worker capabilities are described below.

It is important to point out at this stage that factors other than posture, force and time also affect task performance and injury risk and need to be considered. For example, anthropometrics of the worker will largely affect task performance since a tall worker

will likely find stooping over to collect insects from the low pools more physically challenging than a shorter worker. Similarly, the environment in which a task is performed also has a large impact on both task performance and risk of injury. For example, if the environment is hot and humid the comfort level of the worker is likely to be low and thus fatigue may set in, increasing risk of injury. Due to time constraints, the current tool focuses only on posture, force and time elements. However, it would be beneficial to consider these and other pertinent factors in future research regarding matching physically limited workers and manual work tasks.

3.3 PROCESS OF DEVELOPING THE TOOL

This subsection describes the process involved in developing the assessment tool which addresses the principles outlined in subsection 3 above. The tool needs to assess the task demands, assess worker capabilities, and also match the worker capabilities to the task demands.

3.3.1 Compile a list of physical task demands which may be encountered in the workplace

The first step taken in developing the analysis tool was to define a list of job demands. This was a necessary step before breaking the task into the three factors described by Almgren and Schaurig (2012), and based on the suggestions of the framework described above (see subsection 3). This step allowed the job to be divided into critical factors to determine physical requirements to perform the tasks. To allow the tool to be used in a number of different workplaces, a list of all possible physical task demands which may be encountered in any physically demanding workplace was compiled by consulting different Ergonomic assessment tools and workplace assessment instruments (Hignett & McAtamney, 2000; Hildebrandt, 2001; Karhu, Kansil, & Kuorinka, 1977). These authors described physical task demands such as different body postures, head movements, carrying loads, pushing and pulling, reaching and fine object manipulation. Table 1 shows the different categories of task demands included (a) and an example of the components in each category (b) (also see Appendix 3: Full list of task demands). The list will allow any job to be defined by its critical factors, and thus allow comparison of these factors and demands with the capabilities or limitations of the worker.

Table 1a: Categories of task demands included in assessment tool

Body postures
Carrying loads
Pushing/Pulling
Reaching
Lifting
Lowering

Table 1b: Examples of components in the body postures category

Body postures	Standing upright - free
	Standing upright - supported
	Standing upright - in front of table
	Standing bent over/Stooping
	Sitting upright - free
	Sitting upright - supported
	Sitting bent over
	Seated on reclined chair with wheels
	Seated on swivel chair
	Squatting
	kneeling on one knee
	Kneeling on both knees
	Walking
	Twisting - standing
	Twisting - seated
	Lying prone
	Lying supine

3.3.2 Compile a list of all possible anatomical movements necessary to perform tasks in manual work

Similar to the task demands described above, overall movement capabilities of the worker need to be determined, and the framework presented by Mattison and Goebel (2007) suggest that the limiting factors related to the physical capabilities of the worker be defined. In order to achieve this, as well as allow applicability to different workers with different impairments, it was determined that the functional capacity of the worker in all physical movements needs to be assessed. Thus, the next step of this research involved systematically considering the moveable joints of the human body from head to toe and a list of all possible movements of these joints was compiled. The importance of listing all the possible movements of the joints ensures that thorough assessment of the physical capabilities of the workers, not only in movement capabilities, but force production capabilities during those movements and assessment of other capabilities required to perform the job.

The list of all possible anatomical movements initially included different movements of the head, neck, shoulders, wrists, fingers, lumbar spine, hip, knees, and ankles. This list initially yielded a large amount of data which would have resulted in complex data tables since there is a total of approximately 27 movements for all joints considered, when all planes of movement are evaluated. As such, the decision was made to limit the amount of data by focusing on the eight movements of the hips and lower back (see Table 2) since injuries related to manual work have been found to be most prevalent in these regions (Legge et al., 2013).

Table 2: Movements of joints with most prevalent injury rates

Hip	Flexion
	Extension
	Abduction
	Adduction
Lower back	Flexion
	Extension
	Lateral flexion
	Rotation

3.3.3 Describe physical task demands by the movements necessary to perform the demands

Since the two lists described above still yielded very different information, and in order to allow better comparison and matching (depicted by the red line in Figure 2) of the information pertaining to task characteristics and worker abilities (Mattison & Goebel, 2007) the next step was to attempt to understand the bi-directional impact of the different sets of data collected from assessing the task demands and the worker capabilities. In order to understand the impact of the physical capabilities on the task demands, it was necessary to determine which anatomical movements are required to achieve the individual task demands defined, based on anatomical characteristics of the task demand. For example, considering a seated posture (see Figure 5), it is apparent that hip flexion, knee flexion, and ankle dorsi-flexion are among the body movements required to adopt this posture.

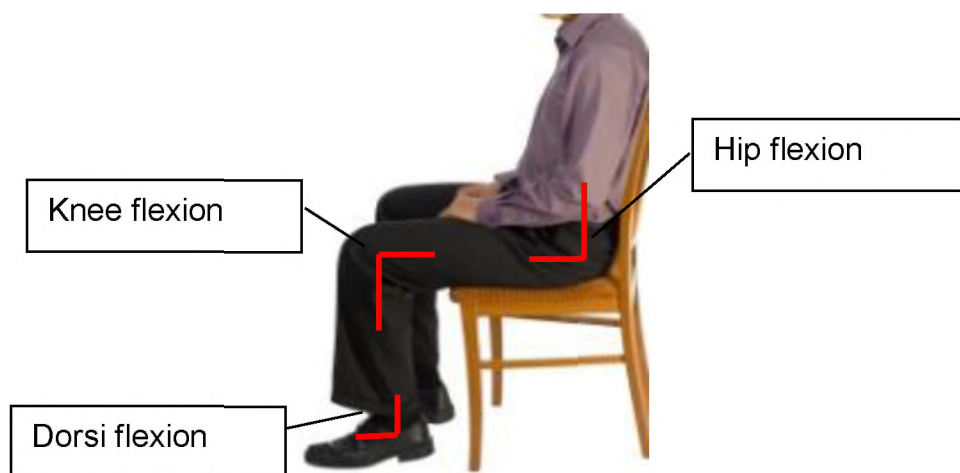


Figure 5: Anatomical demands of sitting upright on a chair (Body Literate, 2016)

Bearing in mind the anatomical movements, it was necessary to split the task demands into the movements required to adopt the posture (starting from neutral anatomical position taken as standing upright with arms hanging by the sides and legs straight), maintain the posture, and return to the neutral anatomical position after performing the task. This ensured that all movements involved in the task are considered (see Table 3).

Table 3: Example of description of joint movements involved in adopting and maintaining a posture, and returning to neutral anatomical position

	Standing bent over/Stooping
Adopting	Hip flexion; Lower back flexion
Maintaining	Hip extension; Lower back extension
Returning	Hip extension; Lower back extension

However, it was noted that there was repetition of some movements within the different phases, so joint movements involved in any or all of the phases were only listed once for each task to avoid redundancy of data (Table 4).

Table 4: Example of task demands described as movements involved in adopting, maintaining and returning from the posture (repeated movements only listed once)

Movements involved in demands		Movements to be measured
Body posture	Standing upright - free	Hip flexion + extension; LB flexion + extension
	Standing upright - supported	Hip flexion; LB flexion
	Standing upright - in front of table	Hip extension; LB extension
	Standing bent over/Stooping	Hip flexion + extension; LB flexion + extension
	Sitting upright - free	Hip flexion + extension; LB flexion + extension
	Sitting upright - supported	Hip flexion + extension; LB flexion + extension
	Sitting bent over	Hip flexion + extension; LB flexion + extension
	Squatting	Hip flexion + extension; LB flexion + extension
	Kneeling on one/both knees	Hip flexion + extension; LB flexion + extension
	Walking	Hip flexion + extension; LB flexion + extension

Knowing which movements are involved in each task demand is useful in ensuring that workers who are physically limited are not placed to perform tasks that may place them at risk. For example, if the main task demand for the job is walking, the worker needs to have sufficient movement in the spine, hips and lower limbs to walk safely.

3.3.4 Describe movements by the physical task demands which require those movements

After describing physical task demands by the movements necessary to perform the demands, the next step to achieve the bi-directionality between the task demands and the worker capabilities, was to determine the impact of the task demands on the physical capabilities. To realize this, each body movement was also defined in terms of the different physical demands that require that movement (Table 5 and Figure 6).

Table 5: Examples of task demands which involve hip flexion

Hip Flexion
Standing upright - free
Standing upright - in front of table
Standing bent over/Stooping
Sitting upright - free
Sitting upright - supported
Sitting bent over
Squatting
Kneeling on one/both knees
Walking
Twisting - standing
Twisting - seated
Seated on swivel chair



Squatting¹



Reaching²



Pushing³

Figure 6: Some of the physical task demands which involve hip flexion

1 ESB Professional, 2016

2 Paulausky, 2014

3 Dreamstime.com, 2016

Knowing which task demands involve each movement is useful when making placement decisions for physically limited workers since it allows for specific consideration of potentially risky tasks, based on the requirements of that task. For example, if a worker has limitations in hip flexion, and it has been determined that squatting, stooping and climbing stairs require hip flexion, then any tasks which require squatting, stooping and/or climbing stairs need to be carefully assessed to allow for appropriate matching.

3.3.5 Range of motion and posture

Based on the cube model presented above, it is necessary to determine range of motion requirements of task, and range of motion capabilities of the worker in order to fully describe physical task demands and the worker capabilities, and thoroughly assess compatibility of task demands and worker capabilities. The importance of range of motion and posture was noted in section 2.1.2, since biomechanical stressors particularly related to joint positions have been found to be closely linked with development of MSDs in the workplace (Aptel et al., 2002). Thus, range of motion and postures required to perform the task, as well as range of motion capabilities of the worker need to be determined in order to determine the fit between the worker and the task, and thus the safety of the worker when attempting to meet task requirements.

With this in mind, it was evident that an important aspect to consider in terms of posture is the harmful effect static postures can have on the body since they do not regularly allow time for recovery (Almgren & Schaurig, 2012). One common source of static loads is holding the body or a body part in a fixed posture, even if the tasks are varied. In this case, the time on task needs to be limited in order to reduce postural load. Similarly, if the force level is high, the posture load needs to be low and as far as possible postures which do not place excessive stress on the body need to be adopted.

Task demands

Once the movements involved in performing the job have been described (using the output of subsection 3.3.1 above), it is necessary to determine the actual range of joint motion required to perform the given task. To achieve an accurate record, workers should be observed, and preferably photographed or videotaped, while performing the

task (Gallagher, Moore, & Stobbe, 1998). The range of motion is then determined from analysis of the video footage and measured from the neutral standing or seated posture adopted prior to any performance of movement involved in the task, to the most extreme range necessary for each joint to move through in order to perform the different aspects of the tasks.

For example, in Figure 7 below, trunk flexion during standing stooped over would be measured from standing upright (a) to the final position of the trunk during the stooped posture (b).

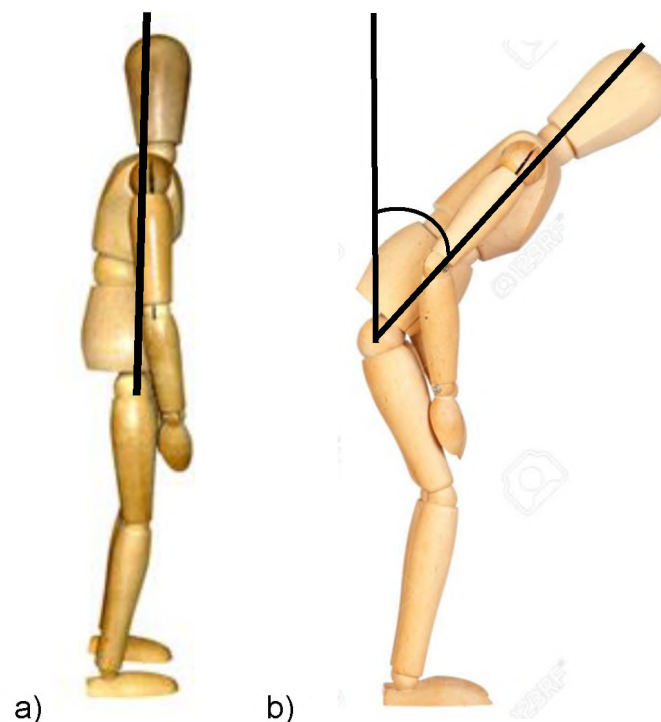


Figure 7: Measuring range of motion of trunk flexion when standing stooped over a) starting position b) stooped posture with angle of trunk flexion shown

Images sourced from <http://previews.123rf.com/images/gelpi/gelpi1103/gelpi110300002/8988943-Wooden-mannequin-stooping-isolated-on-white-background-Stock-Photo.jpg>

Worker capabilities

After the range of joint motion required to perform the given task has been assessed, in order to allow appropriate matching of task demands and worker capabilities related to range of motion and posture, it is important to determine range of motion capabilities and limitations of the specific impaired worker being placed.

Most joint ranges of motion are measured using an instrument called a goniometer which is specifically used for the measurement of angles. The axis of the goniometer is placed over the fulcrum of movement (usually the middle of the joint being moved), the stationary arm is aligned parallel to the longitudinal axis of the proximal segment of the joint, and the moving arm is aligned parallel to the longitudinal axis of the distal segment of the joint (Norkin & White, 2003).

Specific methods for measurement of hip flexion and extension, as well as lower back flexion, extension, lateral flexion and rotation are detailed in Appendix 4: Goniometry guidelines. For this research, it was decided that range of motion should be measured in the position the worker usually adopts to perform the task. In some cases this may have varied from conventional practices, but this was determined to be most appropriate for the nature of the research and was done to allow accurate assessment of the specific physical capabilities of the worker related to the specific demands of the task. For example, if the worker performs the task standing, the starting position to measure hip range of motion is upright standing with both legs straight, even though conventionally hip range of motion is measured supine (see Appendix 4: Goniometry guidelines). Active range of motion should be measured for work-related ranges of motion since it is most similar to the movements performed in the workplace. Active range of motion is defined as unassisted voluntary joint motion (Norkin & White, 2003).

3.3.6 Force

Similar to the cube model proposed by Almgren and Schaurig (2012), Garg and Kapellusch (2009) emphasised the importance of matching strength requirements of the job with the strength capabilities of the worker. It has been shown that musculoskeletal injuries often occur when the physical requirements of jobs exceed the job-specific strengths of the worker performing the job (Kumar, 2001). The force variable described in the cube model described by Almgren and Schaurig (2012) can be defined as the relative muscle exertion required to perform the task. This is usually taken as a percentage of the individual's maximal voluntary capacity (MVC) of the movement involved (Sperling, Dahlman, Wikstrom, Kilbom, & Kadefors, 1993). These authors describe a high force level as more than 30% of the MVC, while a low force level is less than 10% of MVC. As the force level increases, time on task should decrease to compensate for the increased stress placed on the worker (as described

in section 3.3.7 below). In cases of very high force, however, if the imposed load is above the threshold for tissue damage (Marras, 2000), the time factor will be irrelevant since the body cannot withstand such forces at all and will likely be damaged (Almgren & Schaurig, 2012).

Although the worker performing the task will not necessarily be exerting maximal force with every movement, it is important to know if they are capable of producing sufficient force to meet the maximum force required to perform the task.

Since force effects are largely dependent on the magnitude of the force, the direction of the force during the task, and the interfaces involved in transmitting the force, as well as the specific nature of the task, further assessment was necessary if there was a force component to the task. This further assessment was either in the form of the injured worker actually performing the task in a trial run to determine if they are capable of moving the load, or measurement of the actual force that is manipulated to perform the job, as well as measurement of the force producing capabilities of the worker. Measurement of the magnitude of the load to be moved can be done using a normal scale or a strain gauge, depending on the nature of the task. Similarly, measurement of force production capabilities of the worker can be done using a strain gauge. As with posture and range of motion described in the section above, it is important to measure force capabilities in the same position and direction in which the force will be manipulated when performing the task since gravity and muscle position will affect force production capabilities.

3.3.7 Time on task

After assessing force and range of motion demands, the remaining aspect of the cube model which needs to be considered is the time factor. Time spent performing a task, as well as time spent performing individual movements or sustaining certain postures need to be determined since the duration of the activity can significantly affect the amount of strain placed on the worker (Almgren & Schaurig 2012). These authors purport that if an activity is only performed for a short amount of time and on an irregular basis, it is not likely to be harmful. On the other hand, if the same activity is performed for extended periods of time, for example an entire day, it is likely to cause fatigue and the risk of injury increases (Almgren & Schaurig, 2012). Thus, it is

necessary to determine the duration of different task components in order to determine the extent to which these components will strain the worker.

In reality, the work organisation generally dictates how much and how often the worker must perform different components of the task (Sperling et al., 1993). These authors describe a high time factor as intermittent performance of the same task for more than half the shift. If the task is performed continuously, high time stress is considered to be more than 30 minutes at a time (Sperling et al., 1993). Conversely, the same authors describe a low time stress is considered to be less than one hour of intermittent performance of one task, or less than 10 minutes of continuous performance.

Similarly, Sperling et al. (1993) suggest that recovery time after an exertion, such as during performance of a work task, is as important as the time on task. To allow continued performance of strenuous tasks, sufficient recovery time needs to be provided between exertions (Almgren & Schaurig, 2012). These authors further postulate that repetition of a task is not harmful if sufficient recovery time for complete recovery is provided. When that is not the case, repetition can also be harmful, albeit in a chronic manner, rather than the acute harm caused by over loading during strenuous activities (Almgren & Schaurig, 2012).

Task demands

To determine the time requirements related to each physical task demand, both the frequency and duration of each movement was measured during the initial observation. Repp, Roberts, Slack, Repp, and Berkler (1976) describe frequency measurement as recording the number of occurrences of different movements per unit time, be it a shift, or portion thereof. The duration of each movement should be averaged over a number of repetitions in order to determine an accurate duration measurement for one repetition. Total duration for each movement can then be calculated for the entire shift, or a portion thereof, by multiplying the duration per repetition by the number of repetitions recorded for that time period. Ideally the frequency and duration observations should be repeated over at least three different time periods at different points in the shift in order to achieve the most comprehensive and accurate results representative of the different activities performed throughout the shift (Repp et al., 1976).

For example, if a worker has to install engines in 40 cars in an eight hour shift, the worker may stand stooping over the bonnet for 300 seconds 40 times in the shift. Alternatively, it could be that in a 60 minute period during the shift the worker adopts a stooped posture 5 times, but for 300 seconds each time.

Worker capabilities

The capabilities of a worker to repeat a task over and over, or to maintain a particular force for a certain amount of time will be affected by the nature of the task, and the nature of the movement involved. Since it is impractical to measure endurance and repetition capabilities for each task demand and each joint movement, the relationship depicted in Figure 8 below was used to prescribe appropriate time parameters, based on the force being manipulated (Demura & Nakada, 2010). The relationship depicted is based on the maximum force production capabilities of the worker and relates these to the amount of time the worker should be able to continuously maintain a certain percentage of the force (Demura & Nakada, 2010). Once force production capabilities have been measured, as described above, the appropriate time factor can be applied to ensure safety for the worker.

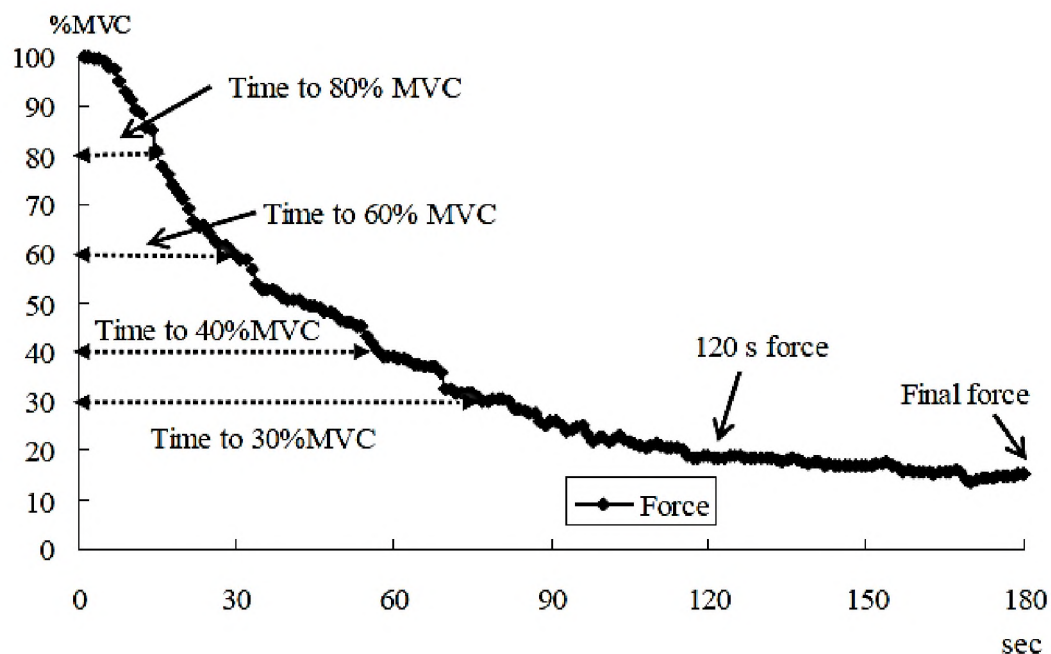


Figure 8: Relationship between force levels and endurance time (Demura & Nakada, 2010)

This principle of linking force levels and endurance time has become less popular over the last few years since it is believed that the relationship depicted underestimates the time limit. However, for this research, it is beneficial to have an underestimation of time of force exposure since it will reduce the risk of overload or strain for the worker and thus contribute to ensuring appropriate placement for physically limited workers.

CHAPTER 4 – CASE STUDY

This chapter applies the assessment method developed in Chapter 3 through the use of a case study to empirically test the assessment tool. Results of the testing are given and a discussion is presented to describe the findings.

The aim of the case study was to test the tool previously developed, to determine applicability, usability, as well as shortfalls and limitations of the tool.

4.1 PROCEDURE

The general approach for the case study done to test the tool developed was to find an organisation which involves manual work, and assess workers who do not have physical limitations performing a manual task. The next step was to find a worker with physical limitations due to an injury or disability and assess range of motion and force capabilities. Once a job and a worker were assessed the tool was used to compare the information obtained from the task analysis and worker assessment. This comparison was done to determine if the worker could meet task demands, and be productive, without increased risk of injury. The details of the recruitment and assessment processes are described in the subsections below.

4.1.1 Ethical considerations

Ethical approval was applied for through the Department of Human Kinetics and Ergonomics Ethics Committee. Due to injured workers being considered a vulnerable population the application was escalated to the Rhodes University Ethics and Standards Committee where approval was subsequently granted (see letter of approval in Appendix 5 – Ethical clearance).

The main concerns of the ethics review process was exposing mismatch between the worker and the tasks they perform, and subsequent exposure of increased risk to the worker, since the research involves assessment and determination of fit between a physically limited worker and the tasks involved in performing a job.

The most pressing concern was the ethics of identifying that the job the physically limited worker currently performs places them at risk of injury. To allow for this, a job which the physically limited worker is NOT currently performing was analysed. The assessment tool being tested was designed to determine whether the worker will be

able to perform a job they are not currently performing. This could be in the case of a worker who needs to return to the job they performed prior to an injury, or a new position they need to assume subsequent to acquiring physical limitations. The tool is not meant to test whether the worker's current job is appropriate, but rather if the suggested job placement is appropriate.

Similarly, there was concern over the fact that the worker assessed will be given a report and feedback on the findings of the research, but that information on how to reduce risk or how to improve the range of motion will not be provided to the worker. This means that the research may expose the worker to knowledge of their physical limitations, but does not offer remediation of these limitations. Prior to the testing, it was determined that details of the medical practitioner involved with treatment of the injury or disability be obtained from the worker and permission sought to liaise with the medical practitioner to facilitate remediation of the limitations exposed by the research. If the worker is not currently under the care of a medical professional, the research team committed to facilitating access to medical care for the worker to address limitations, which were highlighted by the testing procedure. In the case of the worker assessed during the case study, the injury occurred seven years ago so the worker is not involved in ongoing care with a medical professional who is equipped to address range of motion and force limitations. However, the worker does frequent a Prosthetist. Despite the worker having the limitations which are described later in this chapter, Biokinetics reasoning suggests that if the limitations are not causing pain or discomfort and not hindering activities of daily living then immediate attention from a medical practitioner is not necessary, unless the worker decides this for themselves. Thus, the worker was advised to consult with the Physiotherapists and Biokineticists who work at the same practice as the Prosthetist should he want to reduce physical limitations.

4.1.2 Sampling

An organisation, which has manual tasks with little automation, was approached and asked if they were willing to allow the researcher to perform analyses on their workers. The project aim and process was explained to a representative of the organisation (see Appendix 6: Information to the organisation) and written consent (Appendix 7: Organisation informed consent) was obtained to perform the research.

4.1.3 Assessment

Once permission had been granted by the organisation, a manual job involving use of predominantly the lower back and hips was identified. A description of the workers' responsibilities was gained from the supervisor prior to observation. The organisation chosen is a small enterprise, and there are a small number of workers who have similar responsibilities and perform similar tasks. The structure of the organisation is such that there are a group of physically able workers who all perform similar tasks, while the physically impaired workers perform some of the same tasks, but also some different tasks to the physically able workers. The physically able workers were approached and asked if they consent to being observed performing the tasks in order to determine the movements involved in the task (see Appendix 8: 'Apparently Healthy' worker informed consent). A thorough explanation was given as to the purpose of the research and what exactly is required from the workers. A full cycle of the task was observed to ensure a thorough description of the physical components of the task. An initial assessment of the photographs taken of the physically able workers performing the tasks was done to determine the postures and physical demands required to perform the tasks.

Range of joint motion required to perform the given task was measured from the photographs. The starting point for range of motion was taken as the neutral standing or seated posture adopted prior to performance of movement involved in the task. The end point was taken as the most extreme position to which each joint must move in order to perform the different aspects of the tasks (see Appendix 4: Goniometry guidelines). Frequency and duration of individual task demands were also determined to fully describe the stress on the worker.

Subsequently, a worker who experiences limitations of the lower back or hips was identified and approached to participate in the study. A thorough explanation was given regarding the reason for the study and the process involved. Following the explanation, if the worker agreed to take part, an informed consent form was presented and explained and the worker was asked to sign it before they took part (see Appendix 9: Physically limited worker informed consent).

An assessment of the injured worker’s movement capabilities and limitations was then performed (See Table 6 for an example of range of motion (ROM) data sheet). The assessment was performed in a private room, on site, to ensure privacy and confidentiality during the assessment.

Table 6: Template data collection sheet for worker capabilities – Range of Motion

Movements	ROM (in degrees measured from neutral position)
Hip flexion	
Hip extension	
Hip abduction	
Hip adduction	
LB flexion	
LB extension	
LB lateral flexion	
LB rotation	

Range of motion capabilities were assessed to determine whether the worker is capable of performing the task without excess strain or risk of injury. Range of motion of the joints were measured using a goniometer, with the goniometer axis placed over the axis of movement of the joint, the stationary arm aligned parallel to the longitudinal axis of the proximal segment of the joint, and the moving arm aligned parallel to the longitudinal axis of the distal segment of the joint (Norkin & White, 2003). For example, when measuring hip flexion, the axis of the goniometer is placed over the lateral region of the greater trochanter of the hip, the stationary arm and the moving arm parallel to the femur. The worker starts in an upright standing position with both legs straight, then lifts the leg being measured as high as possible. The knee can be bent if necessary (see Appendix 4: Goniometry guidelines).

If there was a load to be moved during movement of the lower back and hips, further assessment was performed, as described in subsection 3.3.6.

The data collected from the task and the worker was entered into the analysis tool developed and a comparison done to determine if the worker was capable of performing the task, at no increased risk of re-injury or further injury.

4.1.4 Feedback and reporting

A descriptive report (see Appendix 10: Participant feedback) was provided to the participant showing the results from the assessments performed to determine their capabilities. In this case study this feedback served as evidence of sufficient capabilities to perform with low risk of injury.

This research employed a hypothetical scenario and did not aim to move the worker to the job analysed. If the worker did need to be placed in a job they are not currently performing and the fit between the worker and the task demands was deemed inappropriate, the worker would be consulted to determine if they want the assessor to engage in discussion with the organisation to try and improve the fit through job accommodation or assessment of a different job. This process was determined to be the best approach to ensure that the assessors do not cause unfair disadvantage for the worker due to mismatch between the worker capabilities and the task demands.

4.2 RESULTS

Table 7: Summary of activities performed during testing

Total hours of observation	3
Number of observers used	1
Number of workers observed	2-3 in one task 9 in total (1 physically limited worker)
Number of tasks assessed	4 for the apparently healthy workers 3 for the physically limited worker
Number of postures assessed	18
Number of range of motion measurements on physically limited worker	6
Number of range of motion mismatches between task and worker	2 – hip and lower back flexion
Changes made to the tool	None (contextually) Some formatting was changed to allow easier interpretation

4.2.1 Task analysis

The physically able workers were approached and consent obtained to observe them performing their tasks. These workers adopt a general maintenance role which includes various tasks performed on different days and at different times. Multiple observations were performed to obtain information pertaining to each task. The tasks performed are summarised in Table 8 below, along with photographs taken throughout the observations.

Table 8: Tasks performed by the 'apparently healthy' workers

Task	Postures adopted
Cleaning pools	
Collecting insects off the plants in the pools	

Removing and replacing sediment



Building and grounds upkeep



Once the observations were completed, the presence of different task demands involved in performing each task was recorded. Additionally, the frequency of each demand in a one hour cycle, duration of one repetition of each demand, and the presence of force manipulation if relevant were recorded (see Table 9 below). Frequency of each demand was collected by asking the worker how often they perform the movement and then applying their report to a scale developed for this specific study to allow simple data collection (see Table 10 below). Duration of each repetition was measured by the researcher over 3 different repetitions and then averaged and recorded in Table 9. Accumulative duration for one day was estimated based on frequency of repetitions and duration of one repetition, as well as total time to perform the task which requires the relevant demand.

Presence of force was recorded, quantity of force manipulated was measured and recorded to determine force requirements of the task.

Table 9: Records of task demands and accompanying attributes (force, frequency and duration)

	Demand	Posture present	Force	Frequency	Duration (1rep)	Duration (accumulative/day)
Body posture	Standing upright - free					
	Standing upright - at table					
	Standing bent over/Stooping	X		5	30s	+/-3hrs
	Sitting upright - free					
	Sitting upright - supported					
	Sitting bent over	X			10mins-1hr	3+hrs
	Squatting	X	X	4	5s	
	Kneeling on one knee					
	Kneeling on both knees					
	Walking	X	X	4	5s	
Body posture	Climbing stairs	X		4	5s	
	Descending stairs	X		4	5s	
	Twisting - standing	X	X	4	3s	
	Twisting - seated	X		4	3s	
	Lying prone					
	Lying supine					
	Seated on reclined chair					
	Seated on swivel chair	X			10mins-1hr	3+hrs

	Demand	Posture present	Force	Frequency	Duration	Duration
Carrying loads	On back					
	On front	X	X: 8kg	4	5s	
	On side					
Pushing	Standing					
	Walking	X	X: 0-5kg	3	5s	1hr
	Seated					
	Legs only					
Reaching	Whole body	X		5	3s	
	In front	X	X	4	3s	
	To side	X	X	4	3s	
	Behind					
	Above shoulder level/overhead one arm					
	Above shoulder level/overhead both arms					
Lifting	From floor	X	X: 5.1kg	4	5s	+/-3hrs
	From waist height	X	X: 8kg	4	5s	+/-3hrs
	From shoulder height					
	From above shoulder height					
	To waist height	X	X: 8kg	4	5s	+/-3hrs
	To shoulder height					
	To above shoulder height					
Lowering	To floor	X	X: 5.1kg	4	5s	+/-3hrs
	To waist height					
	To shoulder height					

Table 10: Frequency Scale

1	2	3	4	5
1-2/day	1-2/hour	1-2/30min	1-2/15min	>1/min

The range of motion for each anatomical movement required to perform different task demands was determined by analysis of the photographs taken during the observations (see Appendix 11: Examples of angle measurements). Some physical task demands were observed in more than one of the different tasks performed by the workers. For example the workers had to stoop when working with the sediment, as well as during building tasks and grounds upkeep, but to different ranges of motion. In order to account for this repetition of observed behaviours, the largest range of motion observed for each anatomical movement was taken as the maximum range required for the worker to be able to perform the tasks. Maximum range of motion for each movement involved in performing the task demands are shown in Table 11 below.

Table 11: Maximum range of motion (in degrees) requirements for the tasks

	Hip flexion	Hip extension	LB flexion	LB rotation	LB lateral flexion	LB extension
Cleaning pools	-	10.8	77.9	33.0	-	-
Removing and replacing sediment	33.6	12.1	64.6	-	12.7	18.6
Building and grounds upkeep	47.2	20.2	117.0	-	11.6	7.8
Collecting insects off plants in the pools	68.0	-	14.7	40.0	-	-

4.2.2 Worker analysis

The next step was to assess a worker who has physical limitations due to an injury or disability. As noted before, a number of the workers at the organisation perform similar tasks. In order to reduce overlap of responsibilities, a worker was chosen who performed few or none of the same tasks as the workers who were observed for task analysis. A worker who underwent above-the-knee amputation on the right leg seven years ago as the result of injuries obtained in a car accident was assessed to determine physical capabilities and ability to meet the task demands determined in the previous subsection. A thorough history was taken regarding the effects of the amputation and movement limitations experienced. The worker reported being able to

ascend and descend stairs without difficulty, as well as being able to push trolleys and sweep with ease. The worker reported not being able to carry heavy loads since this affected balance and stability as a result of the prosthetic limb.

The worker was asked what tasks he performs at the organisation. It was determined that the worker performs different tasks to the tasks assessed. The tasks performed by the physically limited worker are shown in Table 12 below.

Table 12: Tasks performed by the worker assessed

Collect and release insects from the pools
Sweep and clean the tunnels
Fertilise and spray the pools

Comparing the tasks of the physically able workers in

Table 8 and those of the physically limited worker in Table 12 shows that the different groups of workers perform different tasks, with the only similar task being that of collecting insects from the pools. Thus, the aim of the assessment was to determine whether the physically limited worker could perform the other tasks if he was to assume the same role as the physically able workers. Assessment of the physically limited worker's range of motion of the lower back and hips, as well as lifting strength was performed to allow comparison to the information previously obtained for the task demands. Range of motion results are shown in Table 13 below.

Table 13: Range of motion for physically limited worker

Movement	Range of motion	
	Left	Right (amputated side)
Hip flexion	86°	55°
Hip extension	44°	20°
LB lateral flexion	51°	50°
LB rotation	84°	84°
LB flexion	106°	
LB extension	44°	

Using the assessment tool developed to compare task and worker

The maximum ranges of motion required to perform the tasks assessed (Table 11) were compared to the minimum range of motion abilities of the worker (Table 13) to ensure that the worker is not pushed past their limitations. The output from the assessment tool developed is shown in Table 14 below.

Table 14: Output from assessment tool showing maximum range of motion values for each task (Values highlighted in red represent those which are greater than the minimum range of motion capabilities of the worker)

	Hip flexion	Hip extension	LB flexion	LB rotation	LB lateral flexion	LB extension	Risk
Cleaning pools		10.8	77.9	33			No
Removing and replacing sediment	33.6	12.1	64.6		12.7	18.6	No
Building and grounds upkeep	47.2	20.2	117		11.6	7.8	Yes
Collecting insects off plants in pools	68		14.7	40			Yes

Results presented in Table 14 show that the limitations of the worker would place them at increased risk of injury during movements which require hip flexion and lower back flexion. This increased risk is due to the fact that the range of motion requirements of the tasks exceed those of the capabilities of the worker and thus may place increased pressure on the worker to adopt postures they are not capable of adopting. Tasks

which involved these movements include building and grounds upkeep and collecting insects of the plants in the pools.

It is important to note that even if the tool has not highlighted risks for some of the tasks, if the worker is to perform these tasks, there should be an initial observation of the worker when placed in the job to ensure low risk of injury. Just because the assessed task demands and worker capabilities are shown to be compatible by the output of the tool, it does not guarantee that the movement patterns adopted by the worker to meet task demands will minimise risk of injury during performance.

Force

The next step in the assessment process was to determine whether the worker could meet force requirements of the task demands. As previously stated (in subsection 3.3.6), force can be measured in two ways, namely placing the worker in the task and asking them to perform a trial run of manipulating the force, or actual measurement of production capabilities using a dynamometer.

Due to the specificity of the force manipulation when pushing (see Table 8), the worker was asked to perform the pushing motion and it was determined that the worker could meet the task demands with low risk of injury during the movement since they did not find it strenuous or difficult to push the trolley.

Similarly, the worker was asked to perform the carrying task to determine whether they could meet the force requirements (see Table 9). The worker reported feeling unstable while carrying heavy loads, due to reduced confidence in the stability during walking on the prosthesis while carrying a weight. Thus, it was determined that the capabilities of the worker do not meet the requirements of the carrying task demand and the task of carrying while building and replacing sediment would place him at increased risk of injury.

Lifting force of the worker was measured using a back strength dynamometer, with the worker producing a lifting force of 41.5kg. This exceeds the lifting force needed for the task demands recorded (see Table 9). This suggests that the worker will be able to perform the lifting tasks involved in building and replacing sediment with low risk of injury. However, due to the inability to carry loads, as noted above, the worker will not be able to fully perform the tasks involved in replacing sediments.

Time

As previously stated in subsection 3.3.7 it is impractical to measure endurance and repetition capabilities for each task demand and each joint movement. As such the relationship between force and time depicted in Figure 8 was used to prescribe appropriate time parameters for lifting tasks, based on the worker's force production capabilities. The worker was able to lift 41.5kg, this was taken as the maximum voluntary capacity (MVC). The force requirement for the lifting task was 5kg, which is 12.05% of the worker's MVC. Based on the relationship described by Demura & Nakada, (2010) the worker should be able to perform the task repetitively for approximately 169 seconds (2 minutes and 49 seconds). The interpolation is shown in Figure 9 below.

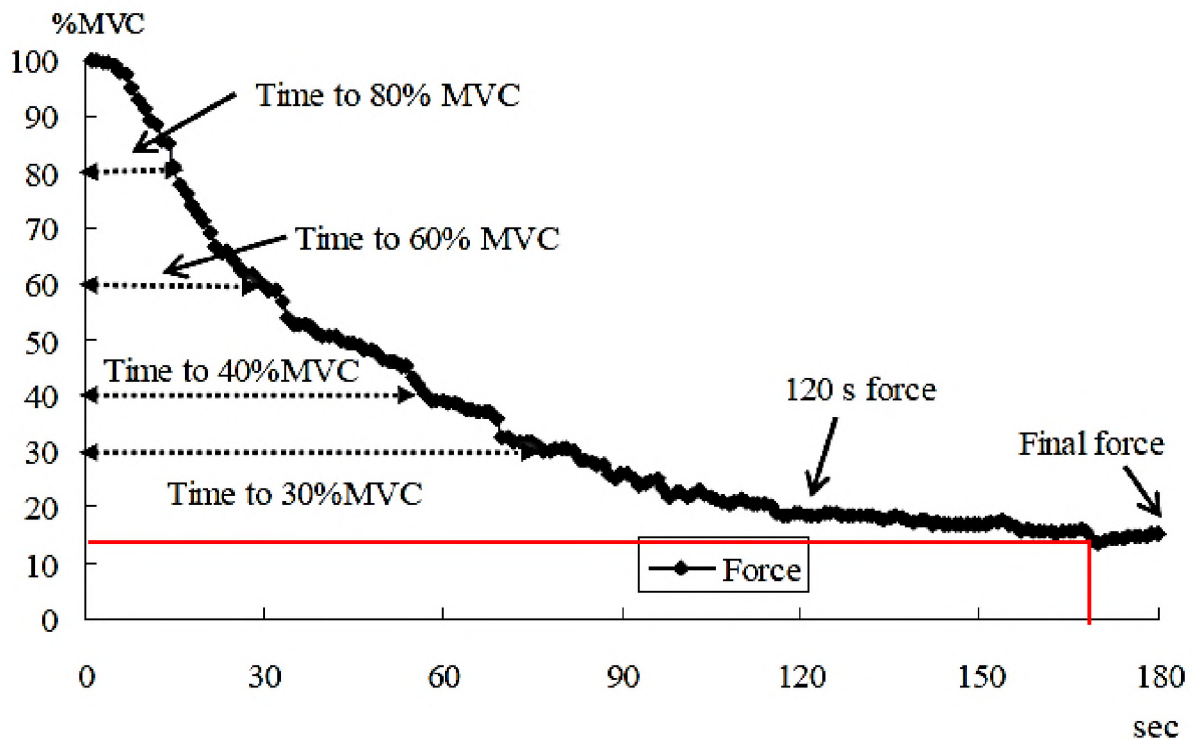


Figure 9: Relationship between force levels and endurance time (Demura & Nakada, 2010) (Red line shows interpolation of time from force capabilities of the worker).

As described in subsection 3.3.7, this principle of linking force levels and endurance time tends to underestimate the time limit for the relevant force production. This suggests that the worker will likely be able to perform the lifting task for longer than

169 seconds. However, setting the time limit at 169 seconds will likely reduce the risk of overload or strain for the worker.

Due to the specificity of the force production for the trolley pushing, it was not possible to quantify the force capabilities of the worker in this task. Based on the trial repetition of the pushing task, it was determined that the force requirement did not place the worker at risk of injury since they were able to execute the task without difficulty and strain. Furthermore, the worker reported only needing to perform the pushing task once or twice in 30 minutes, which is not likely to place the worker at risk of injury due to force manipulation during pushing.

It is important to acknowledge that information obtained from subjective reporting is not as reliable as information from objective measures, making it more difficult to formulate evidence-based decisions. In order to account for the difficulty in quantifying forces for specific tasks, such as the trolley pushing, it may be useful to consider employing a validated subjective measure such as the Borg Ratings of Perceived Exertion scale or a Pain/Discomfort scale in order to accurately describe the strain placed on the worker during the task. This aspect should be incorporated into the design of the tool in order to improve reliability and validity.

Ergonomic assessment

This was done to determine if it would be appropriate for the physically limited worker to perform the tasks done by the physically able workers. Since the limited worker was not able to perform the carrying task (which was involved in building, as well as replacing the sediment), the only other task which the physically able workers perform that could be assessed is collecting insects from the pools. The worker was asked to perform the collecting task to determine the level of risk. Since the focus of this research is the lower back and hips, an established and validated tool which assesses the posture of the whole body, as well as force manipulation capabilities was developed. The Rapid Entire Body Assessment (REBA) aims to allow postural analysis in different planes of movement, with sensitivity to musculoskeletal risks (Hignett & Mcatamney, 2000). The REBA considers static, dynamic, rapid changing and unstable postures, and reflects that coupling and force components of tasks are important considerations when assessing work (Hignett & Mcatamney, 2000). This

assessment was chosen to determine if the fit between the worker and the tasks is appropriate because it is a pen and paper method and can be used in almost any environment. In addition, the assessment is quick and easy to perform, and not invasive for the worker or the work process. The REBA considers specifically neck, trunk and leg posture, lower arm, upper arm and wrist positions, as well as handle position and design, and force quantity. Results from the REBA are shown in Table 15 below.

Table 15: REBA scores for the different components

Body area	Score	Comments
Neck	2	2 – more than 20° of forward flexion
Trunk	3	3 – between 20 and 60° of flexion
Legs	3	1 – sitting; more than 60° of knee flexion
Lower arm	1	1 – between 60 and 100° of elbow flexion
Upper arm	3	3 – between 45 and 90° of flexion; -1 – arm is supported; +1 shoulders raised
Wrist	2	1 - between 15° flexion and 15° extension; 1 – wrist bent from midline and twisted
Coupling	0	No handle
Force	0	Less than 4.99kg

The REBA yielded a final score of 9, which is considered high risk. The developers determined that if the task performance falls in this category, there needs to be investigation of the worker's conditions and change needs to be implemented to reduce risk (Hignett & Mcatamney, 2000). Risk can be reduced by changing postures of different body parts, as well as reducing force components and static posture durations. In order to appropriately reduce risk, specific scores of the different sections of the REBA should be considered to see where the greatest risk is present. The changes which could be made for this particular worker will be discussed in Chapter 5.

CHAPTER 5 – DISCUSSION

This chapter provides a discussion about the lessons learnt during the development and testing of an assessment tool designed to thoroughly assess physically limited workers to appropriately place them in their workplace, whilst at the same time limiting risk of injury or re-injury. Outlined in this chapter is the knowledge and experience gained during application in the case study context. The chapter goes on to highlight the usefulness and limitations of the tool, and recommended adaptations to improve the tool are suggested. Finally, the additions to existing knowledge provided by the development of the tool are presented.

5.1 LESSONS LEARNT DURING APPLICATION OF THE TOOL

The application of the assessment tool in the case study, highlighted that the tool was rather straight forward and easy to use. However, the case study also highlighted a number of aspects of the tool which seemed difficult during application.

One such aspect which was slightly difficult to deal with at the time of assessment was that the format of the tool did not allow for observation, measurement and recording of the varying postures, forces and time components of the different tasks performed by the worker. This was due to the number of different tasks involved in the identified worker's job description, as well as the irregularity of task performance and cycle time. Analysing tasks in an environment with set tact times for each process, such as a production line setting where the processes and cycles occur repetitively and for specified periods of time would likely have been easier.

However, in reality, physically limited workers are often given jobs which do not have set cycle times in order to reduce time pressure and thus strain on the worker. Additionally, physically limited workers may be placed on modified duty which again is not likely to involve set cycle times and processes, but rather varying times and alternating processes. Thus, the flexibility of the tool to record varying ranges of motion, as well as different force and time components for different task demands, allows application of the tool in environments that are typical for physically limited workers and attempt to accommodate altered physical capabilities.

In the case study performed, both photographic and video evidence was collected. In hindsight, the case study application proved that photographs are more suitable for

analysis by the tool than videos since it is easier to measure range of motion from photographs. With this in mind, it is highly recommended that photographic evidence of the extreme ranges of motion for each different task demand observed, is collected to allow thorough analysis of the task by the tool. Furthermore, it is also important to measure and record the varying forces manipulated to give a thorough description of the force components for each task demand. Using the tool to assess the worker was straightforward and easy to perform once the assessor was familiar with the goniometric guidelines (see Appendix 4: Goniometry guidelines), and procedures for measurement of force capabilities using a dynamometer.

Limitations of the case study

It is important to note that the aim of this pilot testing of the tool was not to evaluate the validity or efficacy, but to determine usability and applicability and highlight what needs to be altered to allow assessment of workers with different physical limitations and easy application in varying workplaces. Further testing of the tool will need to be performed to determine its reliability and validity in varying workplaces, with varying physical limitations.

5.2 CONSIDERATIONS AND NECESSARY ADAPTATIONS TO THE TOOL

The application of the tool revealed some limitations which were not initially apparent, as well as reiterating some limitations which were already known by the researchers.

Delimitations

As previously stated in Chapter 3, the initial form of the tool only allowed consideration of limitations to the lower back and hip in order to reduce the complexity of data collected. In order to allow the tool to be applied to a variety of physical limitations, the assessment process needs to be extended to the other joints of the body. Range of motion measurements, force quantification and analysis of time factors need to be described to allow full assessment of limitations affecting any joint, not limited to the lower back and hips.

Furthermore, although it was possible to use the tool in the case study context, in order to accurately determine and prove usability of the tool in a broader context, a usability criteria should be developed prior to further testing of the tool. Once the tool has been

used it should be compared to the criteria developed to determine whether it meets the pre-determined standards of usability.

Limitations of the tool

One limitation which was revealed was that, although the output of the tool is easy to understand and clearly highlights the tasks which place the worker at risk, in the current format the output still includes irrelevant information, namely the tasks which are not risky. Thus, a separate output sheet which only lists the problematic task demands and the components which place the worker at risk of injury (for example, hip flexion during building) is necessary to allow quicker and easier interpretation of the output. This selective output will further allow the assessor to quickly identify tasks which need additional assessment to determine whether adaptations can be made to assist worker performance.

In addition, a basic, clear and concise instruction manual needs to be developed in order to allow users who are not familiar with the tool to perform accurate assessments, without having to undergo extensive training before using the tool.

Furthermore, the tool requires the assessor to have some knowledge of the process of identifying and assessing job demands, as well as the understanding of human anatomy and movement characteristics. This is necessary to ensure that instructions given are correctly executed, and that the measurements and observations are done properly and accurately. Furthermore, the assessments need to be done safely, which requires the assessor to have some knowledge of acceptable human movement parameters, as well as how to deal with assessment of injured participants. The process of developing the tool attempted to consider this limitation and allow use by professionals who have some knowledge or experience in assessment of the workplace, for example Ergonomists, Occupational Health and Safety Experts, Doctors, Nurses, and Health and Wellness Practitioners.

Finally, a specific limitation of the tool exposed by the case study was that the tool does not allow for assessment of balance capabilities of the worker. In the case study, the worker reported that he was unable to perform carrying tasks because he is unstable on his prosthesis and does not have sufficient balance to carry heavy loads. Despite finding this balance limitation of the worker, the tool does not allow for further

assessment of actual balance capabilities of the worker in order to allow accurate prescription of tasks with respect to balance requirements. Modifications should be made to the tool to allow assessment of balance in order to provide a detailed and thorough assessment of all worker physical capabilities.

5.3 ADDITION TO KNOWLEDGE

This sub-section highlights the addition to knowledge provided by the tool. As previously described in (subsection 2.5.1) there are a number of job analyses which are commonly used to determine job requirements, movements, postures and motions involved in a job. However, these assessment tools are based on normative data which assumes normative functioning with no limitations. Similarly, there are a number of commonly used assessments to determine worker capabilities. Once again, these assessments and their interpretation tends to be based on normative data in which full functionality is assumed. The tool developed does not assume normality and allows for individualistic data to be collected and applied, based on the specific characteristics of the worker and the job being assessed.

To account for both the task demands and the worker capabilities, and to consider the physical limitations of the worker, the tool was developed based on the propositions by Bridger (2009) and Das and Sengupta (1996), which state that demands from the technological and environmental systems need to be weighed against capabilities of the user in order to achieve compatibility.

The development of MSDs has been linked to the relationships between a number of different factors such as external loads, organisational factors, that is how the job process is structured, and individual characteristics of the workers performing the tasks (Jezukaitis & Kapur, 2011; Karsh, 2006). Similarly, work station design (Das & Sengupta, 1996) and biomechanical components of a job (Aptel et al., 2002) have also been linked to development of MSDs if not appropriately set and controlled. Thus, it is important to try and assess all of the influencing factors when attempting to place a worker, particularly if the worker is already physically limited. In an attempt to address the number of influencing factors, the tool developed includes assessment of ROM, force components and time factors for both the worker and the job. Thus, the tool tries

to assess and match the factors and relationships which have been deemed important when dealing with MSDs and physical limitations in the workplace.

Since there are so many different anatomical structures that can be affected in a physical injury, such as tendons, ligaments, muscles and so on, (Occupational Safety and Health Administration, 2016), as well as varied and individualistic symptom presentation, the assessment tool was developed to consider physical limitations with any causation, affecting any structure in the body. The aim was to allow applicability of the tool in an assortment of workplaces, with a variety of individuals with diverse physical limitations.

To account for human variability in size and capability (Das & Sengupta, 1996) as well as to try and accommodate all possible presentations of physical disorder and work demands in the job setting (Chi, 1999; Karsh, 2006), the tool was developed in a way that will allow specific worker and task characteristics to be inputted into a general assessment framework which can process such varying data.

Physically limited employees commonly experience discrimination as the assumption is that their performance will be affected by their limitations (Chi, Pan, Liu & Jang, 2004). In an effort to reduce this discrimination, the tool was developed to address this problem, and allow appropriate placement of the worker in a role where their performance will not be affected. The tool considers both the task demands and worker capabilities (and limitations) and highlights the tasks which the worker has difficulty performing, therefore ensuring the worker and task are appropriately matched and able to meet the task demands based on their capabilities. In this way, the tool draws on the suggestions from Quagrain, Winter and Issa, (2014) that appropriate analysis can allow job modification or identification of alternative jobs which better suit the workers altered capabilities.

There tends to be an increased effect from physical injury in developing countries because of limited resources for prevention and treatment following an injury (Takala, 1998) so preventing injury is important. South Africa is an industrially developing country so it is likely that there are a large number and variety of hazards. The tool developed helps to easily identify these hazards in the marketplace so risk can be

reduced. Furthermore, the tool attempts to achieve appropriate placement and risk analysis to decrease risk of injury occurring in the first place.

The tool also attempts to keep workers in the workplace, and ideally in their current job maintaining their level of productivity. Thus, the worker will be able to maintain financial independence and feelings of usefulness and confidence (Helm et al., 1999). Similarly, the hope is that there will be less financial effects on the organisation due to loss of skill and the need to train replacement workers or alter workflow (Krause et al., 2001; Panel on Musculoskeletal Disorders and the Workplace, 2001).

In the same way, the tool allows companies to fulfil the Code of Good Practice on Key Aspects of Disability in the Workplace by appropriately accommodating workers who have acquired physical limitations (Merrill, n.d.). The pilot testing showed that the tool is useful for identifying areas of the job, which may require modification or accommodation to allow the worker to maintain productivity.

Comparing the existing literature with the results from the pilot testing has exposed aspects of research with physically limited workers which requires further attention and focus. This paper has provided substantial information for future research and development of a basic and standard tool, which can be used to perform accurate assessments of physically limited workers to ensure a correct fit in their workplace.

CHAPTER 6 – CONCLUSIONS AND RECOMMENDATIONS

6.1 SUMMARY OF DEVELOPING AND TESTING THE TOOL

An assessment tool was developed by combining and adapting information from various existing tools used to assess worker capabilities and task demands. A theoretical framework previously developed by Mattison and Goebel (2007) influenced the development of this tool which attempts to match physically limited workers with task demands.

Based on this framework, the process of developing the tool started with dividing the job into critical factors to determine physical requirements to perform the tasks. Similarly, to determine the physical capabilities of the worker, the anatomical demands of performing movements and adopting postures were defined. This was done by systematically considering the moveable joints of the human body from head to toe and compiling a list of all possible movements of these joints.

Knowing which physical movements are involved in performing each task demand is useful in ensuring that workers, who are physically limited, are not required to perform tasks that may place them at risk. Thus, each task demand was described by the anatomical movements necessary to perform them. To achieve bi-directionality between the task demands and the worker's movement capabilities, the impact of the task demands on physical capabilities was determined by defining each body movement in terms of the different physical demands that require that movement. This aspect is necessary since it allows for specific consideration of potentially risky tasks, based on the requirements of that task.

Based on the cube principle described by Almgren and Schaurig, (2012) assessment capabilities to determine range of motion, force and time components of the task, as well as the capabilities of the worker in these three aspects were incorporated into the tool. This was done to ensure full description of the task demands, as well as capabilities of the worker, not only to move but to manipulate force. Assessment of these aspects for both the task and the worker allows matching of the requirements of the task and the capabilities of the worker.

Once the tool was developed, it was necessary to test the tool for applicability and to determine if there were limitations in the tool which reduce usefulness in a workplace.

The pilot testing of the tool was done in a case study format. Once ethical clearance had been obtained, an organisation which employs workers with physical capabilities was approached to ask if they would be willing to let the tool be tested in their workplace. Written consent was obtained from the manager of the organisation, as well as the physical able and physically limited workers employed. A manual task was identified and the physically able workers who perform the task were photographed in order to determine task demands, range of motion requirements of the task, forces manipulated, as well as time components for different task requirements. Subsequently, a worker with physical limitations who performs different tasks to the physically able workers was identified. It was important for the physically limited worker to perform different tasks since the aim of the tool is to determine whether the physically limited worker could return to tasks performed prior to the injury, or to assume new tasks in a new position, despite their physical limitations. Range of motion and force manipulation capabilities of the physically limited worker were determined through assessment of the worker, based on the information required by the tool. Force capabilities were used to determine time capabilities based on the principles described by Demura and Nakada (2010).

Inputting the information collected during assessment into the tool developed showed that lower back flexion requirements of building and grounds upkeep, as well as hip flexion during collection of insects from the pools would place the worker at risk of injury or further injury. This increased risk is due to the task demands for range of motion for lower back and hip flexion being greater than the worker's capabilities. Application of an existing, validated ergonomics assessment tool confirmed the output of the tool since it determined that collecting bugs off pools placed the worker at high risk, demanding a need to investigate the worker's conditions and changes to reduce risk.

6.2 CONCLUSIONS

In conclusion, the tool developed was successful in providing an assessment process which considered the physical abilities and limitations of the worker, as well as the requirements of the task. The tool provided useful information to be used in the process of job assignment to allow appropriate placement of a physically limited worker, with limited risk but the possibility for continued productivity. Although some

aspects of the chosen job were determined to be risky, this information allows those aspects to be analysed further to determine whether accommodations can be provided to allow the worker to perform safely. If accommodations do not reduce the risk, another job may need to be identified for the worker.

6.3 RECOMMENDATIONS FOR FURTHER RESEARCH

Further testing of the tool will need to be performed to determine its reliability and validity in varying workplaces, with varying physical limitations.

LoBiondo-Wood and Haber (2014) define reliability as the ability of an instrument to measure a variable consistently. There are two types of reliability which are important for this tool. The first is known as test-retest reliability (LoBiondo-Wood & Haber, 2014). An instrument is said to have test-retest reliability if it gives the same results on repeated occasions, that is, it will give the same results on the test and the retest. Since the tool was only pilot tested on one occasion, it is important to determine whether the tool would produce the same output in the same testing conditions, if the test was repeated on a different day. The second type of reliability important for this tool is known as inter-rater reliability (LoBiondo-Wood & Haber, 2014). An instrument is said to have inter-rater reliability if the tool provides the same results for different assessors. Since the pilot testing of the tool was done by the researcher involved in development of the tool, it is important to determine whether different assessors obtain the same results from the tool.

Validity has been defined as the extent to which an instrument measures the different aspects of a concept accurately (LoBiondo-Wood & Haber, 2014). As with reliability, there are two different types of validity which need to be determined for this tool. The first is known as criterion-related validity which relates to the extent to which the results of the tool reflect the actual behaviour of the subject being assessed (LoBiondo-Wood & Haber, 2014). Testing criterion-related validity for the tool developed is essential since it is important that the tool accurately reflects both the actual task demands assessed, as well as the actual physical capabilities and limitations of the worker being placed. Measuring criterion-related validity will also determine the performance of the new tool compared to the performance of existing tools which have been proven to be a valid measure of tasks and workers (LoBiondo-Wood & Haber, 2014).

The second type of validity which needs to be determined is known as construct validity (LoBiondo-Wood & Haber, 2014). This validity determines the extent to which an instrument measures a theoretical construct by validating the underlying theory of the instrument (LoBiondo-Wood & Haber, 2014). Since the tool was developed from an existing theoretical framework, it is important to determine whether the tool has accurately translated the theoretical framework into an assessment process.

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APPENDICES

APPENDIX 1: EXAMPLE OF COMMON JOB ANALYSIS TOOL – RAPID ENTIRE BODY ANALYSIS (REBA)

REBA Employee Assessment Worksheet

Based on Technical note: Rapid Entire Body Assessment (REBA), Hignett, McAtamney, Applied Ergonomics 31 (2000) 201-205

A. Neck, Trunk and Leg Analysis

Step 1: Locate Neck Position

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

Step 2: Locate Trunk Position

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

Step 3: Legs

 Adjust: 30-60° +1, 60° +2

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

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

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

Scoring:
 1 = negligible risk
 2 or 3 = low risk, change may be needed
 4 to 7 = medium risk, further investigation, change soon
 8 to 10 = high risk, investigate and implement change
 11+ = very high risk, implement change

SCORES

Table A: Neck

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

Table B: Lower Arm

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

Table C

Score A (score from table A + load/force score)		Score B (table B value + coupling score)											
		1	2	3	4	5	6	7	8	9	10	11	12
1	1	1	1	1	2	3	3	4	5	6	7	7	7
2	1	2	2	3	4	4	5	6	6	7	7	8	8
3	2	3	3	3	4	5	6	7	7	8	8	9	9
4	3	4	4	4	5	6	7	8	8	9	9	9	9
5	4	4	4	5	6	7	8	8	9	9	9	9	9
6	5	5	5	6	7	8	8	9	9	10	10	10	10
7	7	7	7	8	9	9	9	10	10	11	11	11	11
8	8	8	8	9	10	10	10	10	10	11	11	11	11
9	9	9	9	10	10	10	11	11	11	11	12	12	12
10	10	10	10	11	11	11	11	11	12	12	12	12	12
11	11	11	11	11	12	12	12	12	12	12	12	12	12
12	12	12	12	12	12	12	12	12	12	12	12	12	12

Step 7: Locate Upper Arm Position:

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

Step 8: Locate Lower Arm Position:

Step 9: Locate Wrist Position:

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

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

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

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

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

Table C Score + Activity Score = Final REBA Score

Task name: _____ Reviewer: _____ Date: ____/____/____ provided by Practical Ergonomics
 This tool is provided without warranty. The author has provided this tool as a simple means for applying the concepts provided in REBA. © 2004 REBA Consulting, Inc. rbarner@ergosmart.com (516) 444-1667

APPENDIX 2: EXAMPLE OF A COMMONLY USED FUNCTIONAL CAPACITY EVALUATION – NORDIC QUESTIONNAIRE

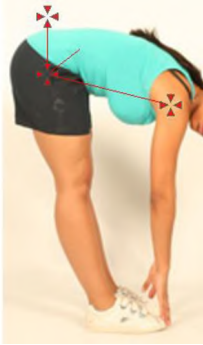

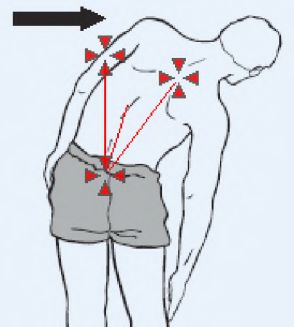

Standardised Nordic questionnaire (Kuorinka I. et al. 1987).




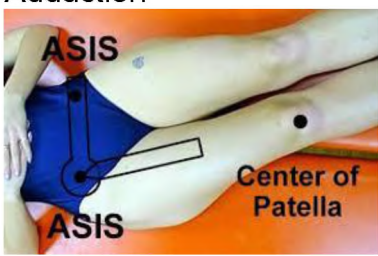
To be answered by everyone	To be answered only by those who have had trouble	
Have you at any time during the last 12 months had trouble (ache, pain, discomfort) in:	Have you at any time during the last 12 months been prevented from doing normal work (at home or away from home) because of the trouble?	Have you had trouble at any time during the last 7 days?
Neck No <input type="checkbox"/> Yes <input type="checkbox"/>	No <input type="checkbox"/> Yes <input type="checkbox"/>	No <input type="checkbox"/> Yes <input type="checkbox"/>
Shoulders 1 <input type="checkbox"/> No 2 <input type="checkbox"/> Yes, in the right shoulder 3 <input type="checkbox"/> Yes, in the left shoulder 4 <input type="checkbox"/> Yes, in both shoulder	No <input type="checkbox"/> Yes <input type="checkbox"/>	No <input type="checkbox"/> Yes <input type="checkbox"/>
Elbows 1 <input type="checkbox"/> No 2 <input type="checkbox"/> Yes, in the right elbow 3 <input type="checkbox"/> Yes, in the left elbow 4 <input type="checkbox"/> Yes, in both elbows	No <input type="checkbox"/> Yes <input type="checkbox"/>	No <input type="checkbox"/> Yes <input type="checkbox"/>
Wrist / Hand 1 <input type="checkbox"/> No 2 <input type="checkbox"/> Yes, in the right wrist / hand 3 <input type="checkbox"/> Yes, in the left wrist / hand 4 <input type="checkbox"/> Yes, in both wrist / hand	No <input type="checkbox"/> Yes <input type="checkbox"/>	No <input type="checkbox"/> Yes <input type="checkbox"/>
Upper Back No <input type="checkbox"/> Yes <input type="checkbox"/>	No <input type="checkbox"/> Yes <input type="checkbox"/>	No <input type="checkbox"/> Yes <input type="checkbox"/>
Low Back (Small of the back) No <input type="checkbox"/> Yes <input type="checkbox"/>	No <input type="checkbox"/> Yes <input type="checkbox"/>	No <input type="checkbox"/> Yes <input type="checkbox"/>
One or both hips / thighs No <input type="checkbox"/> Yes <input type="checkbox"/>	No <input type="checkbox"/> Yes <input type="checkbox"/>	No <input type="checkbox"/> Yes <input type="checkbox"/>
One or both knees No <input type="checkbox"/> Yes <input type="checkbox"/>	No <input type="checkbox"/> Yes <input type="checkbox"/>	No <input type="checkbox"/> Yes <input type="checkbox"/>
One or both ankles / feet No <input type="checkbox"/> Yes <input type="checkbox"/>	No <input type="checkbox"/> Yes <input type="checkbox"/>	No <input type="checkbox"/> Yes <input type="checkbox"/>

APPENDIX 3: FULL LIST OF TASK DEMANDS

Body posture	Standing upright - free	Reaching	Both hands/one hand
	Standing upright - supported		Both arms/one arm
	Standing upright - in front of table		Whole body
	Standing bent over/Stooping		In front
	Sitting upright - free		To side
	Sitting upright - supported		Behind
	Sitting bent over		Above shoulder level/overhead one arm
	Squatting		Above shoulder level/overhead both arms
	Kneeling on one/both knees	Screwing/ winding	Fingers only
	Walking		Hand and wrist
	Twisting - standing		Lower arm
	Twisting - seated		Whole arm
	Lying prone		Whole body
	Lying supine	Object manipulation	lower arm only
	Seated on reclined chair		wrist only
	Seated on swivel chair		hand only (grip)
Head	Forward		fingers only
	Up	Pushing/ Pulling	standing
	Down		walking
	Bent to side		seated
	Twisted to side		arms only
Carrying	with hands only		legs only
	on back		feet/foot only
	on front		whole body
	on side		

APPENDIX 4: GONIOMETRY GUIDELINES

	<p>Flexion</p> 	<p>Starting position: Subject stands upright with feet hip width apart, knees straight and arms hanging down by the side.</p> <p>Testing motion: The trunk is bent forwards as far as possible without tipping the pelvis forwards, keeping the feet flat.</p> <p>Starting measurement: Mark a line that connects the two posterior superior iliac spines (PSISs), and a point on the spinous process 15cm above the PSIS line.</p> <p>Range of motion: The difference between the distance from the line to the point at the starting position and the end position.</p>
Lumbar	<p>Extension</p> 	<p>Starting position: Subject stands upright with feet hip width apart, knees straight and arms hanging down by the side.</p> <p>Testing motion: The trunk is bent backwards as far as possible without tipping the pelvis back, keeping the feet flat.</p> <p>Starting measurement: Mark a line that connects the two posterior superior iliac spines (PSISs), and a point on the spinous process 15cm above the PSIS line.</p> <p>Range of motion: The difference between the distance from the line to the point at the starting position and the end position.</p>
	<p>Lateral flexion</p> 	<p>Starting position: Subject stands upright with feet hip width apart, knees straight and arms hanging down by the side.</p> <p>Testing motion: The trunk is bent sideways as far as possible without tipping the pelvis to the side, keeping the feet flat.</p> <p>Axis alignment: S1 spinous process (between the PSISs).</p> <p>Range of motion: From vertically up from the axis at the starting position to in line with C7 at the end position.</p>
	<p>Rotation</p> 	<p>Starting position: Subject is sitting with knees bent and feet crossed, hips facing forwards and arms crossed across the chest. A rod can be held across the chest for easy indication of the shoulder position. Mark the starting position on the floor directly down from the acromion process (in line with the rod).</p> <p>Testing motion: The trunk is twisted to the side as far as possible without bending forwards or backwards, or tipping the pelvis forwards, while keeping the knees facing forwards and feet flat. Mark the end position on the floor directly down from the acromion process (in line with the rod).</p>

		<p>Axis alignment: On the floor directly under the middle of the seated position.</p> <p>Range of motion: From the marked starting position of the shoulder to the marked end position of the shoulder.</p>
Hip	<p>Flexion</p> 	<p>Starting position: Subject stands upright with feet hip width apart and knees straight.</p> <p>Testing motion: The leg is lifted up in front of the body as high as possible. The knee is allowed to bend.</p> <p>Axis alignment: Greater trochanter of the femur.</p> <p>Range of motion: From the vertical of the thigh at the starting position to the final position of the femur.</p>
	<p>Extension</p> 	<p>Starting position: Subject stands upright with feet hip width apart and knees straight.</p> <p>Testing motion: The leg is lifted up behind the body as far as possible. Keep the knee straight throughout.</p> <p>Axis alignment: Greater trochanter of the femur.</p> <p>Range of motion: From the vertical of the thigh at the starting position to the final position of the femur.</p>
	<p>Abduction</p> 	<p>Starting position: Subject stands upright with feet hip width apart and knees straight.</p> <p>Testing motion: The leg is lifted laterally away from the other leg, keeping the foot facing forwards and the leg in line with the body (no flexion or extension).</p> <p>Axis alignment: Anterior superior iliac spine (ASIS).</p> <p>Range of motion: From the horizontal in line with the left and right ASISs to the final position of the femur.</p>
	<p>Adduction</p> 	<p>Starting position: Subject lies supine with both legs straight, feet pointing upwards, and one leg abducted enough to allow adduction of the other leg.</p> <p>Testing motion: The leg is moved towards the abducted leg as far as possible without moving the hips or spine.</p> <p>Axis alignment: Anterior superior iliac spine (ASIS).</p> <p>Range of motion: From the horizontal in line with the left and right ASISs to the final position of the femur.</p>

Hip flexion and extension measurement procedures were adapted from testing procedures outlined by Norkin and White (2003), while lumbar flexion and extension were adapted from procedures described by Reese and Bandy (2010). According to these authors, it is important to note that since total vertebral column range of motion is an accumulation of the small amount of movement that occurs at each intervertebral articulation, overall range of flexion or extension of the lower back is measured.

The procedures described in literature tend to be absolute, medical procedures designed to reduce effort of the movement. In order to allow appropriate representation of the joint movements and demands during work processes, the procedures have been adjusted to allow measurement to be taken in a posture similar to that generally adopted in the workplace in an attempt to produce results that are as realistic as those seen during performance of the task at work.

APPENDIX 5 – ETHICAL CLEARANCE



RHODES UNIVERSITY
Where leaders learn

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10-Nov-2016

Dear Jessie Pearson,

Ethics Clearance: Appropriate integration of workers with physical limitations into a manual workplace

Principal Investigator: Jessie Pearson

This letter confirms that a research proposal with tracking number: RU-HSD-16-09-0009 and title: **Appropriate integration of workers with physical limitations into a manual workplace** was given ethics clearance by the Rhodes University Ethical Standards Committee pending attention to the following:

The ethics protocol is approved on the following stipulations:

That information regarding the researcher making a commitment to assist with access to a medical practitioner be included in the informed consent forms and the information letter, as well as in the document on risks and benefits.

The risk and benefits document states that "if they would like feedback to be given to the employer in an attempt to improve worker safety and comfort. If the participant is happy to continue performing the tasks with no interventions then the organisation will not be informed of the misfit between worker and task. However, a waiver will be signed by the worker to remove all legal obligations on the researchers to report risks in the workplace".

This possibility must be included in the informed consent forms for both the organisation and the participants.

Please contact the Ethics Committee for clarification of the stipulations, if deemed helpful.

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 completion of the research. The purpose of this report is to indicate whether or not 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.

Yours Sincerely,

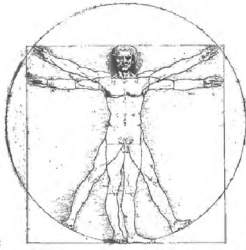
A handwritten signature in blue ink, appearing to read 'J. Marx', is written over a light blue horizontal line.

Dr J. Marx: Chairperson RUEESC.

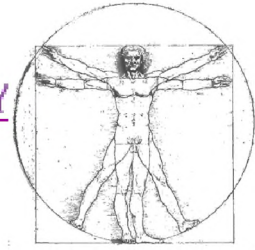
Note:

1. This clearance is valid from the date on this letter to the time of completion of data collection.
2. The ethics committee cannot grant retrospective ethics clearance.
3. Progress reports should be submitted annually unless otherwise specified.

APPENDIX 6: INFORMATION TO THE ORGANISATION



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INFORMATION TO THE ORGANISATION

Dear Sir/Madam,

Thank you for agreeing to be involved with my Masters Research project. Your help is greatly appreciated and I hope your organisation can benefit from the knowledge gained in the process. This letter explains the project and also what your worker can expect as they take part in the testing process.

The Masters project is called:

**“APPROPRIATE PLACEMENT OF WORKERS WITH PHYSICAL LIMITATIONS IN A
MANUAL WORKPLACE”**

If you have any questions or need me to explain a point you do not understand, please do not hesitate to contact me.

Background to the study

Research has shown that people who are physically impaired often get discriminated against. One of the reasons is that co-workers and supervisors think the work performance of the injured person will be affected by the physical impairment (Chi et al., 2004). After an injury, it is important for the worker to be able to return to work so they can continue being productive and have financial independence. It is also important to make sure they are protected from re-injury or further injury.

Research aim

My research aims to develop and test an analysis tool which will make it possible to properly assess a worker, who has been injured, and make sure they are correctly placed in their workplace and the risk of injury or re-injury is reduced.

To achieve this aim, I will try to answer the following questions:

1. What are the important things to consider when assessing an impaired employee so that they can be correctly placed in a manual workplace?
2. Can an assessment tool, which considers the specific physical impairment, and specific task demands, be used to correctly place a physically impaired worker in a manual workplace?

Importance of the study

Research has shown that there are high numbers of injuries in the workplace in industrially developed countries. Since South Africa is still developing industrially, and still has a large population of manual workers, it is possible that it will have a large number of physically limited workers due to injuries. These limitations usually come from high workloads and poor workspace designs. By doing this study, I hope to come up with a useful tool, which will make sure a worker is correctly fitted to their workspace so that they are not only producing at their highest level, but that they are safe and have a low risk of further injury or re-injury.

Testing procedure

The reason your organisation has been selected for my project testing is because you employ workers who are physically impaired, and the work done by your organisation has a large manual component.

The testing will start with using the tool that I developed to assess a worker with no injuries, who is doing a job which involves movement of mostly the lower back and hips. The reason for this is to see what postures and movements they use to do the task.

Next, I will assess a physically impaired worker's movement capabilities and limitations and compare these with the movement demands of the job assessed to see if they would be able to safely do the job. I will require a private room, at your workplace, to carry out the assessment. The reason being that it is very important for privacy and confidentiality of the worker be protected.

General information to help your worker prepare for the testing exercise:

What to wear: They can wear normal work clothes, provided it allows them to do the tasks they would usually do at work. If they are a lady, because some exercises are going to involve lifting their legs, it may be better to wear trousers for the testing. All the testing will be done with their clothes on.

How long it will take: The assessment should not take longer than 90 minutes, and I will mention to your worker that you are aware they are taking part in the research so you know they are not just missing work.

Steps we will follow during the testing:

Step 1: I will ask the worker some easy questions about their injury, for example:

1. When did the injury happen?
2. Has the injury affected their movements and how?
3. Have they had any treatment for the injury?
4. Do they have any other injuries at the moment?

Step 2: I will then measure the movement of their hips and back by asking them to bend forwards and backwards, as well as lifting their legs up in front of them and behind. These movements may cause some pain if the injury has affected their movement, but as soon as they feel pain or discomfort, they will be instructed to let me know. We will then see how we can carry on the test and finish it without causing further unnecessary pain or discomfort to them.

Step 3: If the task being assessed involves moving a load, they will be asked to do a force production test. These will be exercises like those done in step 2 above. Once again, if they experience unbearable pain during the test, they will let me know and we will see how we can carry on the test and finish it without causing further pain or discomfort.

Step 4: After the exercises, I will enter the information from step 2 into the analysis tool and check to see if their movement capabilities, and what the job requires, are similar and do not put them at increased risk of injury or further injury. This is an important step as the information will be helpful to make sure the worker and their workstation are well matched so they can continue to be productive in their workplace.

Step 5: I will do a final assessment while they actually perform the job I assessed. The reason for this is to see if it would be suitable for them to do that job, even with their injury. This step is just to confirm that the information from the tool I developed, and used to do the test, actually works.

Risks

Because of the kind of project I am doing and the testing methods I use, the worker may feel some pain and discomfort during the assessments. This is necessary because we will need to test their body somewhat, in order to get correct information about their abilities and limits (for example, how much movement they have in their back etc.). For the testing to be successful, it is very important for them to **tell me as soon as they feel pain or discomfort** – even if it means that we stop the exercise straight away to avoid further injury.

Benefits

There are huge benefits of doing the testing.

To the worker personally: They will be given a report of what I find during the assessment. This will help them to know if there are any limitations they can try to work on to improve their performance, as well as reduce discomfort from stiffness and pain. This will allow them to continue performing well at work and continue to have financial independence. Although this research may provide minimum benefit to them directly, since it is just the start of a long research process, it will provide useful information for research to help other injured workers in the future.

To physically impaired workers in general: This research will help us gather information in a real life case study, which will give us very useful information that will help make good decisions when placing injured workers, in suitable jobs. It also gives us the opportunity to test a tool, which may help correctly place other physically impaired workers in their workplace.

To you as an organisation: You will have a reputation for your invaluable assistance in partnering in research programmes which seek to develop solutions to, not only reduce injuries in the work place, but appropriately place impaired workers in the workplace. The testing opportunity, made possible by your organisation, may eventually allow us to work together with other organisations to come up with solutions for appropriate placement of physically impaired workers in the workplace, whilst reducing injury and re-injury.

Please note:

We will assure your worker right up front, that:

1. While you have given us permission to approach them and ask for their help with the testing, the project is completely independent from the company.
2. Their involvement is completely voluntary and they are free to withdraw from the testing at any stage. However, I would really appreciate it if they could continue to the end.
3. They cannot fail this test and because they are not needing to move jobs, the assessment will not have an effect on their current work status and they will not need to change positions in the company. The assessment is purely for research purposes so any response they give is acceptable.
4. Their choice to take part or not take part, will not negatively affect their job or employment status in anyway.
5. All information collected during the testing will be kept confidential. Not even their company will see it.
6. Their name will never be used in any of our reports.
7. All videos or photographs taken will be edited so no one recognises them, and the footage will be used only for analysis purposes.
8. Findings of this research may be referenced in future studies for the purpose of extending the knowledge, but confidentiality will always be maintained at all times.

Thank you in advance for agreeing to assist with my project. Please do not hesitate to contact me (details below) if you have any concerns, questions or just need to chat about the project.

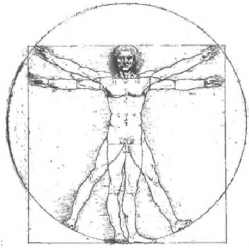
Yours sincerely,

Jessie Pearson

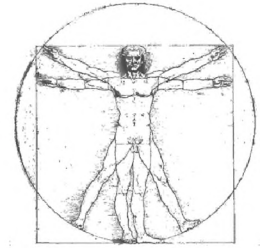
Principal researcher
079 486 7916
g10p0143@campus.ru.ac.za

Supervisor:
Swantje Zschernack
s.zschernack@ru.ac.za

APPENDIX 7: ORGANISATION - INFORMED CONSENT



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Human Kinetics and Ergonomics Department

I, have authority to provide consent on behalf of my organization and have been fully informed of the research project entitled;

“APPROPRIATE PLACEMENT OF WORKERS WITH PHYSICAL LIMITATIONS IN A MANUAL WORKPLACE”

All testing procedures, associated risks and the benefits from taking part in this study have been verbally explained to me as well as in writing. I have had ample opportunity to ask questions and to clarify any concerns or misunderstandings. I am satisfied that these have been answered satisfactorily.

- I consent for the researcher to recruit participants from among the employees under my supervision.
- I consent for the research to be conducted on the property.
- I consent to having videos and/or photographs taken of the workers, knowing that these will be altered to ensure anonymity of the workplace and the worker, and on the condition that the worker has given consent in this regard.
- I give permission to the researchers to perform relevant measurements on the workers, on the condition that the worker has given consent in this regard, and understanding that the measurements will be done as quickly as possible to ensure as little disruption to the work process as possible.
- I understand that this research requires no effort from the organization, but that the worker is required to take time out of their work schedule to participate (maximum 90minutes). I give consent in this regard, provided that proof can be given to show that the worker was participating in the study and not just absent from work.
- I agree that participation in the study is completely voluntary for the worker and there will be no negative consequences should the worker decline to participate.
- I agree that the results of the study will not negatively impact the workers standing within the organization and will not disadvantage them in any way.

I have read and understood the above information, as well as the information provided in the letter accompanying this form. I therefore allow this research project access to the workers and work processes in my organization.

Waainek supervisor:

_____	_____	_____
(Print Name)	(Signed)	(Date)

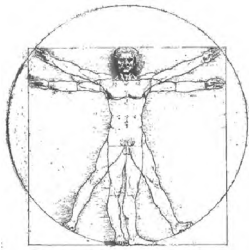
Research supervisor at Waainek:

_____	_____	_____
(Print Name)	(Signed)	(Date)

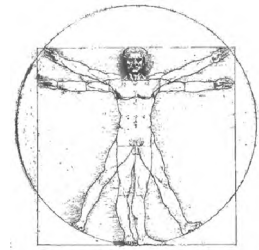
Principal researcher:

_____	_____	_____
(Print Name)	(Signed)	(Date)

APPENDIX 8: 'APPARENTLY HEALTHY' WORKER - INFORMED CONSENT



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I, have been fully informed of the research project entitled;

“Appropriate PLACEMENT of workers with physical limitations in a manual workplace”

All testing procedures, associated risks and the benefits from taking part in this study have been verbally explained to me as well as in writing. I have had ample opportunity to ask questions and to clarify any concerns or misunderstandings. I am satisfied that these have been answered satisfactorily.

- I consent to having videos and/or photographs taken, given that these will be altered to ensure my anonymity.
- I give permission to the researchers to perform relevant measurements on me, and understand that these measurements will be taken in a professional manner. I understand that if I am uncomfortable at any point in the process I can request cessation of the measurements.
- I give permission for my information to be used in publications and/or future research projects, provided that anonymity and confidentiality is maintained.
- I waive any legal recourse against the researchers from the Department of Human Kinetics and Ergonomics (HKE) at Rhodes University, from claims resulting from personal injuries sustained whilst participating in the above mentioned research. I am aware and fully understand that the Department of Human Kinetics and Ergonomics is not responsible for any injuries due to my personal negligence and non-compliance with instructions. This waiver shall be binding upon my heirs and personal representatives.
- I understand that I am able to withdraw from the study at any point, irrespective of external influences placed on me by the researcher, and that my performance (or lack thereof) will not affect my position in the workplace.

I have read and understood the above information, as well as the information provided in the letter accompanying this form. I therefore consent to voluntarily participate in this research project.

Participant providing consent:

_____	_____	_____
(Print Name)	(Signed)	(Date)

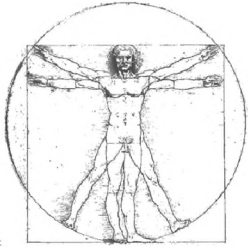
Witness:

_____	_____	_____
(Print Name)	(Signed)	(Date)

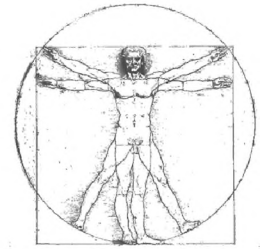
Principal researcher:

_____	_____	_____
(Print Name)	(Signed)	(Date)

APPENDIX 9: PHYSICALLY LIMITED WORKER - INFORMED CONSENT



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I, have been fully informed of the research project entitled;
“APPROPRIATE PLACEMENT OF WORKERS WITH PHYSICAL LIMITATIONS IN A MANUAL
WORKPLACE”

All testing procedures, associated risks and the benefits from taking part in this study have been verbally explained to me as well as in writing. I have had ample opportunity to ask questions and to clarify any concerns or misunderstandings. I am satisfied that these have been answered satisfactorily.

1. I consent to having videos and/or photographs taken, given that these will be altered to ensure my anonymity.
2. I give permission to the researchers to contact my medical professional (Name _____) to gain access to my medical records related to the injury relevant to this study.
3. I am not currently under the care of a medical practitioner and give the researchers permission to put me in contact with a medical practitioner to help address any findings of pain or discomfort.
4. I give permission to the researchers to perform relevant measurements on me, and understand that these measurements will be taken in a professional manner. I understand that if I am uncomfortable at any point in the process I can request cessation of the measurements.
5. I give permission for my information to be safely stored and used in publications and/or future research projects conducted by other researchers, provided that anonymity and confidentiality is maintained.
6. I waive any legal recourse against the researchers from the Department of Human Kinetics and Ergonomics (HKE) at Rhodes University, from claims resulting from personal injuries sustained whilst participating in the above mentioned research. I am aware and fully understand that the Department of Human Kinetics and Ergonomics is not responsible for any injuries due to my personal negligence and non-compliance with instructions. This waiver shall be binding upon my heirs and personal representatives.
7. I understand that I am able to withdraw from the study at any point, irrespective of external influences placed on me by the researcher, and that my performance (or lack thereof) will not affect my position in the workplace.

I have read and understood the above information, as well as the information provided in the letter accompanying this form. I therefore consent to voluntarily participate in this research project.

Participant providing consent:

_____	_____	_____
(Print Name)	(Signed)	(Date)

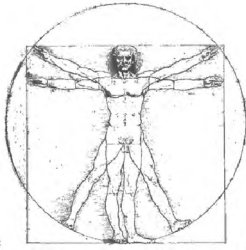
Witness:

_____	_____	_____
(Print Name)	(Signed)	(Date)

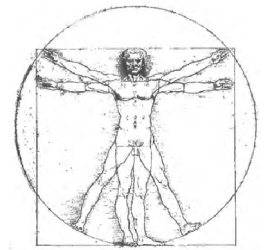
Principal researcher:

_____	_____	_____
(Print Name)	(Signed)	(Date)

APPENDIX 10: PARTICIPANT FEEDBACK



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Jessie Pearson (Master's candidate)

jessietp@gmail.com – cell: 079 486 7916

***Human Kinetics and Ergonomics Department, Rhodes University,
Grahamstown***

Dear Participant,

Thank you for participating in my research project titled “**Appropriate integration of workers with physical limitations into a manual workplace**”. As explained to you before you participated, the aim of the research was to develop and test an analysis tool which will make it possible to properly assess a worker, who has some physical limitations, and make sure they are correctly placed in their workplace, to reduce the risk of injury while still allowing them to perform at work.

It is important for a worker to be able to return to work so they can continue being productive and have financial independence. It is also important to make sure they are protected from re-injury or further injury.

During the assessment I measured a number of things, including of range of motion and force. The results obtained are summarized and explained below.

Range of motion

We tested range of motion of your hips and lower back. Results are shown in Table 16 below.

Table 16: Range of motion (ROM) of the hips and back

Movement	ROM (degrees)	
	Left	Right
Hip flexion	94	55
Hip extension	44	20
LB lateral flexion	51	50
LB rotation	84	84
LB flexion	106	
LB extension	44	

Both flexion and extension of the left leg were greater than the right. This is to be expected since it is likely that you favour your left leg to take pressure and strain off your right leg. Range of motion for the movements of the back was similar on both sides. This suggests that your amputation has not affected movement of your back as much as movement of your hips and legs. Since the range of motion measured is active range of motion (you did the movements yourself), it does not necessarily show the full range of motion since it depends on the strength of your muscles and you had to move against gravity. If range of motion was tested by the researcher performing the movements (for example moving your leg for you) the results may have been different, and would show the flexibility of the joints and muscles more than your movement capabilities.

Strength

Muscle strength when lifting was measured for your back and hips. You were able to lift 41.5kg. This is less than what is expected for men your age (101-120kg). This could be due to the fact that you have not been lifting heavy loads because of your prosthesis. You reported feeling unstable when lifting and carrying heavy loads, so your lifting strength is not being trained on a regular basis. Based on your current job, your lifting strength is fine since there is no need for you to be able to lift heavy loads.

Once again, thank you for helping me with my studies. If you have any questions, please contact me on jessietp@gmail.com.

Yours Sincerely,

Jessie Pearson - Researcher

Swantje Zschernack - Supervisor

APPENDIX 11: EXAMPLES OF ANGLE MEASUREMENTS





d)



e)

Figure 10: a) Measurement of hip flexion from leg vertical (162.7degrees), b) Measurement of back flexion from trunk vertical (73.5 degrees), c) Measurement of trunk rotation from trunk horizontal (32.3 degrees), d) Measurement of trunk lateral flexion from trunk vertical (11.1 degrees), e) Measurement of trunk extension from trunk vertical (6.2 degrees)