ERGONOMIC HAZARDS TO MEAT INSPECTORS AT SELECTED HIGH THROUGHPUT RED MEAT ABATTOIRS IN THE WESTERN CAPE

by

WILLIAM NORMAN JEPHTAS

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Supervisor: Prof. J.P. Odendaal
Co-supervisor: Prof. I.S. Human

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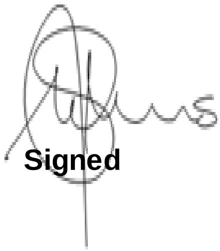
DECLARATION

I, William Norman Jephtas, declare that the contents of this thesis represent my own unaided work, and that the thesis has not previously been submitted for academic examination towards any qualification. Furthermore, it represents my own opinions and not necessarily those of the Cape Peninsula University of Technology.



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Signed **Date**

ABSTRACT

Abattoirs play a pivotal role in the meat value chain and performs the fundamental function of converting livestock into meat. During the early 1990s the country's new socio-economic policies ushered in the deregulation of the meat industry and the privatization of meat inspection services. As a result, the independence of meat inspection at abattoirs were seriously under threat. As the local abattoir environment changed, so did the working environment and the conditions under which meat inspectors performed their duties. The aim of this study was to evaluate the presence, the effects, and the prevalence of ergonomic hazards to meat inspectors at selected high throughput red meat abattoirs in the Western Cape. The objectives of this study were to: (a) identify the type of ergonomic hazards that may be present within the working environment of meat inspectors, (b) evaluate the perceived effects that these hazards may have on meat inspectors, (c) assess the prevalence and the impact of these hazards to meat inspectors, and (d) identify potential barriers or opportunities that the abattoir industry may face in addressing ergonomic hazards within this sector.

The selection of abattoirs comprised of single, double, and triple species plants. Apart from the design and layout of each facility, the conditions under which meat inspectors performed their duties varied considerable from abattoir to abattoir. The sample population consisted of ten abattoirs, at least one manager at each of the selected abattoirs (except for abattoirs D_2 and I_3 where two managers per facility participated), all the inspectors, and four representatives from industry. The study used structured questionnaires, semi-structured interviews, and direct participant observations (using photographs and video clip recordings) to obtain the relevant information. The photographs and video clips were used to conduct secondary assessments using the Rapid Entire Body Assessment (REBA) tool.

The outcomes of the study highlighted that a number of ergonomic hazards exist within the work environment of meat inspectors. These include repetitive work, the use of hand tools, working with the hands, arms, and shoulders in elevated positions, and inadequate working areas that gave rise to inspectors adopting awkward working postures. Consequently, the lack of effectiveness of job or task rotation programmes, including inadequate rest or recovery breaks further contributed to the occurrence of these risk factors.

The study aims to contribute to a greater understanding of the role and importance of ergonomic hazards to meat inspectors. The study further provides a platform for stakeholders (i.e., abattoirs, service providers, and government) to engage and continuously strive to address and reduce the effects and impact of ergonomic hazards within the local red meat abattoir industry.

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- Above all, to my Creator for giving me the strength, wisdom, and knowledge to complete the research.

DEDICATION

I dedicate this dissertation to my parents and my family. To my father, the late William Stephanus Jephtas (1945 - 2016) thank you for believing in me. To my mother, the late Catherine Louisa Jephtas (1950 - 2023) thank you for always being a source of strength. Your motherly care and support were shown in many ways. To my wife Ilene, your partnership, steadfastness, and love sustain me.

“יפתח”

“Belief in yourself, find peace within, prosper in what you do and be content”.

GLOSSARY

Terms/Acronyms/Abbreviations	Definition/Explanation
AM	Ante-mortem
CIEHF	Chartered Institute of Ergonomics and Human Factors
CTD	Cumulative Trauma Disorder
CTS	Carpal Tunnel Syndrome
DALRRD	Department of Agriculture, Land Reform, and Rural Development
DoL	Department of Labour
EASP	Externally Applied Surface Pressure
HSE	Health and Safety Executive
HT	High Throughput
IEA	International Ergonomics Association
IMI	Independent Meat Inspection
ILO	International Labour Office
ILO	International Labour Organisation
ISO	International Standards Organization
LT	Low Throughput
MI	Meat Inspector
ME	Meat Examiner
MSD	Musculoskeletal Disorder
NAMC	National Agricultural Marketing Council
NEO	National Executive Officer
OHS	Occupational Health and Safety
OIE	Organisation International des Epizooties
PEO	Provincial Executive Officer
PM	Post-mortem
RMAA	Red Meat Abattoir Association
RT	Rural Throughput

WCG	Western Cape Government
WHO	Word Health Organisation
WRMSD	Work-related Musculoskeletal Disorder
WRULD	Work-related upper limb disorder

Definitions

Abattoir means a slaughter facility in respect of which a registration certificate has been issued in terms of section 8(1) and in respect of which a grading has been determined in terms of section 8(2) of the Meat Safety Act (South Africa, 2004).

Abduction means the movement of a limb or body part away from the centre or mid-line of the body (Davis, 2019).

Adduction means the movement of the body part towards the centre or mid-line of the body (Davis, 2019).

Animal means any animal referred to in Schedule 1 of the Meat Safety Act (South Africa, 2004).

Animal product means any by-product obtained from the carcass of an animal other than the meat thereof (South Africa, 2004).

Ante-mortem inspection means the inspection of animals prior to slaughter (Van Zyl, 1995).

Assignee means any person, undertaking, body, institution, or association designated under section 4 of the Act (South Africa, 2004).

Carcass means the dressed carcass derived from an animal after the hide or skin (or hair in the case of pigs), the entrails, the pluck, the shanks, and head (in the case of cattle, sheep, goat), the tail (in the case of cattle), the diaphragm, and lactating udders have been removed (South Africa, 2004).

Department means the Department of Agriculture, Land Reform and Rural Development in the National Government (South Africa, 2004).

Dressing means the progressive separation, in the dressing room or area, of an animal into a carcass (or sides of a carcass), other edible parts and inedible material (South Africa, 2004).

Dressing room means a room or area, separate from the bleeding room or area, where a carcass is dressed by removing the feet, head and skin, and evisceration is done (South Africa, 2004).

Ergonomics means the scientific discipline concerned with the fundamental understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data, and methods to design in order to optimise human well-being and overall system performance (South Africa, 2019).

Ergonomic risk means a characteristic or action in the workplace, workplace conditions, or a combination thereof that may impair overall system performance and human well-being (South Africa, 2019).

Evisceration means the removal of the contents of the thoracic and abdominal cavities (South Africa, 2004).

Extension means the straightening of limbs (i.e., means increasing in angle) at the joint (Davis, 2019).

Flexion means the bending the limbs (i.e., reducing the angle) at a joint (Davis, 2019).

Hazard means a source of or exposure to danger (South Africa, 1993).

Independent Meat Inspection Scheme means a scheme established under the Meat Safety Act (South Africa, 2017).

Meat means those parts of a slaughtered animal which are ordinarily intended for human and animal consumption and which have not undergone any processing other than deboning, cutting up, mincing, cooling or freezing, and includes meat which— *(a)* has been treated with a substance that does not substantially alter the original characteristics thereof; and *(b)* assumes its original characteristics after a substance referred to in paragraph *(a)* has physically been removed therefrom (South Africa, 2004).

Meat Inspection Service means the performance of ante-mortem, primary, and secondary meat inspections by a registered inspector who may be employed by an assignee and may include hygiene management and regulatory control as agreed on with the Provincial Executive Officer for each abattoir and includes reporting of non-conformances to the Provincial Executive Officer (South Africa, 2004).

Premises include any building, structure, enclosure, land, road, harbour, jetty, quay, or mooring (South Africa, 2004).

Primary meat inspection means the inspection, by a registered inspector, of a carcass and organs directly after flaying and evisceration in terms of Part VI B (South Africa, 2004).

Red offal means the lungs, heart, liver, diaphragm, spleen, tongue, and demasked head of the slaughtered animal (South Africa, 2004).

Registered Inspector means a person contemplated in section 11(1)(c) of the Act who is registered by the provincial executive officer under regulation 111 to do a meat inspection service in a particular abattoir (South Africa, 2004).

Rough offal means the stomach, intestines, feet, and skin-on head of the slaughtered animal except in the case of pigs where the head and feet are part of the carcass (South Africa, 2004).

Secondary meat inspection means the inspection, by a registered veterinarian, of a carcass and organs detained during primary meat inspection (South Africa, 2004).

Slaughter means the killing of an animal and the performance of the usual accompanying acts in connection therewith to obtain meat and animal products therefrom (South Africa, 2004).

Unit in relation to a quantity standard for determining throughput for red meat, means -
(i) one cow, ox, or bull or two calves; (ii) one horse; (iii) six sheep or goats; or (iv) four small pigs (porkers) or two bacon pigs or one sausage pig (South Africa, 2004).

Zoonotic disease is any disease or infection that is naturally transmissible from vertebrate animals to humans (WHO, 2020).

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CHAPTER ONE
INTRODUCTION

1.1 Introduction

Abattoirs play a pivotal role in the meat value chain and performs a fundamental function in converting livestock into meat (Olivier, 2004). During the early 1990s the abattoir industry underwent rapid and radical change due to a shift in socio-economic policies (Spies, 2011). The changes stemmed mainly from: (a) changes in the legislative environment; (b) the transformation of the meat industry; and (c) the privatisation of meat inspection services [National Agricultural Marketing Council (NAMC), 2001].

In line with legislative requirements in the Meat Safety Act (Act No. 40 of 2000), meat inspectors are duty-bound to operate independently (South Africa, 2000) from an abattoir and to ensure that the requirements for ante-mortem and post-mortem inspections are complied with (South Africa, 2004). Their scope of practice reveal a set of systematic approaches built on scientific principles that are aimed at identifying and addressing food safety risks (Van Zyl, 1995).

The Meat Safety Act is concerned with the slaughter and dressing of carcasses, meat inspection, proper handling and storage of meat, cleaning and sanitation, and hygiene management practices but does not address occupational health and safety, and ergonomics (South Africa, 2004; Hlasa, 2006).

Subsequently, the abattoir industry became a highly regulated environment driven by fierce economic competition (Olivier, 2004). The role of occupational health and safety, post 1994, remained elusive with little or no evidence to substantiate the development, management or the implementation of health and safety at red meat abattoirs (Hlasa, 2006; Maseko, 2016).

Consequently, several high throughput abattoirs have since incorporated “health and safety” into their management and operational systems. In assessing the nature of occupational health and safety risks at high throughput red meat abattoirs, the aim of this study was to conduct an analysis of the presence, the effects, and the prevalence of ergonomic hazards within the field of meat inspection.

1.2 Background to the research problem

The changes that occurred in the red meat industry affected both abattoirs and meat inspectors (Spies, 2011). The introduction of the Meat Safety Act (i.e., Meat Safety

Act, No. 40 of 2000) revised the abattoir grading system and instituted new structural, daily throughput, and hygiene management criteria for all abattoirs (South Africa, 2004). The privatisation and the rendering of meat inspection services by designated service providers noticeably influenced the work and working conditions under which meat inspectors performed their duties (Lubbe and Groenewald, 1992; South Africa, 2015).

In an assessment of the local red meat sector, the NAMC warned that the country could face crucial challenges relating to indifferences in standards and dissimilarities in production capabilities because of the deregulation of the red meat industry. The council viewed these challenges as potential barriers to sustainable development within the red meat sector (NAMC, 2001).

Spies (2011) highlighted that the Red Meat Abattoir Association (RMAA), during 2009, reported that 488 red meat abattoirs existed in the country with nearly one third classified as high throughput. Most of the high throughput red meat abattoirs were relatively small in comparison to the “bigger abattoirs” of the past. The newly classified high throughput category comprised of abattoirs that slaughtered more than 20 units per day (i.e., 20 cattle or 120 sheep or 20 sausage pigs or 40 baconer pigs or 80 small pigs or any combination of species in excess of 20 units per day) (South Africa, 2004).

Many smaller abattoirs, when likened to the historically bigger ones, did not compare favourably in terms of its overall compliance. The lower grade abattoirs were mainly equipped with manual operational systems and faced serious challenges in maintaining a sustainable supply of meat (Olivier, 2004; Abdullahi *et al.,* 2016). To overcome these shortcomings, facilities introduced extended working hours and longer production cycles (La Novara, 1991).

The normal working hours applicable to the South African employment environment constitutes of an eight-hour workday and a forty-hour workweek (South Africa, 1997). The operating environment of meat inspectors varies from facility to facility and may be further affected by factors such as:

a) longer production cycles (in order to meet market demands);
b) increased production volumes;
c) lack of uniform standards;
d) poor remuneration levels; and
e) unskilled labour (NAMC, 2001).

As a result, many abattoirs may operate longer shifts during peak production cycles or during seasonal times to meet their production demands. These longer shifts could, as stated by Hlasa (2006), be up to 15 hours per day.

Although the fundamental principles involved in the performance of meat inspection remained relatively unaffected, the occupational environment within which meat inspectors functioned changed. Meat inspection is performed in an environment governed by specific structural and operational requirements (i.e., specific requirements for the height of dressing rails applicable to production areas, working platforms or stands). In addition, the performance of meat inspection necessitates the use of a specific set of hand tools i.e., knives, hooks, steels used for sharpening of knives, and scabbards.

Hence, it is important to acquire thorough knowledge and understanding of the type of risks associated with the performance of meat inspection as well as the risks associated with the use and the application of their hand tools.

1.3 Statement of the research problem

As the statutory, business, and operating environments around meat inspection evolved, many abattoirs experienced challenges in maintaining the required levels of compliance. The introduction of innovative meat safety legislation noticeably influenced the cost of compliance at red meat abattoirs (Olivier, 2004) as well as the need for adequate and effective research on the impact and the effects of occupational health and safety risks within the local abattoir environment.

The absence of substantive evidence on the scope and the application of ergonomics at high throughput red meat abattoirs may contribute to: (i) a lack of knowledge on the importance of ergonomics within the red meat industry; (ii) the absence of sufficient information on the types of hazards to which meat inspectors may be exposed (with specific reference to ergonomic hazards); (iii) deficiencies in applying the principles of ergonomics in designing or shaping the working environment of meat inspectors (i.e., height of rails, dimensions of platforms and stands, type and quality of hand tools used, sufficiency of required or available floor space to perform their duties); (iv) a fragmented regulatory system aimed at addressing ergonomic challenges; and (v) a need for adequate awareness in terms of the effective management or reporting of ergonomic hazards.

1.4 Significance of the study

Limited information currently exists within the South African context to address the concerns of ergonomics within the red meat abattoir industry. Research into the scope and impact of ergonomic hazards on meat inspectors remains non-existent. Nonetheless, the occurrence and prevalence of ergonomic hazards may not only affect the health of meat inspectors, but also their livelihood (Harmse *et al.,* 2016).

The outcome of this study aims to provide government and industry with the necessary knowledge and insight into the relevance and the importance of ergonomic hazards. In addition, it may also provide stakeholders an opportunity to understand the impact of ergonomic hazards on meat inspectors and to improve the approaches to ergonomics within the red meat abattoir industry.

1.5 Research question

What is the presence, the effects, and the prevalence of ergonomic hazards to meat inspectors at selected high throughput red meat abattoirs in the Western Cape?

1.6 The aim of the study

The aim of this study was to analyse and assess the presence, the effects, and the prevalence of ergonomic hazards to meat inspectors.

The primary focus was to define the nature and the scope of ergonomic hazards to which meat inspectors were exposed when exercising their duties under the Meat Safety Act of 2000.

1.7 Research objectives

a) To identify the type of ergonomic hazards that may be present within the working environment of meat inspectors.
b) To evaluate the perceived effects that these hazards may have on meat inspectors.
c) To assess the prevalence and the impact of these hazards to meat inspectors.
d) To identify potential barriers or opportunities that the abattoir industry may face in addressing ergonomic hazards within this sector.

1.8 Delineation of the research

The study focused on meat inspectors at selected high throughput red meat abattoirs in the Western Cape. The abattoirs selected for this project were all within a 200 km radius from Elsenburg (Head Office of the Department of Agriculture, Western Cape).

The project also involved the government department(s) that may play a role in the regulation of abattoirs as well as industry stakeholders involved in the provision of meat inspection services and authorised under the Meat Inspection Scheme (South Africa, 2015).

1.9 Layout of the thesis

The thesis layout provides a brief overview and details of the various chapters of the main body of work. It is comprised of seven main chapters that is presented as follows.

a) **Chapter 1** provides a brief overview of the background to the study. In addition, it also presents the research problem, the significance of the study, the aims and objectives as well as the delineation of the research project.
b) **Chapter 2** is the literature review and provides information on the presence, the effects, and the prevalence of ergonomic hazards in the meat industry.
c) **Chapter 3** provides information on the methodology used to collect the necessary data to substantiate the aims and objectives of this study.
d) **Chapter 4** provides the results of the study based on the information collected from the various facilities.
e) **Chapter 5** provides a discussion of the study outcomes considering the results obtained.
f) **Chapter 6** provides a summary of the project, its limitations, and recommendations for future studies.
g) **Chapter 7** provides a list of the references consulted in accordance with the Harvard method of referencing.

CHAPTER TWO
LITERATURE REVIEW

2.1 Introduction

The South African red meat sector has grown steadily over the past few years. The void created by the deregulation of the meat industry generated considerable challenges to the country's red meat sector (NAMC, 2001). The demand for meat effected substantial changes in productivity levels at abattoirs and resulted in a greater obligation on facilities to maintain consumption levels (Luppnow, 2007). The NAMC raised concerns about dissimilarities that existed between the different categories of abattoirs. These differences posed serious challenges to the development of a sustainable red meat industry. The introduction of an innovative statutory framework noticeably affected the cost of compliance at abattoir level. The highly competitive environment in which many abattoirs found themselves made it increasingly difficult to maintain adequate compliance levels (NAMC, 2001). The privatization of meat inspection involved the termination of government subsidies, which increased the cost of meat inspection services to abattoirs and bringing changes to the socio-economic environment, within which meat inspectors practiced (Lubbe and Groenewald, 1992). Considering these and other challenges, concerns developed around the working conditions that evolved within abattoirs (Fitzgerald, 2010). The need therefore exists to adequately and effectively assess the impact and the effects of occupational health and safety hazards within the local abattoir sector.

The objective of this review is to examine and analyse the existing body of knowledge on ergonomics, its theories, and how it relates to the South African red meat abattoirs. The aim is to present an extensive view on the role that red meat abattoirs play in the development and the occurrence of ergonomic hazards. This chapter gives an overview of the type and the effects of ergonomic hazards on workers in the meat industry (including other manufacturing or service industries) and provide a profile of each element. It begins with a broad overview before focussing on the sections that are most relevant to this study. The literature review commences with a brief outline of the historical developments in the abattoir sector and describes the emergence and development of occupational health and safety and the role it played within a growing industry. In addition, it also includes a summary of occupational health and safety research at both national and international levels.

The second part of the review defines ergonomics and outlines its occurrence and prevalence in countries where similar studies were conducted. This is followed by discussions on the causes of ergonomic hazards, before aiming to address ergonomic hazards at abattoirs in the Western Cape (with specific reference to high throughput red meat abattoirs). In addition, interventions to ergonomic hazards in the meat industry is also discussed. An analysis of the literature completes this section of the review, reflecting on the gaps and the weaknesses of the theories and the knowledge around the causes of ergonomic hazards.

Knowledge or information on methods of assessment and medical examination or management of ergonomic related hazards are not applicable to this study and was therefore not included in this review.

2.2 Literature search strategies

A preliminary search was conducted to determine the extent and application of existing literature and to define key terminology. The sources used included electronic databases, cited publications, and online library services. A list of key words was documented and presented in Table 2.1.

Table 2.1: Key words used in literature search

Key words	Combinations
food safety	history; production; systems; food health;
animal slaughter	slaughterhouses; practices; species; history;
meat safety	origin; processing; plants; systems; meat packing;
abattoirs	history; planning; layout; design; development; modernization;
meat inspection	functions; areas; performance;
agriculture	industrial; animal production; health; nutrition; environment;
ergonomics	history; definition; hazards; risks; practices; human factors;
musculoskeletal disorders	risks; causes; occurrence; effects;
occupational health and safety	risks; systems; controls; research; history;

The above-mentioned key words were used as separate terms or as combinations. These terms were used to search electronic data bases or to identify references where the key words were part of any of the data fields. References were considered for inclusion in the review, irrespective of the published date, including those in peer reviewed sources. Publications that were not in English or where no translation existed were excluded from the search. The data sources that were used in the literature search were as follows:

a) Ergonomic abstracts
b) National Department of Agriculture, South Africa
c) Red Meat Abattoir Association (RMAA)
d) www.researchgate.net
e) www.springer.com
f) www.elsevier.com
g) www.ebscohost.com
h) www.openaccess.com
i) www.ilo.org
j) www.tandfonline.com

The abstract of each of the reference documents were reviewed to determine their relevance to the field of study. The documents that were included in the list of references were reviewed fully and are included in this chapter. Additional literature that substantiated some of the arguments put forth were also included.

2.3 Abattoirs

2.3.1 Historical overview

According to Fayemi and Muchenje (2013), the concept of deriving meat from an animal date back to early antiquity. Curtis (2001) argued that the developments around the consumption of meat in ancient civilizations centred on primitive structures (he named abattoirs or slaughterhouses) where animals were "butchered and inspected" either by a priest in terms of Egyptian culture or by the king's chef in terms of Neo-Assyrian culture.

Contemporary concerns around meat safety can be traced back to the medieval civilizations of Europe. Evidence show that the first modern public abattoir system was pioneered by Napoleon during the 18th century (Dolman, 1957). Gil & Durao (1990) defined an abattoir as a premises that has been approved and registered by the relevant controlling authority where animals can be slaughtered to meet the demands for food. Fuentes *et al.* (2015) deemed the earlier type of abattoirs as "reasonably simple" structures, which were affected by regulatory changes and privatization. Consequently, the infrastructural investments made by private multinationals resulted in the closing or taking over of numerous public abattoirs. Dolman (1957) understood that modern-day advances in meat safety evolved to incorporate a systems approach that involved the production, slaughter, processing, storage, distribution, and preparation of meat to satisfy consumption requirements.

2.3.2 Industrialization of abattoirs

During the early stages of the industrial revolution, slaughterhouses (as it were known) played an important role in sustaining economic development. Animal slaughter became recognized as one of the first mass-producing industries in the US as early as 1880 (Fitzgerald, 2010). Following the outcomes of World War II, the traditional approaches to food production changed and was replaced by ground-breaking industrial practises, which sparked the tremendous increases in global food production (Walker *et al.,* 2005).

In low-income countries, in Africa, the meat industry played a key role in sustaining local economic development (Jerie and Matunhira, 2022). Slaughter facilities differed in size from large-scale industrialized facilities to poorly regulated small-scale facilities in rural areas (Cook *et al.,* 2017). In rural areas animals were slaughtered under informal and non-regulated conditions or in deteriorated or outdated slaughter facilities (Oluchi and Elochukwu, 2023). However, many countries like Namibia, Botswana, and South Africa developed established meat industries that are able to compete within the international export markets (Cabrera *et al*., 2010). With specific reference to the South African meat industry, the Abattoir Commission (ABACOR), during its existence, embarked on the renovation of existing and the establishment of new modern-day abattoirs in the country. Since 1967 until its deregulation in 1992, ABACOR administered the location, registration, establishment, and servicing of abattoirs in South Africa (Farming SA, 1972; Olivier, 2004).

The shift from rural to industrial economies, the increased demand for meat, a growing urban population, innovative scientific knowledge, and the emergence of new technologies were some of the factors that prompted substantial changes in meat production systems (Fuentes *et al.,* 2015). The introduction of more advanced and highly sophisticated technologies allowed for different types of animals to be slaughtered at the same time and in larger quantities. It replaced the traditional hand-slaughter methods employed by individual butchers (Miele, 2016). The mechanization of production systems resulted in the large-scale industrialization of abattoirs and gave rise to the further development of globalized meat production. Mechanical lines placed the control of the overall process and the pace of work in the hands of abattoir management and not the abattoir workers (Tappin *et al.,* 2008; Gillespie, 2017).

2.3.3 Automation and worker safety

Broadway and Stull (2008) discovered that work in the modern-day abattoir is unpleasant and physically demanding. It was observed that employees remained on their feet for most part of the day and performed the same tasks over and over for the entire duration of a shift or a day. Gillespie (2017) was of the view that the physical and psychological impact of this type of work would have a lasting effect on employees. Notwithstanding the benefits of mechanization, the higher line speeds impacted negatively on the health and safety of abattoir workers. During the latter part of the twentieth century, occupational injuries among workers in the meat industry were reportedly higher than in any other industry. Dangerous working conditions together with the physically demanding nature of the work were considered as some of the main contributors to high employee turnover rates (within the meat industry) (Fitzgerald, 2010). Fitzgerald also highlighted an article in the New York Times, dated 2005, that raised serious concerns about the working conditions associated with modern-day abattoirs.

2.4 Occupational health and safety

2.4.1 Conventional approaches

Approaches to occupational health and safety traditionally focussed on the rates of occupational exposures linked to zoonotic or communicable diseases. Certain occupations showed a higher degree of risk-related infections caused by viruses, parasites, fungi, bacteria, or their toxins. The initial approaches to occupational health and safety hazards focussed on cuts or abrasions (physical hazards), tuberculosis or hepatitis B virus or Brucellosis (biological hazards), and poison (chemical hazards) (Banjo *et al.,* 2013). Apart from the above, numerous studies exist that addressed the relevance and impact of occupational health and safety within the meat industry (national and international domains). Most of these focussed on the impact of the traditional “occupational health and safety” concept (i.e., biological, physical, and chemical hazards). The scope of occupational health and safety therefore did not adequately incorporate the principles of ergonomics until after the early to mid-1900. The principles of ergonomics were introduced in the work environment, originally within the US meat industry, during the early 1980s. US companies as early as the 1990s reported rising costs in terms of workers’ compensation claims relating to “non-accident related injuries”. This gave rise to the emergence of ergonomics as a new scientific discipline that formed part of the broader principles or prescripts in the field of occupational health and safety (Albert and Spencer, 2003; CIEHF, 2023).

2.4.2. Health and safety concerns in the meat industry

The move from an agrarian to an industrialized agricultural sector reportedly had a huge impact on both the environment and human health. This prompted calls from interested parties for increased regulation of the meat industry to protect the environment and the health and welfare of employees (Walker *et al.,* 2005). Banjo *et al.* (2013) stated that occupational health and safety, in reference to abattoirs, was somewhat overlooked in many countries, especially amongst the low-income countries.

The following section provides a summation of health and safety concerns raised within various countries:

Australia: The meat industry, supported by an export-based economy, ranked among the industries with the highest incidence of occupational hazards. The most common occupational health and safety risks related to injuries included sprains and strains (Tappin *et al.,* 2016).

Britain: The Bureau of Investigative Journalism reported that abattoirs in Britain were amongst the industries with the poorest safety records in the UK. The meat industry employed approximately 75 000 workers who performed difficult and repetitive work on fast-moving production lines (Wasley and Heal, 2018).

Canada: Barter (2014) conducted a study of the Canadian meat industry and pointed out that contemporary meat production negatively impacted on workers' health and well-being. The study revealed that physical and psychological injuries suffered by employees were due to increased production capacities and internal processes.

Kenya: Poor working conditions, poor work practices, or the lack of adequate equipment were identified as factors contributing to the risk of upper extremities and back disorders among employees in slaughterhouses and meat processing plants (Cook *et al.,* 2017; Makori *et al.,* 2018).

New Zealand: The meat industry was one of the biggest contributors to the country's export-based economy. The industry became one of the leading employers of both skilled and unskilled labour. Consequently, the incidence of musculoskeletal disorders (MSD) in the meat industry was reportedly higher than that of any of the other industries. Reports showed that the injury rates in the meat sector remained quite high in comparison to the rates found in other manufacturing sectors (Tappin *et al.,* 2016).

Nigeria: Improper market and abattoir planning was identified as some of the main contributing factors to occupational hazards within the meat industry. Workers were exposed to a number of hazards, such as overexertion, manual and repetitive work, awkward positions, and lifting of objects (Oluchi and Elochukwu, 2023).

South Africa: Harmse *et al.* (2016) in a study on occupational health and safety hazards at poultry abattoirs indicated that a lack of adequate legislative support created challenges to industry and to employees. Poor housekeeping in abattoirs contributed to poor working conditions that could contribute to slips, trips and falls (Maseko, 2016). Abattoir workers are exposed to noise levels in excess of the occupational noise rating limit of 85dB(A) (Hlasa, 2006).

USA: Broadway and Stull (2008) understood that the meat industry had always been synonymous with dangerous work. In the USA employees were only, as late as the 1980s, mandated to wear the necessary health and safety equipment i.e., hardhats, safety glasses, earplugs, steel-toed and rubber-soled boots. Hendrix and Dollar (2017) revealed that the American abattoir industry appeared more focused on profits, output, optimum line speeds, and efficiency of the slaughter process than on the health and well-being of the workers. Consequently, Fitzgerald (2010) indicated that during the 1990s the incidence of occupational health and safety hazards began to decrease because of developments made within the field of ergonomics.

Zimbabwe: The meat industry was one of the pillars in the economic development of the agriculture sector. However, research indicated that abattoir workers faced occupational health and safety hazards due to sub-standard abattoir infrastructure and poor working conditions (Jerie and Matunhira, 2022).

In conclusion, the field of occupational health and safety thus includes a wide scope of disciplines that covers a variety of hazards, which may be applicable to abattoirs and may include physical hazards, chemical hazards, biological hazards, ergonomic hazards, and psychological hazards (Maseko, 2016).

2.4.3. Health and safety – a legal framework for abattoirs

At the forefront of the occupational health and safety landscape in South Africa, is Section 24 of the Constitution of South Africa No. 108 of 1996, which clearly states that every person has the right to an environment that is not harmful to their health and well-being (South Africa, 1996). Consequently, the Occupational Health and

Safety Act (Act No. 85 of 1993) requires all employers to establish an adequate health and safety management system and to provide, as far as possible, a working environment that is safe and free of health and safety risks to employees (South Africa, 1993; Maseko, 2016). The following section provides an outline of regulations promulgated under the Occupational Health and Safety Act (Act No. 85 of 1993) and how it may apply to abattoirs.

The General Safety Regulations (G.N. R1031 of 30 May 1986)

The regulations mandate employers to conduct risk assessments and determine the type of hazards present in the workplace. The regulations provide an outline of the type of safety equipment, facilities, and procedures that employers and employees must adhere to within their respective occupational settings. In addition, these regulations require employers to provide first-aid facilities containing the minimum prescribed items and to ensure that suitably trained first-aid workers are available.

The Environmental Regulations for Workplaces (G.N. R2281 of 16 October 1987)

Maseko *et al.* (2017), in a study on occupational slips, trips, and falls amongst workers in the meat sector in Gauteng Province, identified that slippery and wet floors in abattoirs increased the risks of injuries amongst workers. The study also highlighted that a lack of adequate housekeeping resulted in poor working conditions in participating abattoirs. The study further highlighted that these conditions were in contrast to the requirements set out in the Environmental Regulations for Workplaces (South Africa, 1987). The regulations clearly states that employers must ensure that indoor workplaces are clean, orderly, and free of materials and tools, which may not be necessary for the work done at a given time or in a given workplace.

Compensation for Occupational Injuries and Diseases Act (Act No. 130 of 1993)

This Act provides a framework for the compensation of disablement caused by occupational injuries or diseases sustained or contracted by employees in the course of their employment, or for death resulting from such injuries or diseases and for matters connected therewith. Chapter VII of the Act makes provision for compensation for occupational diseases where employees: (a) contracted a disease mentioned in the first column of Schedule 3 as a result of his or her work; (b) contracted a disease other than a disease mentioned in Schedule 3 which was also as a result of his or her work. The Act clearly describes the responsibilities of both employee and employer in the reporting of occupational diseases. Furthermore, the Act identified repetitive work as the causative factor for the overstraining of muscular tendinous insertions.

Regulations for Hazardous Biological Agents (G.N. R1390 of 27 December 2001)

Workers in abattoirs may also be exposed to physical and biological agents that could be responsible for the development of a number of illnesses (Banjo *et al.,* 2013; Abdullahi *et al.,* 2016). Based on the requirements set out in the Regulations for Hazardous Biological Agents (South Africa, 2001), employers are required to: (a) identify and manage potential biological hazards; (b) implement measures to protect employees against risks of exposure to hazardous biological agents; (c) maintaining good housekeeping and personal hygiene; and (d) ensure that employees wear protective clothing and respiratory protective equipment, if and where applicable.

The Noise-Induced Hearing Loss Regulations (G.N. R307 of 07 March 2003)

Hlasa (2006) indicated that high throughput abattoirs generated average noise exposure levels in excess of the recommended 85dB(A). The study identified noise sources originating from mechanized and manual processes or activities. The noise sources included conveyors, circular saws, air conditioners, pumps, pneumatic, and mechanical equipment. The Noise-Induced Hearing Loss Regulations (South Africa, 2003) require employers to conduct, at regular intervals not exceeding two years, assessments to determine if workers are exposed to noise levels that may be at or above the prescribed noise-rating limit. Employers are expected to reduce the equivalent noise levels to below 85dB(A) and must identify and demarcate all noise zones, while prohibiting employees from entering these noise zones without the necessary hearing protectors (Hlasa, 2006).

Circular Instruction 180 regarding the compensation of Work-Related Upper Limb Disorders (WRULDs) (G.N. 498 of 23 April 2004)

The Department of Labour (DoL) published the above-mentioned circular to provide for the compensation of Work-Related Upper Limb Disorders (WRULDs). The circular identified the following as risk factors for WRULDs: highly repetitive movements, movements requiring force, movements of extremes of reach, static muscle loading, awkward sustained postures, contact stress, and vibration. The instruction presumed that a worker contracted upper limb musculoskeletal disorder from his or her work if the nature of the work performed included exposure to these risk factors (South Africa, 2004).

The Ergonomics Regulations (G.N. R1589 of 06 December 2019)

The Ergonomics Regulations (G.N. R1589 of 06 December 2019) require employers to conduct, at regular intervals not exceeding two years, an ergonomic risk assessment. The risk assessment must include: (a) a complete list of hazards; (b) everybody who may be at risk; (c) how employees may be affected by these risks; (d) an analysis and evaluation of risks; and (e) the prioritization of risks. The regulations further specify that an employer must conduct regular risk reviews if: (a) the assessment is no longer valid; (b) control measures are not effective; (c) if technological or scientific advances allow for more effective control measures; (d) there are changes in working methods, type of working activities, and type of equipment used to control levels of exposure, and (e) incidents or medical surveillance show that ergonomic risks contributed to adverse health effects (South Africa, 2019).

Harmse *et al.* (2016) in their study on occupational health and safety within South Africa's poultry industry highlighted the need for an improved legislative framework. At the time of the study by Harmse *et al.* (2016) the current framework, depicted in Table 2.2, covered most of the common types of occupational hazards found in the workplace such as noise, extreme temperature (cold), vibration and ergonomic hazards.

Table 2.2: List of physical agents and ergonomic occupational hazards with applicable legislation (as adopted from Harmse *et al.,* 2016)

Physical Agent	Legislation/Regulation		
	SA	U.S.A	UK
Noise	Noise-induced hearing loss regulations, 2003	Occupational noise exposure regulations 1910:95	The control of noise at work regulations, 2005
	NOISE OEL		
	$L_{Ar}8_{hr}$ < 85 dB(A)	Equivalent noise level should be < 90 dB(A) for 8 h also sets: - Action level: 8 h TWA of 85 dB(A) or 50% noise dose	Daily or weekly personal noise exposure of 87 dB(A) & a peak Lp not > 140 dB(C) also sets: - Lower exposure action value: Daily or weekly exposure of 80 dB(A) & peak Lp 135 dB(A); - Upper exposure action values: Daily or weekly exposure of 85 dB(A) & peak Lp of 137 dB(A)
Cold	Environmental regulations for workplaces, 1987	Occupational safety and health act, 1970 - Occupational safety and health standards 1910:999	Workplace regulations, 1992
	COLD OEL		
	The four-hour TWA Dry-bulb temperature index should not exceed 6 ˝C	The Wind-Chill Index is used prescribing maximum exposure times at certain wind chill temperatures	Dry-bulb temperature and air velocity used to determine the Wind Chill Factor - Several OELs provided
Vibration	Nil	Occupational noise exposure regulations 1910:95	Control of vibration at work regulations, 2005
	VIBRATION OEL		
	Nil	ACGIH set an acceleration of 4 m/s^2 for 4–8 h, dropping to 8 m/s^2 for 1 - 2 h	Acceleration as Action limit of 2.5 m/s^2 and an OEL of 5.0 m/s^2
Ergonomic hazards	OHSACT, 1993: General duty clause	OSHACT, 1970: General duty clause	Manual handling operations regulations, 1992
	ERGONOMIC OEL		
	Nil General duty clause	ACGIH: - hand activity tables for hands & wrists based on repetitive-ness & force used - screening & lifting for lower back problems	MAC tool, ART tool

Harmse *et al.* (2016) recognized that the occupational framework within which abattoirs addressed ergonomics hazards was a challenge to both employees and employers.

2.5 Ergonomics

2.5.1 Definition

The term ergonomics are derived from two Greek words i.e., ergon, which means work and nomoi, which mean natural laws. The field of ergonomics are primarily concerned with the science of work and the relationship of an individual to his or her work or the task that is to be performed [International Ergonomics Association (IEA), no date; Guild *et al.,* 2001; South Africa, 2019]. The aim of ergonomics is to make the work and the work environment fit for the worker in order to achieve the greatest efficiencies while workers perform their tasks comfortably (Tomoda, 1997). The International Ergonomics Association defined ergonomics as a science that studies the interactions between people and the organisational systems they work in. The aim is to optimize employee well-being and improve the overall system's performance (IEA, no date; Guild *et al.,* 2001; Tappin *et al.,* 2008). Thus, the disciplines involved in the study of ergonomics are aimed at identifying, eliminating, or reducing the presence or the impact of work-related risks or injuries.

2.5.2 The significance of ergonomics

The International Labour Organisation (ILO), in a study by Tomoda (1997) on the health and safety of meat, poultry, and fish processing workers, identified ergonomic hazards as one of the major concerns facing modern meat processing facilities. In promulgating the Ergonomics Regulations (No. R1589 of 06 December 2019) South Africa identified the field of ergonomics as a key element in promoting a healthy and safe work environment (South Africa, 2019). The International Labour Organisation identified the need to train employees as a fundamental requirement that could assist facilities in addressing ergonomic hazards within the meat industry (Tomoda, 1997).

Furthermore, the International Ergonomics Association indicated that the field of ergonomics were divided into three main areas i.e., physical, cognitive, and organisational ergonomics (Figure 2.1: Multi-disciplinary approach to ergonomics). In the contemporary abattoir environment, physical ergonomics concentrates on the anatomy of workers as well as the physiological and biomechanical characteristics of the work they perform. Cognitive ergonomics therefore focusses on the mental processes, i.e., the reasoning and motor responses, of workers and their interactions with the different elements of the meat production system (and may include intellectual capacity, decision-making, competence, and work-related stress). Organisational ergonomics centres on the impact that the organisational structure, policies, and processes may have on the employee's working environment i.e., work design, design of working times, and participatory design (IEA, no date).

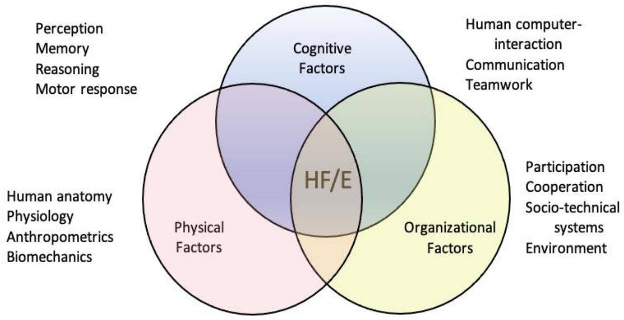


Figure 2.1: Multi-disciplinary approach to ergonomics
(*Source:* https://iea.cc/about/what-is-ergonomics/)

With specific reference to the red meat industry, modern-day abattoirs became synonymous with highly paced work environments, which often incorporated extended working hours. It involved working conditions that required both manual and repetitive work and demanded the exertion of force as well as the adoption of awkward body postures (Harmse *et al.,* 2016). The large-scale industrialization of abattoirs gave rise to the development of the early "dis-assembly line" approach that drastically enhanced process efficiencies within the meat industry. Workers were trained to complete specific tasks instead of a set of systematic procedures, which assisted abattoirs to process more carcasses at faster rates (Tappin *et al.,* 2008). Fast-paced working activities and increased line speeds at abattoirs posed a considerable safety hazard to workers. As a result, the incidence of occupational health and safety risks were noticeably higher in the meat industry than in any other industry in the US (Fitzgerald, 2010). Johnson and Etokidem (2019) discovered that abattoir workers were exposed to several physical and ergonomic hazards. Banjo *et al.* (2013) concluded that in countries where the meat industry contributed significantly to socio-economic development and employment, occupational health and safety hazards existed due to the presence of physical, chemical, biological, and ergonomic risk factors.

2.5.3 The role of biomechanics in ergonomics

The performance of working activities could generate a range of biomechanical forces within the human body (Vieira and Kumar, 2004). The magnitude of these forces can be determined using the disciplines involved in biological sciences and the field of engineering mechanics. This interdisciplinary approach gave rise to the development of occupational biomechanics. Occupational biomechanics is the study of the physical interaction of workers with their tools, machines, and materials aimed at enhancing the worker's performance while minimizing the risk of musculoskeletal disorders (Guild *et al.,* 2001; Marras, 2012). Workplaces should be well designed to ensure that the load imposed on a worker do not exceed the tolerance levels in the body (Carayon and Smith, 2000; Marras, 2000; Dianat *et al.,* 2016). If the magnitude of any load imposed on the body is less than the tissue tolerance levels, the task is deemed to be safe. A worker will be at risk of injury or inflammation if the imposed load equals or exceeds the tissue tolerance level (Davis and Marras, 2000). Workers may be exposed to two types of traumas, i.e., acute or cumulative. Acute trauma occurs when a single load or force exceeds the tissue tolerance level and may apply to the lifting of heavy objects. Cumulative trauma refers to the repeated and continuous application of force and the lowering of the body's tolerance level to a point where it is exceeded and where tolerance limits are reduced (Karwowski and Marras, 1998; Marras, 2012).

2.5.3.1 *Moments and levers*

Marras (2012) was of the view that the load on a worker's body is partly defined in terms of the magnitude of the weight supported by the body. The total load may be defined in terms of the moment of forces. The moment of a force is the imposed load determined by the position of the weight in relation to the axis of rotation and the joint of interest. Thus, moments are defined as the mechanical lever system of the body. In terms of biomechanics, the musculoskeletal system comprises of a system of levers used to describe the maximum tissue load within a biomechanical model. According to Marras (2012) and as cited in Salvendy (2012), there are three types of lever systems commonly associated with the human body: first-class lever which are levers that consist of a fulcrum placed between the imposed load and an opposing force (internal to the body) that is imposed on the opposite end of the system; second-class levers which are levers that may be applicable to the lower extremities where the fulcrum is located at the end of the lever, the opposing force (internal to the body) is located at the other end of the system and the applied load is between the two; and third-class levers which are levers where the fulcrum is located at one end of the system and the load is applied at the other end of the system while the opposing force (internal to the body) acts between the two.

2.5.3.2 *External and internal loads*

There are two types of forces that normally impose loads on the musculoskeletal system during the performance of work (i.e., external and internal loads) (Marras, 2000). An external load implies that the force imposed on the body is as a result of the forces of gravity acting upon an external object. In order to keep the musculoskeletal system in equilibrium, internal forces on the other hand must be greater than external forces. The internal forces are considered key risk factors that contribute to cumulative trauma and musculoskeletal disorders among employees (Marras, 2012).

2.5.3.3 *Managing internal load*

Workers may be at risk of muscular injury if the forces imposed on the muscle or tendons (during performance of working activities), exceed the tolerance levels of the muscle or tendons. It is therefore important to ensure that workplaces are designed to reduce or minimize the impact of internal forces by addressing the biomechanical arrangement of the musculoskeletal lever system, length-strength relationship, and temporal relationships (i.e., strength-endurance, rest time) (Salvendy, 2012).

a) *Biomechanical arrangement*

The working postures adopted during working activities are influenced by the design of the workplace and can affect the arrangement of the body's musculoskeletal lever system (Vieira and Kumar, 2004). The fact that working activities are performed in a variety of different ways could add additional strain on the musculoskeletal system. It can affect the magnitude of the internal load needed to support external forces (Marras, 2000). The arrangement of the body's lever system can influence the magnitude of external moments imposed on the worker's body, including the size of internal forces. Thus, as the design of work can affect the positioning of the body, it can further influence the transmission of internal forces within the body (Marras, 2012; Salvendy, 2012).

b) *Length-strength relationship*

Muscles that are at rest (resting length), possesses the highest capacity to generate force. If, however, the muscle length changes from the resting position, its capacity to generate force is significantly reduced. The ability of any muscle to generate force will be substantially limited if it stretches or attempts to generate force while at a short length. When performing a task, the length of a muscle determines the total force needed and could influence the level of risk based on the magnitude of internal muscular forces. A moderate force for a muscle in its resting position could become the maximum force that a muscle can generate if it is stretched or contracted. In which case the risk of muscular strain could be increased (Karwowski and Marras, 1998; Marras, 2012; Salvendy, 2012).

c) *Impact of velocity on muscular force*

The magnitude of any force generated in a muscle can be influenced by the extent of muscular movement. Muscular mobility can create momentum, but it can also increase the biomechanical load on the said muscle. An increase in muscular velocity may result in a reduction in the magnitude of force generated in the muscle. Highly paced working activities could cause muscular strain, which may occur at lower levels of external loading that can further increase the risk of tissue disorder (Karwowski and Marras, 1998; Marras, 2012; Salvendy, 2012).

d) *Temporal relationships*

Strength-endurance: Strength may be used as an internal force or as a tolerance level. Workers may be able to generate a significant level of force or strength in a single event. Consequently, if a worker is expected to repeatedly exert himself or herself for an extended period, it could substantially reduce the maximum force in the affected muscle. A worker may only be able to generate a maximum force for a limited time. The strength output of a worker may decrease considerably over time and diminish to almost 20% of its maximum after 7 minutes. If a task demanded greater strength capabilities, it is important to consider the time that it will take to perform such tasks or the time it will take to maintain the peak energy levels in order to prevent muscular trauma (Karwowski and Marras, 1998; Marras, 2012; Salvendy, 2012).

Rest time: The time that a worker rest may have a meaningful effect on his or her strength capabilities. If the force requirements of a task exceed a worker's muscular capacity to exert a force, the risk of cumulative trauma is increased. Workers may experience fatigue if their energy levels are depleted faster than it can be replenished. To produce energy for muscular contractions, the body needs adenosine triphosphate (ATP). After each muscular contraction, ATP changes to adenosine diphosphate (ADP). Consequently, ADP cannot produce significant muscular contractions and must be converted to ATP to enable further muscular contractions. The conversion to ATP can only occur with the addition of oxygen, which is a key ingredient in maintaining high levels of muscular energy. Low levels of oxygen and restrictions in blood circulation may reduce muscular strength over time. However, strength capacities may be replenished if adequate rest periods were introduced. With the introduction of rest periods, the generation of muscular forces may increase as more oxygen is circulated to the muscle, which will allow ADP to be converted to ATP. The relationship between force capabilities and rest periods indicates that if the total strength of workers were to be optimized and the risk of muscular disorders were to be reduced then scheduled and frequent rest periods could be more beneficial than long infrequent ones (Karwowski and Marras, 1998; Marras, 2012; Salvendy, 2012).

2.5.4 The existence of ergonomic hazards

2.5.4.1 Introduction

According to Guild *et al.* (2001), a useful concept in understanding the occupational approach to ergonomics can be defined in terms of an "ergosystem". An "ergosystem" is based on the interaction of three different components i.e., human, machine, and environment. Occupational disorders can develop from conditions that affect the muscle, ligaments, nerves, blood vessels, joints, hands, wrists, arms, shoulders, neck, upper and lower limbs as well as the lower back of workers (Punnett and Wegman, 2004). Kroemer (1989) found that cumulative disorders often affected the soft connective tissues in particular the tendons and their sheaths, which could cause irritation or damage to nerves and might interfere with blood circulation (via arteries and veins). Such disorders occur in the hand, wrist, and forearm areas and may affect the muscle of the neck and shoulders. Kroemer further discovered that some disorders could also cause damage to the bone structure (especially the spine). Cumulative trauma disorders (CTD) is the term used to characterize disorders that are associated with discomfort, impairment, disability or persistent pain in joints, muscles, tendons, and soft tissues (irrespective if these were accompanied by physical manifestations or not).

Harmse *et al.* (2016) observed that these conditions were caused by an over or sudden exertion of force or a continued exposure to working activities that involved repetition, vibration, or awkward postures. Conditions associated with these illnesses may be classified as musculoskeletal disorders (MSD) and falls under the umbrella of work-related upper limb disorder (WRULD). Work-related upper limb disorder is a term used to classify a group of occupational disorders that comprises of MSD. As stated earlier, these hazards may affect the muscles, tendons, nerves, blood vessels, joints and bursae of the hand, wrist, arm, and shoulder. Conditions normally cause pain, swelling, and difficulty in movement. It further includes carpal tunnel syndrome (CTS), tenosynovitis, epicondylitis (elbow), tendonitis, bursitis, and trigger finger.

La Novara (1991) highlighted the need for several key approaches to occupational health and safety in the workplace, i.e., (i) health and safety which involved the use of machines or movable equipment; (ii) health and safety hazards defined in terms of four categories i.e., chemical, biological, physical, and stress"; and (iii) occupational disorders associated with long latency periods between exposure and the identification of symptoms.

2.5.4.2 Potential risk factors (that contribute to ergonomic hazards)

Guild *et al.* (2001) defined risk as the probability that an injury or damage can occur. These authors identified three main elements applicable to all risks: (a) the hazard – which is the source of or exposure to danger, (b) the likelihood that an adverse event or action can occur, and (c) the impact or severity of an event or action if it occurs. According to Guild *et al.* (2001), there is a difference between "ergonomic risk factors" and "ergonomic hazards". The aim of ergonomics is to ensure that workers have a healthy and safe work environment. Ergonomic hazards could therefore only occur in the absence of appropriate control measures. The working conditions without appropriate control measures and based on the argument of Guild *et al.* (2001), should be called ergonomic risk factors rather than ergonomic hazards. The existence of ergonomic risk factors in the workplace can be attributed to a variety of causes. Employees are at risk of developing conditions that could affect their health and well-being even beyond their working environments (Punnett and Wegman, 2004).

Tappin *et al.* (2008) recognized the following as risk factors that contribute to the occurrence and the prevalence of ergonomic hazards in today's working environment:

a) Highly paced working activities causing employees to struggle to keep up with line speeds.
b) No job or task rotation programmes causing an over exposure to risk factors.
c) Performing physically demanding tasks.
d) Inadequate space resulting in awkward postures or stretching over large travel or transfer distances.
e) Knife sharpness affecting the ease with which incisions are made.
f) No rest/recovery breaks increasing the load and intensity of working activities.
g) Inadequate design and layout of equipment and facilities.
h) Long working hours especially during peak seasons.

According to Tappin *et al.* (2008) the following diagram (Figure 2.2: Conceptual model for the role of contextual factors in meat processing musculoskeletal disorders) provides a contextual framework applicable to the meat industry and gives a layout of circumstances under which exposure to physical and psychosocial factors can occur.

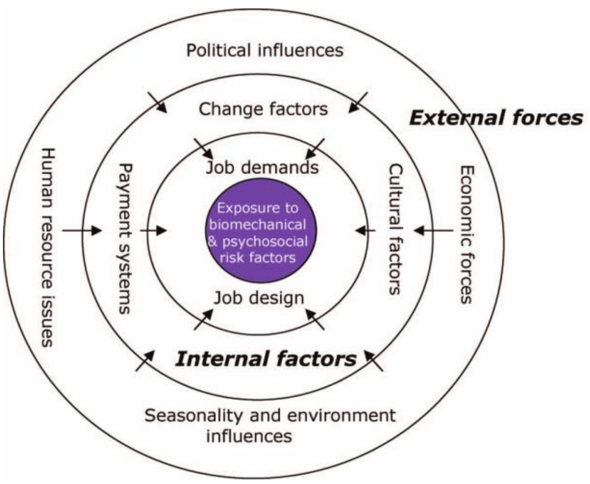
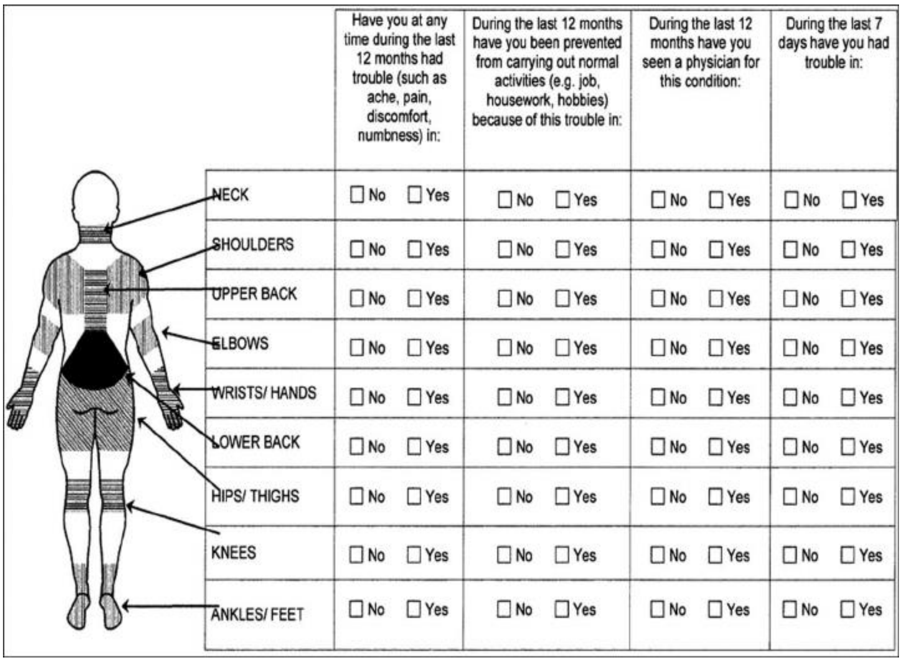


Figure 2.2: Conceptual model for the role of contextual factors in meat processing musculoskeletal disorders (Tappin *et al.*, 2008)

Musculoskeletal disorders are injuries caused by sprains, strains, tears, back pain, hurt back, soreness, carpal tunnel syndrome, and connective tissue disorders. Musculoskeletal disorder is one of the main factors that contributes to the disability burden in the workplace (Mustard *et al.,* 2014). Figure 2.3 provides an overview of the different areas of human body that may be subjected to or affected by ergonomic hazards in the workplace.



	Have you at any time during the last 12 months had trouble (such as ache, pain, discomfort, numbness) in:	During the last 12 months have you been prevented from carrying out normal activities (e.g. job, housework, hobbies) because of this trouble in:	During the last 12 months have you seen a physician for this condition:	During the last 7 days have you had trouble in:
NECK	☐ No ☐ Yes	☐ No ☐ Yes	☐ No ☐ Yes	☐ No ☐ Yes
SHOULDERS	☐ No ☐ Yes	☐ No ☐ Yes	☐ No ☐ Yes	☐ No ☐ Yes
UPPER BACK	☐ No ☐ Yes	☐ No ☐ Yes	☐ No ☐ Yes	☐ No ☐ Yes
ELBOWS	☐ No ☐ Yes	☐ No ☐ Yes	☐ No ☐ Yes	☐ No ☐ Yes
WRISTS/ HANDS	☐ No ☐ Yes	☐ No ☐ Yes	☐ No ☐ Yes	☐ No ☐ Yes
LOWER BACK	☐ No ☐ Yes	☐ No ☐ Yes	☐ No ☐ Yes	☐ No ☐ Yes
HIPS/ THIGHS	☐ No ☐ Yes	☐ No ☐ Yes	☐ No ☐ Yes	☐ No ☐ Yes
KNEES	☐ No ☐ Yes	☐ No ☐ Yes	☐ No ☐ Yes	☐ No ☐ Yes
ANKLES/ FEET	☐ No ☐ Yes	☐ No ☐ Yes	☐ No ☐ Yes	☐ No ☐ Yes

Figure 2.3: Strain assessment based on the Nordic Musculoskeletal questionnaire (Franasiak *et al.,* 2014)

2.5.4.3 The nature of ergonomic risk factors

a) The design of hand tools

According to Johnson (1990) hand tools (i.e., the handle in particular) connected the worker with his or her work. The use of hand tools could contribute to cumulative disorders in the workplace (Vyas *et al.,* 2016). The knife was one of the most basic and essential hand tools used within the meat industry (Stoy and Aspen, 1999; Szabo *et al.,* 2001; Marsot *et al.,* 2007). With specific reference to the South African meat industry, the knife remains one of the primary tools used (Harmse *et al.,* 2016).

The shape of a handle can affect the comfort and the usability of hand tools and the anatomical design of hand tools is a key feature in terms of its overall safety (Lewis and Narayan, 1993; Bisht and Khan, 2017). Patkin (2001) proposed that hand tool handles should be at least 10 to 15 centimetres in length and fit in the width of the palm. The handle diameter should be between 3 to 4 centimetres and permit the thumb to cover the end of the index and middle fingers. However, Bisht and Khan

(2017) found that a handle diameter of 3.5 centimetres was more comfortable to use than a 4.1 centimetre handle. In a study by Vyas *et al.* (2016) it was discovered that any inadequacies in handle design (i.e., inadequate handle sizes) could lead to increased strain on the hand and wrist. Hand tool handles should be designed with small contours to coincide with the curves of the transverse palmar arch (as seen in Figure 4(a): Palmar arch) and follow the natural palmar curve to allow the fingers to flex toward the palm (as depicted in Figure 4(b): Palmar creases and flexor zones). This will allow for the even distribution of force in the hand and across all the digits (Johnson, 1990).

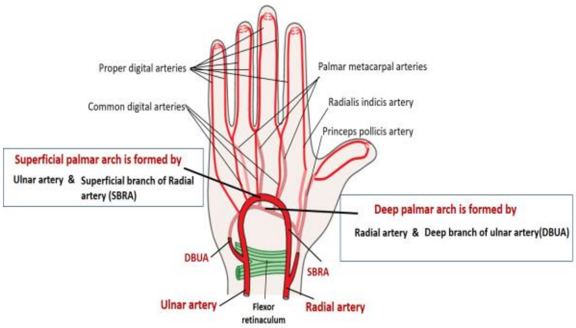


Figure 2.4(a): Palmar arch (Anatomy QA, 2018)

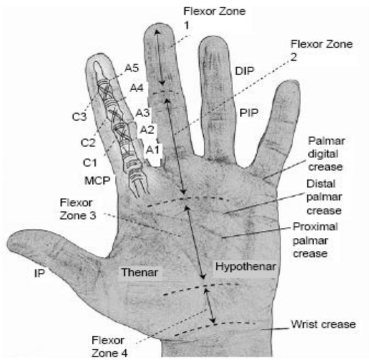


Figure 2.4(b): Palmar creases and flexor zones of the hand (Feldhacker *et al.,* 2021)

Johnson (1990) further indicated that the use of digit separators during handle profiling could become a design deficiency. Handle profiling can limit the use of the hand and might affect the comfortability with which hand tools are grasped or gripped. According to Johnson (1990) any deficiencies in handle design could increase the risk of joint capsule injury, trigger finger, and neurovascular injuries due to the degree of compression caused by the digit separators (as seen in Figure 2.5: Profiled handles with finger separators).

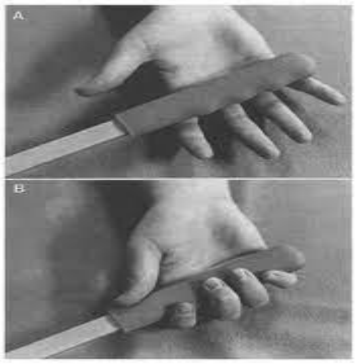


Figure 2.5: Profiled handles with finger separators (Johnson, 1990)

Kadefors *et al.* (1993) and Aptel *et al.* (2002) thought well-designed hand tools helped to mitigate work-related injuries of the hand, wrist, or forearm, which included nerve entrapment, epicondylitis, peritendinitis of the forearm, tenosynovitis, and neuritis of wrists or fingers. Kurpa *et al.* (1979) identified overexertion, sprains, or blunt trauma as the main causes of peritendinitis and tenosynovitis. Leclerc *et al.* (2004) found that the use of hand tools contributed to the burden of injuries in the meat industry. The study determined that: (a) rapid hand motions; (b) repetitive bending and twisting of the hands and wrists; (c) fast pace of work; (d) repetitive grasping; and (e) mechanical strain at the base of the palm were critical risk factors inherent to the meat industry.

The research by Grant *et al.* (1992) and McDowell *et al.* (2012) revealed that the size of the worker's hand in relation to the size of the handle were important factors to consider when designing hand tools. According to Drury (1980), a well-designed handle will allow a worker's hand to curve at least 120° around it and will minimize muscular fatigue. In another study, Bisht and Khan (2017) discovered that designing hand tools to a given hand size may create challenges to workers with different hand sizes. Fransson-Hall and Kilbom (1993) highlighted that the use of finger grooves on handles could increase the external pressure applied to the interphalangeal joints of the fingers.

b) Knife sharpness and cutting force requirements

In their study, Savescu *et al.* (2018) indicated that maintaining a sharp knife is one of the key factors that could affect a worker's performance and that workers used "steeling" to maintain the sharpness of their knives during and between meat cutting operations. The work of McGorry *et al.* (2003) highlighted that knife sharpness could affect a worker's gripping technique as well as the total force requirements during cutting operations. Consequently, the use of a blunt knife may require greater cutting forces and may increase the level of strain on a worker's tendons, joints, and nerve endings (Szabo *et al.,* 2001). According to Karltun *et al.* (2016), the degree of knife sharpness could affect the level of exertion in the affected muscle or joints. This may cause workers to adjust their working techniques and could result in the development of different or new patterns of discomfort. Savescu *et al.* (2018) held the view that a knife's cutting ability may be influenced by many factors, including sharpening and steeling operations. In assessing the impact of two different "steeling" frequencies, Szabo *et al.* (2001) discovered that infrequent steeling could result in a 15% increase in cutting force requirements for shorter cycles and a 30% increase in cutting force requirements for longer cycles. Savescu *et al.* (2018) believed that the method of steeling, the type of tool used as well as the overall setup to accommodate the sharpening process may all affect knife sharpness. The authors were of the view that steeling and knife-sharpening activities were extensions of the normal working activities and must form part of risk prevention programmes.

Marsot *et al.* (2007) assessed the effects of steel grade, blade inclination, and edge angle on the performance of knives (using distinct categories of steel grades, i.e., grades 1, 2, and 3). The study revealed that steel grade had no significant impact on the cutting capacities of knives. However, Marsot *et al.* (2007) found that if blade quality declined, it increased the maximum force necessary to perform cutting operations (Figure 2.6: Cutting force mean values and standard deviations). These authors discovered that the knife that comprised of steel grade 3 showed remarkably low signs of wear with marginal increases in the total force requirements. In their study Marsot *et al.* (2007) further stated that blade inclination brought about a reduction in the cutting force applied from 26.8N to 14.6N at inclines of 0° and 30° (which prompted a decrease of 33% in the total force applied). This study also highlighted that blades should ideally be inclined at 15° angles in relation to its handles and recommended the use of knives that consisted of curved blades because the curved blade could decrease the cutting force by increasing the cutting angle.

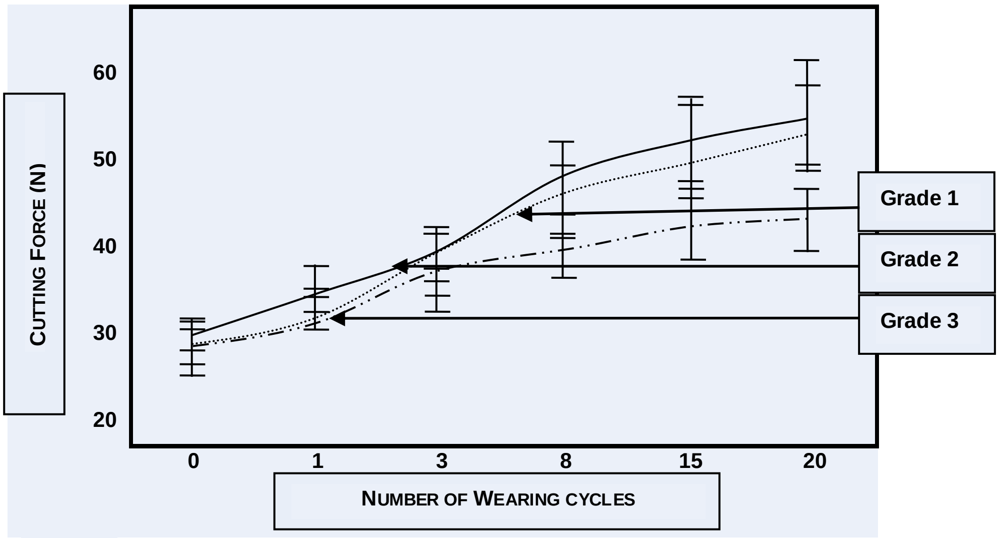


Figure 2.6: Cutting force mean values and standard deviations (steel grade and wear cycle) (Marsot *et al.*, 2007)

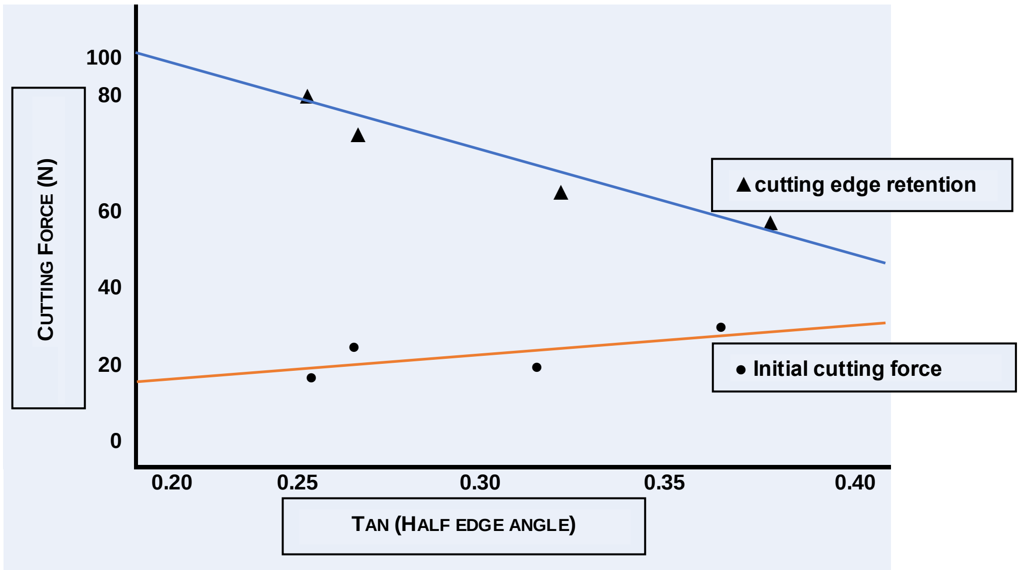


Figure 2.7: Average value and standard deviation of cutting force (Marsot *et al.*, 2007)

Blade finishing could play an important role in maintaining a sharp knife. However, the condition of the blade might contribute to the pace and precision with which manual cutting tasks are performed. The blade condition might also affect productivity as well as product quality and influence the total force requirements of cutting operations (Szabo *et al.,* 2001). McCarthy *et al.* (2007) and McCarthy *et al.* (2010) stated that the sharpness of cutting blades could influence the magnitude of forces generated during cutting operations. McGorry *et al.* (2005) showed that cutting time, peak grip forces, and mean grip forces as well as cutting moments decreased if the quality of blade finishing increased. The study revealed that blade finishing can contribute to the reduction of grip force (by 19.4%), cutting moments (by 18.0%) and cutting times (by 21.5%). These authors also highlighted that the use of fine stone for the sharpening of blades together with a refining agent could effectively reduce the time needed to make a cut (25.3%), the average grip force (21.2%), maximum grip force (25.5%), average cutting moments (28.4%), and peak cutting moments (26.9%). McGorry *et al.* (2005) concluded that adequate blade finishing could improve the effectiveness of knife usage i.e., reducing cutting moments and gripping forces (Figure 2.7: Average value and standard deviation of cutting forces above). According to Szabo *et al.* (2001), increases in cutting force requirements could trigger the onset of fatigue and contribute to a higher risk of muscular injuries.

c) Hand and grip force requirements

A study by Seethamma *et al.* (2019) found that, regardless of the age or gender of workers, handgrip strength was influenced by hand length and forearm circumference. However, Stoy and Aspen (1999) showed that age and gender played a key role in determining the maximum grip strength of a worker. Hand gripping activities that prompt the use of the flexion and extension muscular structures could generate considerable force in the affected tissue (Hägg and Milerad, 1997). The gripping of hand tools may generate a "clamp-like force" in the hand or wrist. Moreover, performing repetitive and forceful working activities can increase the risk of musculoskeletal disorders, which could affect the muscles, joints, and bones in the hand-wrist-arm structure (Dong *et al.,* 2008).

The most common grip used when operating hand tools is the power grip. In the power grip, the fingers are firmly placed around the handle and are overlapped by the thumb (Sancho-Bru *et al.,* 2003). When using the power grip, the thickness of the handle will ensure that, the fingertips do not touch the palm of the hand (Patkin, 2001). Drury (1980) believed that the type of handle used could influence the type of grip applied. Figure 2.8 represents a diagrammatic illustration of the power and precision gripping techniques.

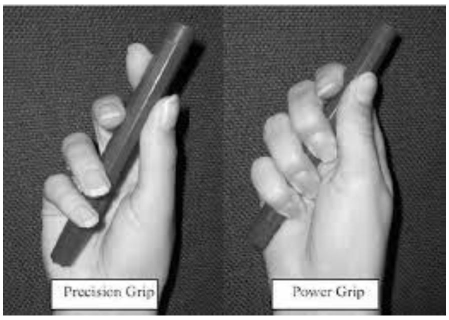


Figure 2.8: Power and precision grip (Tomlinson *et al.,* 2007)

In a study on the impact of handles, Grant *et al.* (1992) reported that the strength of a worker's grip was influenced by the size of the handle and that a worker's grip force decreased if the diameter of the handle increased. Three different handle sizes were used in this study, which comprised of smaller, fit, and larger (Figure 2.9: Maximum grip strength as a function of handle diameter). Grant *et al.* (1992) revealed that the force needed to use the different sizes varied significantly with less force required to use the smaller handle. That study further revealed that there was a 39% increase in grip strength for every 1 centimetre reduction in handle size. In another study, Bobjer *et al.* (1993) highlighted that workers with weak hands or weak grasps could benefit from using hand tools that consisted of high friction handles. The authors were of the opinion that in the meat industry the need for optimum friction were more important than in other industries and that most injuries were caused by using slippery hand tools. Consequently, the study of Bobjer *et al.* (1993) also showed that workers risked causing serious damage to tendons or muscular tissue if they used excessive grip force to limit the risk of tool slippage. Habibi *et al.* (2013) identified workload as a key element that affected grip or pinch strength and highlighted that moderate to heavy workloads decreased grip and pinch strengths.

Figure 2.9: Maximum grip strength as a function of handle diameter (Grant *et al.,* 1992)

In assessing the impact that hand-gripping activities had on shoulder muscle activity, Sporrong *et al.* (1996) discovered a relationship between the supraspinatus and the infraspinatus muscles. The study showed a correlation between the degree of muscle activity in the shoulder and the force applied during hand gripping activities (for different arm positions). In a different study, Tirloni *et al.* (2020) revealed that workers, when performing cutting tasks, frequently flexed or extended their wrists to maintain control over their hand tools. This, together with gripping their knives and using their index fingers extended forward as if to guide the tip of the knife, could result in a reduction of the total force used to hold or operate knives.

Fransson-Hall and Kilbom (1993), in assessing the sensitivity of the hand-to-surface pressure, discovered that high contact forces and small contact areas could lead to increased localized pressures in the hand. The study further revealed that the nerve endings supplying the fingers were relatively unprotected and could become exposed to the external forces required to hold or operate hand tools. The diagrams below provide a brief depiction of some of the most common flexing or extension positions involved in the use of the hand or wrist (highlighting associated risk positions). Figure 2.10 depicts the various strength requirements applicable to different wrist positions and Figure 2.11 depicts different wrist positions.

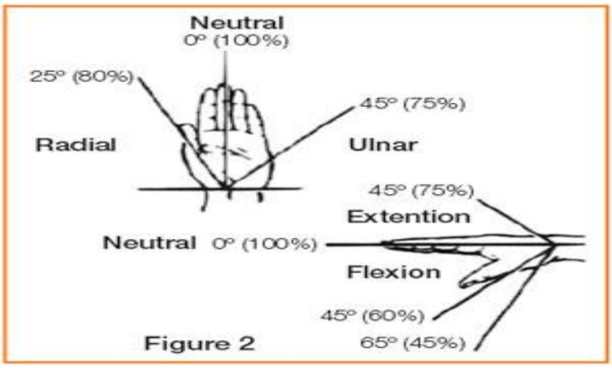


Figure 2.10: Wrist strength and position (Ebben, 2023)

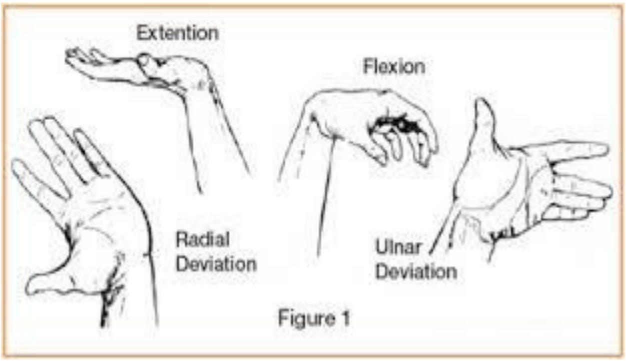


Figure 2.11: Wrist positions (Ebben, 2023)

According to Imrhan (1991) any repetitive work requiring excessive and regular deviations of the wrist or requiring finger flexion exertion could increase the risk of cumulative tissue disorders. The study highlighted that the wrist plays a key role in maintaining grip and pinch force capabilities in the hand and the fingers and that the position of the wrist may affect the strength of the finger flexors (for power grips and pinch grip). Terrell and Purswell (1976) stated that grip strength could be considerably decreased if the wrist deviates from the neutral position. On the other hand, Imrhan (1991) argued that when using the power grip, the grip strength was greatest when the wrist was in the neutral position. This author further declared that pinching with the wrist in a deviated position could also contribute to the occurrence of muscular disorders in the hand. Figure 2.12 shows a breakdown of terminology used when referring to the movement of the hand and wrist.

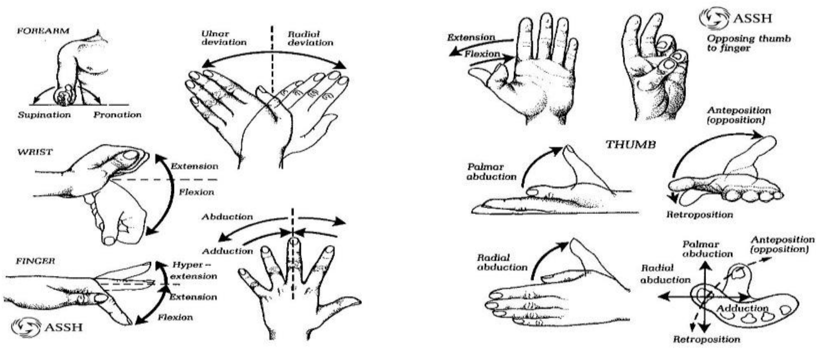


Figure 2.12: Motion Terminology your Surgeon may use (Rochester Hand Center, 2007)

In their research, Fransson-Hall and Kilbom (1993) showed that the thenar musculature, the area around the os pisiforme and the skin fold between the thumb and the index finger are some of the most sensitive regions of the hand. According to Nicholas *et al.* (2012), an increase in the level of exertion in the hand could lead to increased and greater hand contact area with underlying surfaces. An increase in the external pressure on the hand could result in hand surface changes as well as changes in tissue distribution. According to Fransson-Hall and Kilbom (1993), externally applied surface pressure (EASP) of approximately 10 kPa, if applied for longer than 1 hour, could be harmful to human tissue. The exertion of EASP on the hand is subject to the force needed to grip, hold, and operate hand tools. They concluded that the use of hand tools would always result in the application of external pressures on the hand and fingers, which could give rise to disorders of the hand or wrist.

Ross (1994) found that specific occupational hazards could lead to gradual micro-trauma of the underlying structures of the hand or wrist. Micro-trauma can cause swelling of the tendons in the wrist that can result in the compression of the median nerve. Arciniega-Rocha *et al.* (2023) identified repetitive movement and adopting poor hand-wrist positions as some of the main causes of cumulative trauma to the hand or wrist. According to Ross (1994) the continuous flexing and extension of hand or wrist, ulnar deviation, forceful gripping (with palms up), and any movement of the hand from a palm's up to a palm's down position may increase the risk of injuries. Workers may experience a degree of numbness in the fingers supplied by the median nerve, which may cause discomfort or a burning sensation in the hand or wrist. Ross (1994) further stated that if the exposure continues, it might aggravate the situation and result in the loss of grip strength, inflammation of the hand and the arm, and even weakening of the muscle. Fakoya *et al.* (2023) stated that workers can also be exposed to De Quervain's syndrome, a condition caused by continuous friction created between the tendons and their common sheath. This condition could develop from the forceful twisting and gripping of the hand or wrist and may cause severe pain in the wrist, which could result in a sudden loss of strength.

d) Working areas and working postures

Some of the key aspects that could also contribute to the existence of ergonomic hazards in the workplace include the design and application of working procedures, the equipment and tools used in the performance of different tasks, and the design and layout of working environments (IEA, no date). Figure 2.13 provides a breakdown of the different aspects that may relate to the field of ergonomics.

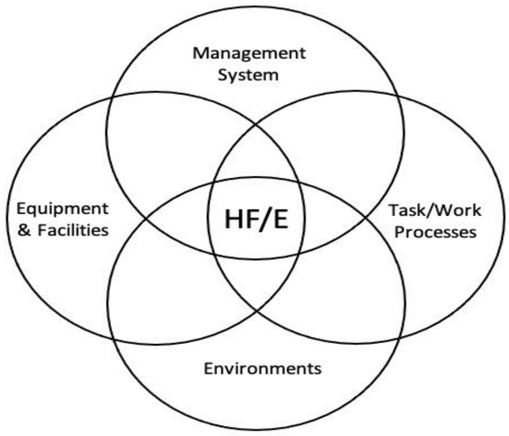


Figure 2.13: Participatory Ergonomics

(*Source:* https://iea.cc/about/what-is-ergonomics/)

According to Tappin *et al.* (2008), inadequate working areas may force workers to adopt poor postures, which could give rise to the development of muscular disorders. In the meat industry, working areas are identified as crammed or cramped (Human Rights Watch (HWR), 2019). Vieira and Kumar (2004) highlighted that the ideal working posture may not exist and that even at low levels of constant muscular activity, workers could still face the risk of musculoskeletal injuries. The authors indicated that working activities that require workers to adopt different working postures, could affect the maximum strength that a worker can generate during a day or shift. A worker’s maximum strength could be affected by the total workload, which might be influenced by the layout of workstations, the nature of tasks performed, and the kind of tools used. In light of the research conducted by Harmse *et al.* (2016) employees must perform their duties within a “comfort zone” and workstations should be adequately designed to prevent the adoption of poor or awkward body postures.

In a study on the impact of muscular disorders among fish trimmers, Quansah (2005) identified that deficiencies in the design and layout of workplaces contributed to the adoption of poor or awkward postures. The author highlighted the following high-risk working postures associated with deficient workplace designs: (a) flexed neck; (b) neck bended to the side; (c) abducted arms; (d) constantly stretching or reaching forward; (e) using of shoulders in elevated position; (f) having wrists deviated from neutral position; (g) flexing of torso; and (h) conducting working activities above or below waist level. In addition to the above, Quansah (2005) showed that inappropriate height clearances often resulted in workers having to adopt cramped or hunched postures, which could contribute to the existence of muscular disorders. Thun *et al.* (2011) believed that working areas should make provision for sufficient space to allow employees to move their arms and legs when executing their duties.

They believed that the space requirements applicable to working areas must provide for adequate reaching or transfer distances necessary for the performance of designated tasks. Figure 2.14 provides an overview of the different muscles involved in arm movement as well as the identification of the different movement planes.

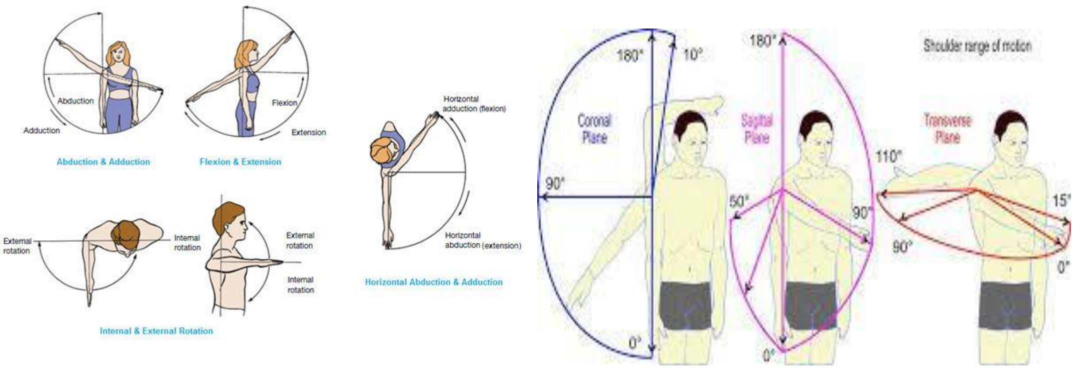


Figure 2.14: Muscles that move the arm [American Council on Exercise (ACE), 2017] and the plane identification (*Source:* https://www.towsonsportsmedicine.com/wp-content/uploads/Shoulder-Exam-ppt-SDAS.pdf

Vieira and Kumar (2004) and Marras (2012) were of the view that the biomechanical alignment, the available space as well as the body position of a worker were key factors that could affect the most basic working postures. Manchikanti *et al.* (2014) stated that workers who maintained static postures for extensively long periods could experience adverse health effects. According to Waters and Dick (2015) these could include lower back pain, fatigue, muscular pain, swelling of the legs, and discomfort of various parts of the body. Vieira and Kumar (2004) also indicated that prolonged standing could cause compression of the veins and capillaries inside the affected tissue. In addition, these authors highlighted that the lack of sufficient oxygen and nutrient supplies may give rise to the development of micro-lesions in the affected muscle and that the constant loading of the spine could have a cumulative effect on the musculoskeletal structure of the back. Shaikh and Shelke (2016), in their review of the effect of prolonged standing at work, highlighted that any working activities that required workers to stand for at least 1 hour without adequate rest could affect their health and well-being.

The adoption of poor working postures could contribute to disorders in the neck, shoulder, arms, hips, and knees (Vieira and Kumar, 2004; Quansah, 2005). Vieira and Kumar (2004) revealed that the flexing of the back at an angle greater than 60° for more than 5% of the working time per day could significantly increase the risk of lower back disorders. Likewise, the rotation of the back at an angle greater than 30°

and for more than 10% of the working time increases the risk and occurrence of low back pain. The study by Mukhopadhyay and Khan (2015) showed that the spine worked harder if it is used in side bending (at 30° angles) and if it is twisted (at 15° angles). Ross (1994) understood that workers may experience cumulative back trauma if they: (a) twist their back at the waist; (b) bend and reach continuously; (c) maintain awkward postures for extensive periods of time; and (d) carry, push, pull, or lift heavy objects below the knees or above the shoulders. Ross (1994) further stated that repeated trauma to the back could lead to permanent scarring or weakening of ligaments, disks, muscles, or tendons. Kroemer (1989) believed that if muscle tissue contracted for more than 15 % to 20% of their maximum capacity, it could result in tissue ischemia and might cause delays in the removal of metabolites, which could increase the physiological stress on the body.

Das and Sengupta (2000) pointed out that mild and severe flexing of the back for more than 10% of the normal working time could increase the risks associated with lower back pain. Subsequently, the adoption of non-neutral postures like twisting or twisting and bending of the back was, according to Das and Sengupta (2000), considered greater risk factors for lower back pain. Figure 2.15 provides a brief overview of the positions that may be adopted by workers during the performance of working activities within different working environments.

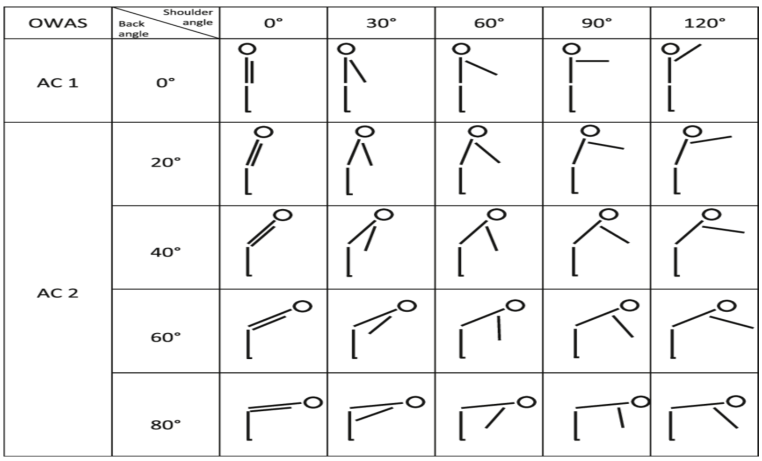


Figure 2.15: Working postures effect on muscle activity (Hellig *et al.,* 2018)

Zadry *et al.* (2011) identified that light repetitive tasks, which were classified as low intensity work, could increase the risk of neck and shoulder disorders. The design and layout of working areas, which require workers to adopt a forward posture with the head and neck can increase the risk of temporomandibular-, neck-, and back pain or disorders (Vieira and Kumar, 2004). Figure 2.16 is a brief depiction of the impact that different flexing positions may have on the structure of the neck.

Figure 2.16: Text neck syndrome (David *et al.,* 2021)

Mukhopadhyay and Khan (2015) discovered that adopting a static working posture for 75% of the time and having the neck flexed at an angle greater than 15° could increase the risk of muscular disorders of the neck. Vieira and Kumar (2004) were of the opinion that the flexing of the neck at angles greater than 15° for 97% of the time and flexing of the neck at angles greater than 30° for 82% of the time may cause serious muscular disorders of the neck.

e) *Physical task requirements*

According to Vieira and Kumar (2004) and Van Nieuwenhuyse *et al.* (2006) a worker's posture, range of movement, force requirements, repetitive work, and shift duration (time spent working) are all aspects that could affect their level of physical exertion. Figure 2.17 (a) and (b) below provide a brief breakdown of the range of movements applicable to different reaching activities.

Figure 2.17(a): Reach zones (Davincenzo, 2018)

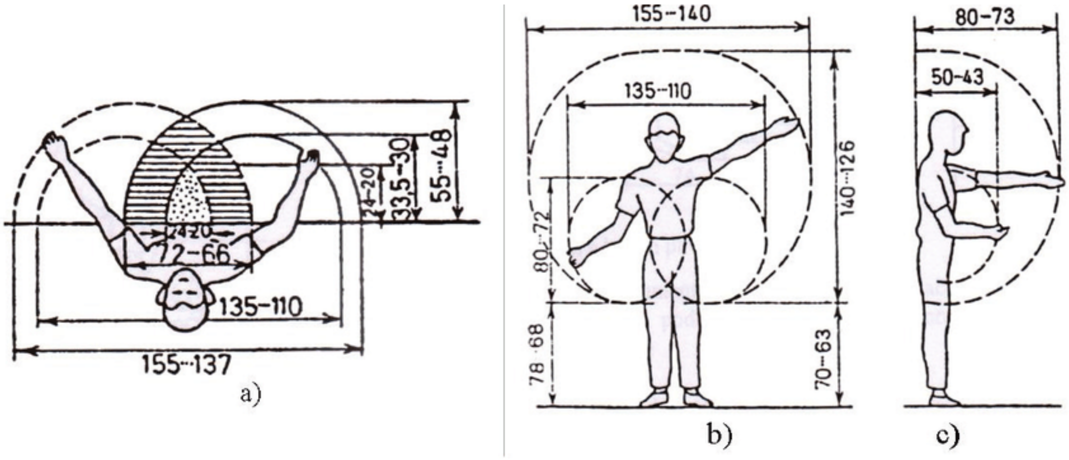


Figure 2.17(b): Zones of normal and maximal arm reach (Sumpor *et al.,* 2015)

Physical exertion provides an overview of the mechanical load to which a worker may be subjected during the performance of his or her work. The degree of physical exertion experienced by workers may be directly related to the biomechanical forces that are generated in the body and could be affected by the degree, the frequency, and the duration of working activities (Vieira and Kumar, 2004). A clear relationship might therefore exist between the performance of repetitive tasks and the prevalence of muscle fatigue (Zadry *et al.,* 2011). Nonetheless, Wartenberg *et al.* (2004) discovered that a distinction exists between muscular fatigue and mental fatigue. Muscular fatigue focuses on the effects of reduced muscular performance, the consequences of impaired task co-ordination and the increased risk of errors or accidents. Mental fatigue is perceived to be the outcome of a slow but cumulative process linked to reduced effort, efficiency, attentiveness, and mental performance. Wartenberg *et al.* (2004) also indicated that the impact of time pressure, the lack of influence over work, and the performance of constant but short repetitive tasks contributed to the risks of muscular and mental fatigue among employees.

Punnett *et al.* (2005) discovered that: (a) the pace of work; (b) repetitive motions; (c) insufficient recovery time; (d) forceful manual exertions; (e) non-neutral body postures; (f) mechanical pressure concentrations; (g) vibration; and (h) low temperatures were some of the most common risk factors that affected workers in the meat industry. According to Mishra *et al.* (1995), a low to moderate force as part of a highly repetitive task could increase the risk of muscular tension, if the force were distributed across fewer muscle fibres. The work of Marras (2000) highlighted that forces that act on the lower back muscle are either internal or external in nature. These forces can be classified as compression, shear, or torsion forces. The external forces together with the forces of gravity acts on the object and on the body. The internal forces however act on the spine and is the result of the body's reaction to the effects of the external forces. Internal forces are normally greater in magnitude than the external forces. Marras (2000) further stated that the load, level, repetition, time of day, and the posture of the spine are factors that could affect the incidence of occupational injuries. Figure 2.18(a) provides an overview of both natural and awkward body positions, while Figure 2.18(b) provides a depiction of different body postures adopted by workers in the construction sector.

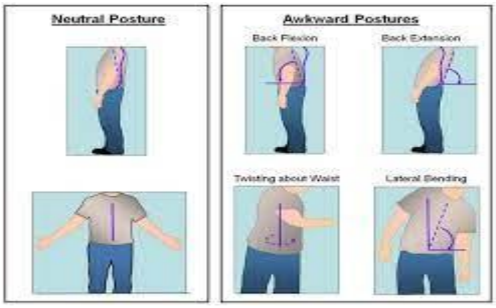


Figure 2.18(a): Neutral and awkward back positions (Middlesworth, 2023c)

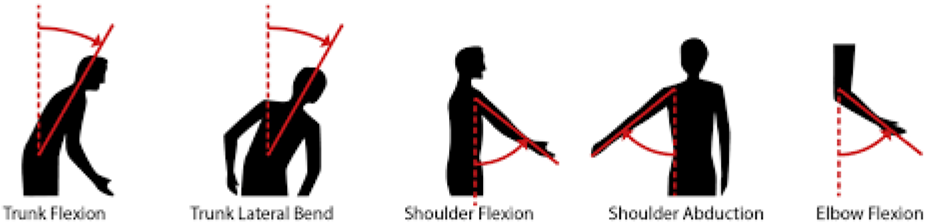


Figure 2.18(b): Ergonomic analysis of construction workers' body postures using wearable mobile sensors (Nath *et al.,* 2017)

Garg and Kapellusch (2009) understood that injuries to the spine or muscle may occur if the physical requirement of the job exceeded the job-specific strength of the worker. Subsequently, weaker individuals could be at greater risk of developing lower back injuries in comparison to their stronger co-workers. The continuous strain on the spine might cause lower back pain and lead to muscle fatigue. These authors further believed that injuries to the spine or muscle could be caused by a constant but relatively low force or by a sustained force applied over an extended period. Lower forces therefore result in higher muscular stresses that may result in moderate injuries to the affected tissue.

Working activities that required workers to work with their arms in an elevated position or adopting extreme arm positions for an extended period could increase the risk of developing tendonitis of the shoulders. Awkward arm positions may increase worker fatigue, which could limit a worker's ability to do lightweight manual tasks (Garg and Kapellusch, 2009). If a worker continues to work with the arms in a constantly flexed position, it significantly increases the risk of damage to or compression of the ulnar nerve. Flexed arm positions may also cause damage to the tendons that are responsible for maintaining the stability and mobility of the shoulders. The compression of the nerves and blood vessels in the shoulder may lead to numbness of the hand and arm (Ross, 1994). According to Kroemer (1989) the inward or outward movement of the forearm and maintaining a bent wrist or deviating the wrist from the normal position may cause considerable strain on the muscles of the shoulder and arm. Sporrong *et al.* (1996) stated that overloading of the supraspinatus muscle might lead to shoulder peritendinitis or impingement. Overhead work could cause heavy static loading of the supraspinatus muscle. The authors highlighted that of all the shoulder muscle types assessed, the supraspinatus muscle was the first to show signs of muscular fatigue which increased the risk of muscular disorders (Figure 2.19: Rotator cuff tendonitis).

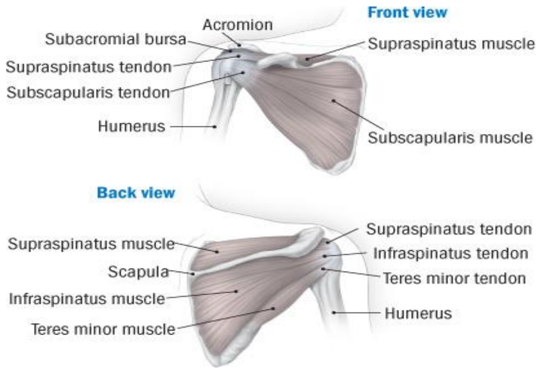


Figure 2.19: Rotator cuff tendonitis (HHP, 2021)

Figure 2.20 provides risk factors involved in the use of arms or shoulders that may be required during working activities.

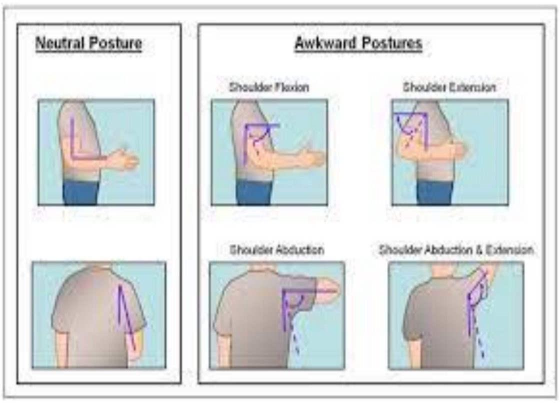


Figure 2.20: Neutral and awkward shoulder positions (Middlesworth, 2023c)

The adoption of non-neutral postures may increase the risk of muscular disorders of the back, neck or shoulders (Schall *et al.,* 2016). Vieira and Kumar (2004) determined that work performed with the hands at or above the shoulders might cause significant levels of discomfort in the shoulders. They subsequently discovered that working with the arms in an abducted position and at an angle greater than 30° for more than a third of the working time, could cause high levels of shoulder pain. Intramuscular pressure may affect the function of the infra- and supraspinatus muscle. Vieira and Kumar (2004), further highlighted that the position of the hand or the arm including the various loads applicable, played a pivotal role in regulating the pressures in the infra- and supraspinatus muscle. The direct increase in muscular pressure of the arm could be affected by deviations of the arm from its neutral position (0°) to 90° in both flexion and abduction directions. According to Harmse *et al.* (2016) a worker's wrist and elbow activity must ideally be close to the neutral position (as indicated in Figure 2.19) and that work must be conducted within approximately 450 mm from the worker's body line. Grant and Habes (1997) illustrated that the force and gripping techniques used by workers were affected by the direction of the cutting motion. The *vertical force* requirements are said to be greatest at heights closer to the mid-line (top to bottom) and the *horizontal force* requirements are said to be significantly affected by the distance from the body as well as the worker's grip.

f) Rest or recovery breaks

Muscular disorders of the lower back, the knees, and the ankles may be caused by having to work in a standing position for extensively long periods with no or little rest or recovery breaks. Prolonged standing eventually restricts blood circulation in the lower limbs and may result in increased loading of the back. Working activities that require workers to stand for approximately 25% – 50% of their working time (of an eight-hour shift or day) could lead to trauma in the lower back, legs, and feet (Vieira and Kumar, 2004; Quansah, 2005; Waters and Dick, 2015). The continued axial loading of the spine can cause severe strain on the intervertebral discs. Control measures aimed at preventing injuries should therefore not only reduce workload intensities, but also limit the risk of exposure by increasing the recovery time. Suitable rest or recovery systems ought to be implemented to effectively reduce or prevent occupational hazards in the workplace (Van Dieen and Oude Vrielink, 1998). Work-rest schedules should assist in determining the duration of work and the frequency of recovery time. An effective work-rest system should therefore aim to increase productivity and reduce the risk of occupational injuries (Mientjes, 2000).

A study by Van Dieen and Oude Vrielink (1998) assessed the impact of different work-rest schedules and its effects on postural workload (in the poultry industry). A standard work-rest schedule of 30 minutes work and 30 minutes break were in use for poultry meat inspectors. The following work-rest schedules were developed and tested: (a) 30 minutes shift and a 30 minutes break (30 ± 30); (b) 30 minutes shift and a 15 minutes break (30 ± 15); (c) 45 minutes shift and a 15 minutes break (45 ± 15); and (d) 60 minutes shift and a 15 minutes break (60 ± 15). The (60 ± 15) work-rest schedule showed an increased risk associated with greater load and increased muscular fatigue. The outcomes of the study showed that a reduction in spinal load or muscular fatigue were only possible if more frequent and shorter breaks were introduced. Subsequently, a different approach may be necessary to address the challenges of lower extremity disorders.

In another study on the assessment of different work/recovery ratios, Mientjes (2000) used 25/35, 40/20, and 55/5 second work/recovery ratios. This means that for every 25-, 40-, or 55 seconds of work, a period of 35-, 20-, or 5 seconds are allowed for recovery within a one-minute cycle. Muscular fatigue was common among all the workers involved in the study. The study revealed that changes in the body postures (as adopted by employees) could also assist in reducing the risk of muscular discomfort, pain, or injury. However, although the level of risk was different for each of the work/recovery ratios, all work ratios could contribute to discomfort among workers based on the duration of exposure. The author discovered that the level of muscular fatigue shown during the 35/25 and 40/20 second work/recovery schedules were marginally less than the 55/5 second work/recovery ratio. Subsequently, the study also revealed that workers experienced a greater level of discomfort during the 55/5 second/minute work/recovery ratio than the 35/25 and 40/20 second work/recovery ratios. Figure 2.21 provides an overview of the relationship between fatigue and recovery.

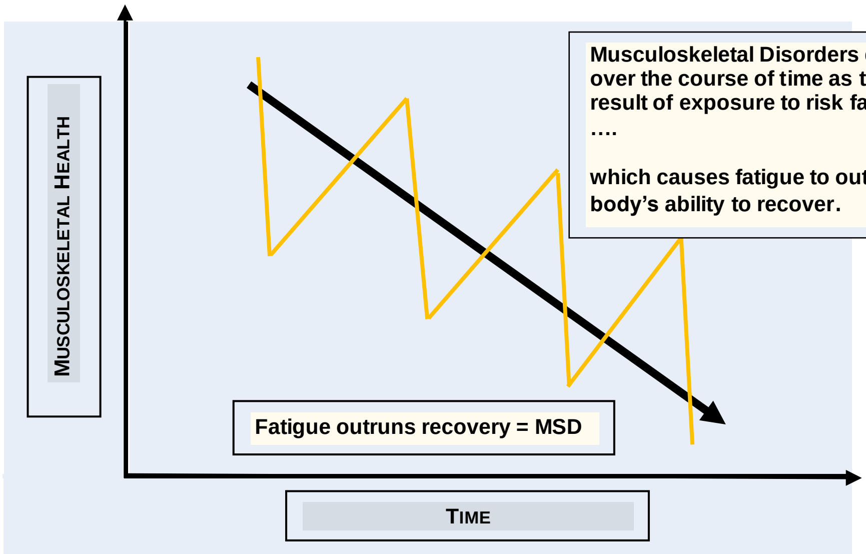


Figure 2.21: Fatigue vs recovery (Middlesworth, 2023b)

The impact of external pressures on a worker's body are rarely evident at once but may only surface after some time. Thus, it was discovered that low external pressures if applied for long periods could induce more tissue damage than high external pressure applied over a shorter period. Work should therefore be organized in such a way that workers are allowed to obtain intervals of relief between the varying degrees of exposures. The duration of exposure to any external pressure must therefore be controlled (Fransson-Hall and Kilbom, 1993). Figure 2.22 provides an outline of the impact that recovery may have on the health and well-being of a worker.

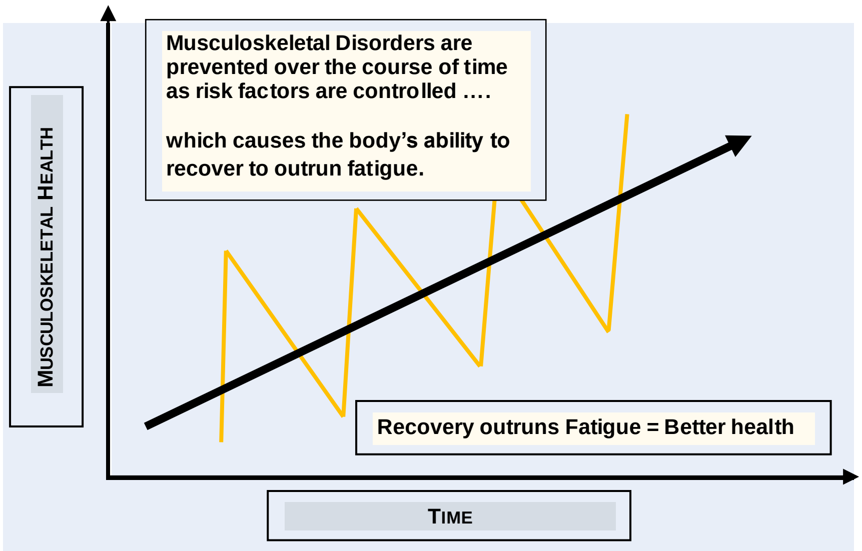


Figure 2.22: Recovery vs fatigue (Middlesworth, 2023b)

Park and Kim (2020) discovered that workers who had sufficient time to rest or to recover were less likely to report musculoskeletal disorders or symptoms. Muscular disorders were more likely to occur when workers were constantly fatigued without being given adequate recovery time. It is understood that long working hours do not necessarily lead to shorter resting periods, but that extensively long working schedules could in fact lead to limited rest or recovery breaks. The study revealed that women were more likely to report the incidence of muscular disorders than men. It can be argued that men might find it socially unacceptable to report pain or that woman are expected to have a lower pain threshold than their counterparts. Furthermore, symptoms of muscular disorders may also be associated with age and could be because older workers were more likely to develop reduced muscular strength or elasticity. In addition, the study highlighted that service and sales workers reported lower extremity pain due to the fact that they performed most of their tasks in a standing position (and for most part of the day).

g) *Task or job rotation*

Task or job rotation may be defined as the lateral transfer or movement of employees between various functions or tasks within a job. Each task requires a specific but different set of skills and responsibilities and is often performed for a specified period (Huang, 1999). Frazer *et al.* (2003) stated that the main objective of any job rotation programme is to mitigate the risks associated with fatigue and muscular tension. It should therefore follow a set of clearly defined intervals (applicable to any given day) aimed at adequately reducing the level of risk faced by employees. These authors believed that a job rotation programme in which a worker is deemed to use the same set of muscle or joints to perform a variety of different tasks cannot be expected to effectively reduce the level of risk. A reduction of the average time that a worker may be exposed to a specific workload could result in a reduction of the physical exertion experienced by the worker. Subsequently, Frazer *et al.* (2003) indicated that spreading high workloads among a larger number of workers instead of having the same worker continuously exposed to higher levels of risk would provide the opportunity to divide the total risk among the entire workforce and to reduce the overall risks to the individual.

Regardless of the arguments in favour of job or task rotation, some research indicated that task or job rotation may not necessarily reduce the risk of occupational injuries. While a comprehensive rotation system may uniformly distribute the cumulative load (among workers), the individual employees that participate in such a rotation system may face the risk of injury or over exposure to such risks. It is therefore important that the effects of job rotation and the risk of injury be fully assessed to determine the potential and cumulative effect of these risk factors (Frazer *et al.,* 2003). Jorgensen *et al.* (2005) identified medical restrictions, decreased product quality and a lack of jobs as major limitations to the successful implementation of an effective job rotation programme. The fundamental purpose of job rotation strategies focusses on rotating workers between tasks for a specific time and to reduce the biomechanical loading on a particular part of the body. Thus, the success of a job rotation system therefore depends on the extent to which biomechanical stressors are balanced throughout the worker’s body.

Schneider *et al.* (2005) highlighted that some of the key aspects to be considered in developing an effective rotation system included: (a) potential jobs; (b) the number of employees that will be affected; (c) the duration of work; and (d) the frequency of rotation. As much as it is important to meet the productivity requirement and maintain high quality, it is imperative that any exposure to occupational health and safety risks be reduced. To achieve this, the risk factors must be quantified in terms of the affected body regions, i.e., upper extremities, lower back, shoulder, neck, knee, and lower extremities. An optimal rotation system must make provision for workers to rotate between high and low risk jobs, thus spreading the risk across the body and not having it concentrated in one specific area. An assessment of the manufacturing sector revealed that most jobs consisted of exposure levels that affected specific areas of the human body and that it therefore increased the risk of over-exposure of employees. Thus, any rotation system should be supported by the implementation of effective ergonomic interventions (Filus and Partel, 2012).

h) Work pace and repetition

The industrialization of abattoirs together with an increase in the demand for meat had a considerable impact on a facility’s throughput as well as the pace of work. The mechanisation of meat processing spearheaded developments in job specialization, which ultimately increased productivity. Seasonal throughput as well as variations in workflow patterns also affected the pace of work that eventually increased the risk of exposure to physical and psychosocial factors (Tappin *et al.,* 2008). McGorry *et al.* (2005) observed that the tasks performed in meat cutting operations were influenced by the production line speeds. As stated previously, Punnett *et al.* (2005) considered the pace of work and repetitive motions as key risk factors that affected a worker’s overall muscle strength. Muscular fatigue developed as a result of extensive periods of physical and mental exertion and effectively reduces a person’s capacity to perform certain tasks. Fatigue is therefore believed to reduce muscle strength and lead to muscular pain or discomfort that eventually could lead to health disorders or injuries amongst employees (Filus and Okimorto, 2012).

The standardization of working activities ultimately gave rise to the concept of repetitive work. Process efficiency essentially depended on the ability of a worker to perform a successive number of tasks (for a number of times). A highly paced work environment together with repetitive tasks are believed to significantly increase the risks associated with work-related-musculoskeletal disorders (WRMSD) (Hägg *et al.,* 2012). The most common characteristics of any production system include standardized cycle times. The need to reduce work cycle times may imply that the working activities may become more repetitive and considerably more intense. Reduced work cycle time is considered an important risk factor that affected work-related injuries and may negatively impact on a worker's well-being (Arezes *et al.,* 2014). A combination of repetitive movements and forceful exertions are recognized as some of the main causes of most cumulative disorders found among workers. Silverstein (1986) believed that repetitive work and forceful exertion could be defined as working activities with a cycle time of less than 30 seconds or situations where workers spent more than 50% of their time performing work that comprised of the same fundamental repetitive movements.

Kelloway (2019) in an article on the dangers involved in meat processing in the US, clearly identified the meat industry as a highly paced work environment. Inspectors in pig processing plants had approximately three and a half seconds to perform the required tasks. With the average line speed expected to increase following the introduction of new pork inspection legislation, workers faced even greater risks in an already hazardous environment. Tirloni *et al.* (2020) summarized that work was repetitive in nature if it comprised of work cycle time that were less than 30 seconds while constituting between 25 to 33 repetitions or movements per minute. Any movement rates in excess of the above guidelines may cause tendon disorders and if the force requirements were higher than expected these repetitive rates should be reduced. Meat cutting operations are considered to affect workers differently depending on which side is regarded as the dominant side (hand holding the knife) and which side performs the supporting activities (holding of the meat with the other hand).

i) Plant design and layout

Workplace design, including working conditions, were some of the main concerns around the occurrence of muscular disorders. Low height clearances applicable to some workstations may require tall workers to adopt working postures that put severe strain on the neck and back, which could lead to neck and back disorders. In contrast, the opposite may also be true as too high workstations may require the shorter workers to overreach or overstretch (Quansah, 2005). The effective and efficient design of workstations may contribute to the reduction of risk and injuries amongst employees. However, inadequate planning and design of workstations may: (a) force workers to adopt awkward postures; (b) cause an over extension or reach during task performance; (c) increase in-contact pressure; and (d) result in unnecessary movements among employees (Fusion Tech, 2014).

Inefficiencies in workplace design are a few key risk factors faced by employees in the manufacturing sector (Carayon and Smith, 2000). Dianat *et al.* (2016) stated that the contemporary workplace provided a platform for continuous and dynamic interaction between the worker and his or her working environment. These interactions should play a pivotal role in workplace design. The authors believed that it is this relationship that might cause physiological and psychological responses in workers that could eventually affect a worker's comfort, performance, and well-being. The research by Norman and Wells (1998) also indicated that enhancements in areas of seating, lighting, and workspace layout resulted in significant improvements in ergonomics that effected a reduction in the incidence of WRMSD. Figures 2.23 (a) and (b) compare the impact that a few minor changes in the design of workstations may have on the reduction of risk factors as well as improving the efficiency of the production process.

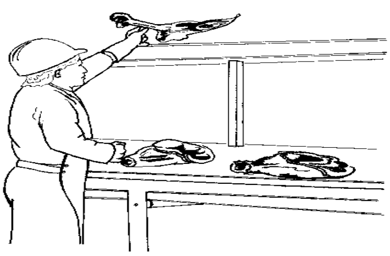


Figure 2.23(a): conveyor high (Macleod, 1996)

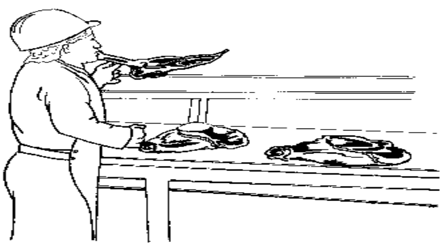


Figure 2.23(b): conveyor low (Macleod, 1996)

White (1999) was of the opinion that if an organization invested in workplace design programmes, it may ultimately reap the benefits in improved ergonomics and overall competitiveness. Dul and Neumann (2009) believed that the contribution of ergonomics to an organization extended beyond just the employee health and safety paradigm. Ergonomics were regarded as having both social and economic benefits to an organization. The greatest concern is that it might be somewhat overlooked during the design and development stages.

Designing a workstation should therefore consider the following: (a) size of the workspace needed; (b) height, depth, width, and shape of the working surface; (c) ease of access to tools or equipment used; and (d) storage space. The following may be common mistakes or challenges found in organizations: (a) work surfaces too high or too low for employees; (b) work surfaces too high or low for products being handles; (c) work surfaces too deep or shallow for employees; (d) workstations take up too much space i.e., length or width; (e) work surfaces not providing enough work space; (f) work surfaces that are inadequately spaced; and (g) design of tools or equipment (Fusion Tech, 2014).

j) Shift design

Knauth and Hornberger (2003) in an in-depth review of shift work highlighted that, studies on the extension of working hours indicated that any increase in working time from eight to nine hours or from ten to twelve hours resulted in an increase in the incidence and the occurrence of risk factors, i.e., fatigue, errors, accidents, burnout, etc. An early start was regarded as shortening sleeping time of employees, thus increasing the risk of fatigue and accidents during a normal shift. In addition, extended working shifts gave rise to challenges regarding staffing levels, workload, job rotation, rest breaks, and additional challenges on a more personal level, i.e., commuting time, personal safety, and domestic responsibilities. Many reasons exist as to why organizations should consider changes in their traditional shift systems. However, Knauth and Hornberger (1998) recommended that organisations must consider the importance of ergonomics during the design of shift systems and must consider the impact that it may have on the health and well-being of employees.

2.6. Socio-economic impact of ergonomic hazards

Takala *et al.* (2014) stated that the International Labour Organization assessed occupational health and safety from an occupational injuries point of view and the World Health Organization (WHO) approached it from an occupational illness or disease point of view. However, both organizations thought that between 5% to 7% of fatalities in the work environment of high-income countries could be attributed to work-related illnesses or occupational injuries. The economic impact of work-related illness and injuries were estimated to be between 1.8% to 6% of a country’s GDP and included both direct and indirect costs.

In their research, Takala *et al.* (2014) further provided a breakdown of the total cost of work-related injuries for a number of countries: (a) US averaged US $250 billion (nearly 1.8% of GDP); (b) Australia averaged AU $57.5 billion (which were 5.9% of GDP) during 2005–2006 and AU $60.6 billion (which were 4.8% GDP) during 2008–2009; (c) Norway - 6.0% of GDP; (d) Sweden - 4.0% of GDP; (e) Finland - 3.8% of GDP; (f) Italy - 3.2%; (g) Denmark 2.7%; and (h) New Zealand - 3.4% of GDP.

Musculoskeletal disorder (MSD) was one of the most common types of work-related disorders found amongst European Union (EU) member state countries. Together with cumulative tissue disorder, MSD constituted about 59% of all reported diseases during 2005. In addition, it made up almost 40% of all work-related cases reported in Great Britain for 2011/2012. The cost implications of occupational diseases or illnesses can be enormous in terms of personal and health care costs. It was estimated that work-related injuries or disease could be around 4% of the global gross domestic products (GDP). The cost estimates included lost working time, worker's compensation, interruption of production capacities, and medical expenses that equalled about US$2.8 trillion. In the EU the cost of work-related disorders were estimated to be at least €145 billion per year (ILO, 2013).

In Great Britain during 2022/2023, a total of 473 000 workers, representing 1 400 per 100 000, were affected by work-related disorders. This resulted in an estimated 6.6 million working days lost due to illness. Work-related musculoskeletal disorders (WRMSD) accounted for 41% of all upper limbs or neck disorders, 41% of back disorders, and 17% of lower extremity disorders. The conditions that affected the back accounted for 44% of days lost, while the conditions that affected the upper extremities and neck accounted for 27% of days lost, and conditions affecting lower extremities accounted for 29% of days lost (HSE, 2023).

Harmse *et al.* (2016) highlighted that in South Africa the total compensation for occupational diseases and occupational injuries showed an increase in worker's compensation from 886 511 reported cases in 2006/2007 to 934 834 reported cases in 2010/2011. According to Maseko (2016), 872 720 compensation claims were processed in South Africa for 2011/2012. Harmse *et al.* (2016) further highlighted that 69% of non-fatal incidents were underreported and reporting only focussed on the number of workdays lost. The underreporting of health and safety hazards often resulted in workers being re-assigned to other tasks whilst the incidents remained unreported.

Fagan and Hodgson (2017) were of the opinion that the absence of information on workplace injuries and illnesses concerned a wide range of stakeholders i.e., researchers, workers, employers, unions, public health experts, and governments. The authors believed that the accuracy of the data was central to determining the fundamental cause of risk. Providing accurate information plays a pivotal role in supporting the assessment of control measures, which were aimed at preventing work-related injuries and illnesses. The lack of accurate information may therefore delay the implementation of any steps that might be necessary to improve the health and safety of the workers. Takala *et al.* (2014) concluded that the cost breakdown for compensation comprised of staff turnover, training of replacement workers, loss of worker output, insurance premiums, and legal cost were deemed as costs carried by employers. The costs incurred by employees included expenses beyond those covered by compensation for medical treatment, rehabilitation, and loss of future earnings. Items like social pay-outs, costs of investigations, inspection, and promotion activities, and loss of human capital for fatal cases and medical subsidy were considered as costs carried by affected households.

2.7. Interventions to ergonomic hazards in the meat industry

Organizations are accountable and responsible to provide employees with a healthy and safe working environment (South Africa, 1993). In doing so, they are expected to assess the level of risk to which employees may be exposed and to implement and manage the necessary control measures to prevent occupational health and safety disorders (South Africa, 2019).

Kroemer (1989) advised that control measures could include the restructuring of tasks, processes, and tools that involve the implementation of job or task rotation, reduction in shift lengths or durations, and the implementation of rest or recovery breaks. Another key intervention in addressing ergonomic risk factors is to design or redesign workstations (Mukhopadhyay and Khan, 2015). Workstation design should ensure that work, particularly activities involving the application of force including gripping tasks are conducted within a comfortable reaching distance (Quansah, 2005). Organizations may consider the following interventions for implementation:

a. Hand tools such as knives should have secure grips and attention should be given to the impact of handle design as it can affect the gripping technique as well as the gripping force applied (Vieira and Kumar, 2004). Adequate provisions should also be made to maintain knives as sharp as possible as this could assist in reducing the maximum force necessary for cutting operations (Savescu *et al.,* 2018).

b. Organizations could also introduce job or task rotation systems by rotating workers between different workstations (jobs or tasks). Rotation systems should be implemented to rotate workers between high and low risk tasks or jobs to mitigate the risk of muscular disorders. Care should also be taken to ensure that the same muscle groups are not put under strain during job or task rotation schedules (Vieira and Kumar, 2004; Vergara and Pansera, 2012).

c. Rest or recovery breaks play a key role in working environments associated with highly paced and repetitive working activities. Rest schedules should allow employees adequate time for recovery to limit the force and load absorbed by muscle tissue (Park and Kim, 2020). Mukhopadhyay and Khan (2015) advised that workers should be allowed to take short breaks of 5 to 10 minutes for every 30 minutes of continuous work.

d. Another intervention is to ensure that workers receive adequate training in the use and handling of hand tools, the importance of rest or recovery breaks and the wearing of personal protective equipment (Tomoda, 1997). If an organization introduced exercises as one of their interventions, these should be designed and conducted by someone with the necessary skill and knowledge (Vergara and Pansera, 2012).

e. Harmse *et al.* (2016) believed that organizations should have access to the services of occupational health and safety practitioners and occupational medical practitioners or occupational health therapists. These professionals could assist in preventing, diagnosing, and treating of occupational diseases using the implementation of proper medical surveillance programmes.

Employers are therefore encouraged to promote the early detection and reporting of disorders or symptoms through the implementation of baseline medical surveillance programmes. Such programmes could be used to assist in the monitoring and assessment of occupational health disorders (South Africa, 2019). At the policy making level (management), organisations should show their commitment to the effective management and control of ergonomics by exhibiting strong leadership qualities and ensuring that a specific budget allocation is set aside for ergonomic hazard control and management (South Africa, 1993; Ross, 1994;

South Africa, 2019). Management must furthermore support the development of a systematic process aimed at addressing ergonomic hazards by incorporating it into their existing health and safety programmes (South Africa, 1993; South Africa, 2019).

2.8. Ergonomic hazards - high throughput red meat abattoirs (Western Cape)

The literature review on the existence and the prevalence of ergonomic hazards at red meat abattoirs in the Western Cape, did not deliver any relevant data sources. The research conducted by Harmse *et al.* (2016) was one of a few sources found (applicable to the poultry industry).

Most of the abattoirs involved in this study are currently equipped with manually operated production systems. A few facilities are in the process of introducing partial mechanization of their production setups. Non-mechanical production systems are believed to allow slaughter staff to influence the pace of work. Workers, however, benchmark their pace or speed against that of the fastest or the most skilful workers on the line, which could create some challenges further down the line (Inkson and Cammock, 1984). Workers may be exposed to hazards that can affect their hands, wrists, arms, shoulders, neck, or backs (as set out in Table 2.3 below). The work performed are repetitive in nature and include wrist turning, stretching, bending, or forceful activities. The principles of an extensive job rotation system or even planned rest periods applicable to the local red meat abattoir industry appears to be somewhat neglected or in most cases even non-existent.

Table 2.3: Associations between CTD and occupational activities. (Kroemer, 1989 as adapted from Putz-Anderson, 1988)

Disorder	Body activities	Typical job activities
Carpal tunnel syndrome	Repeated wrist flexion or extension, rapid wrist rotation, radial or ulnar deviation, pressure with the palm, pinching	Buffing, grinding, polishing, sanding, assembly work, typing, keying, cashiering, playing musical instruments, surgery, packing, housekeeping, cooking, carpentering, brick laying, butchering, hand washing or scrubbing, hammering
Epicondylitis, tennis elbow	Radial wrist pronation with extension, forceful wrist extension, repeated supination and pronation, jerky throwing or impacting motions, forceful wrist extension with forearm pronation	Turning screws, small parts assembly, hammering, meat cutting, playing musical instruments, playing tennis, bowling
Neck tension syndrome	Prolonged static posture of neck/shoulder/arm, prolonged carrying of load on shoulder or in the hand	Belt conveyer assembly, typing, keying, small parts assembly, packing, load carrying in hand or on shoulder
Pronator teres syndrome	Rapid pronation of the forearm, forceful pronation, pronation with wrist flexion	Soldering, buffing, grinding, polishing, sanding
Radial tunnel syndrome	Repetitive wrist flexion with pronation or supination of the forearm	Use of hand tools
Shoulder tendonitis, rotator cuff syndrome	Shoulder abduction and flexion, arm extended, abducted, or flexed in the elbow more than 60 degrees, continuous elbow elevation, work with hand above shoulder, load carrying on shoulder, throwing object	Punch press operations, overhead assembly, overhead welding, overhead painting, overhead auto repair, belt conveyor assembly work, packing, storing, construction work, postal 'letter carrying', reaching, lifting
Tendonitis in the wrist	Forceful wrist extension and flexion, forceful ulnar deviation	Punch press operation, assembly work, wiring, packing, core making, use of pliers
Tendosynovitis, DeQuervain's syndrome ganglion	Wrist motions, forceful wrist extension and ulnar deviation while pushing or with supination, wrist flexion and extension with pressure at the palmar base, rapid rotations of the wrist	Buffing, grinding, polishing, sanding, punch press operation, sawing, cutting, surgery, butchering, use of pliers, 'turning' control such as on a motorcycle, inserting screws in holes, forceful hand wringing
Trigger finger	Repetitive finger flexion, sustained bending of the distal finger phalanx while more proximal phalanges are straight	Operating finger trigger, using hand tools where the handle opening is too large for the hand
Ulnar nerve entrapment, Guyon tunnel syndrome	Prolonged flexion and extension of the wrist, pressure on the hypothenar eminence, sustained elbow flexion with pressure on the ulnar groove	Playing musical instruments, carpentering, brick laying, use of pliers, soldering, hammering
White (or dead) finger syndrome, Raynaud's syndrome	Gripping of vibrating tool, using hand tool that hinders blood circulation	Chain sawing, jack hammering, use of vibrating tool, sanding, paint scraping, using tool too small for the hand, often in a cold environment

2.9. Gap analysis – strengths, weaknesses, and limitations

A fundamental strength of this study is the fact that it is one of a few studies conducted into the impact and the relevance of ergonomic hazards with respect to abattoirs in South Africa. Subsequently, at the time, it is most likely one of the first to be conducted within the local red meat abattoir sector and the only study to highlight the importance of ergonomic hazards in relation to meat inspectors. As much as the analysis and the data is generated from abattoirs in the Western Cape and the results may only be valid to these abattoirs, it can be assumed that the key aspects of this research could apply to other red meat abattoirs within the country. Likewise, because of the fact that the slaughter processes were the same for the specific categories of animals being slaughtered, it supports the ideology of generalizing the results.

A fundamental weakness of this study is the fact that the information sourced were not explicitly applicable to the South African environment and did not distinctly address risk pertaining to meat inspectors. However, the principles used in determining risk as well as the application of ergonomics as a science provided sufficient background to the type and impact of occupational health and safety disorders in the workplace and could therefore be applied to the South African environment.

The first and foremost limitation of this study was the absence of sufficient but specific research into the existence of ergonomic hazards within the South African red meat abattoir industry. However, substantial research was conducted in the field of occupational health and safety but fell considerably short of addressing the role and relevance of ergonomics within red meat abattoirs (especially high throughput red meat abattoirs). Furthermore, limited sources were found that addressed the role of ergonomic hazards and its relevance to meat inspection. Thus, most of the data sources used in this review, addressed ergonomic hazards involved in the meat processing and other related industries.

It is important to state that the current scope of meat inspection as practiced in South Africa may differ from the meat inspection practices adopted internationally (mostly within the high-income countries). In South Africa, meat inspection is still centred on the traditional practices of organoleptic inspection, whereas internationally a more risk-based approach has been adopted (South Africa, 2012; South Africa, 2015). Another fundamental limitation was the lack of information on workers' compensation claims or statistical data. Compensation criteria is said to differ from country to country, which could negatively affect a country's ability to effectively quantify and report on the effects of ergonomic hazards. No information existed that could quantify the extent of ergonomic hazards at high throughput red meat abattoirs in South Africa. Harmse *et al.* (2016) stated that the need existed to create a uniform standard for developing a criterion that can be used in determining suitable workers compensation models (inclusive of ergonomic hazards).

CHAPTER THREE
RESEARCH DESIGN AND METHODOLOGY

3.1 Introduction

Research design and methodology is a systematic approach used to solve a research problem. It provides a scientific basis for conducting research (Kothari, 1990) that outlines the way a project will be conducted as well as the methods that a researcher used (Igwenagu, 2016).

This study was conducted to assess all subjective and objective knowledge or concepts that existed with regards to the presence, the effects, and the prevalence of ergonomic hazards at selected high throughput red meat abattoirs in the Western Cape. The research process was supported by structured questionnaires and semi-structured interviews that were designed to substantiate the data collection process. In addition, participant observations were used to assess the behaviour and practices of meat inspection personnel. The sampling techniques applicable to this project, were selected to improve the success and accuracy of the project. More than 50% of all high throughput red meat facilities in the Western Cape were conveniently selected to participate in the study. The target population thus comprised of abattoirs, meat inspection personnel, abattoir managers, and stakeholder representatives. The data collected during the field investigation was used to sort, analyse, and extract key information relevant to this study.

This chapter provides a brief outline on the necessary permissions obtained and the type of data sources used. In addition, it also provides background information on the sampling strategies adopted, the methods used in data collection and data analysis, the ethical considerations and the purpose and outcomes of the pilot study.

3.2 Research design

A cross-sectional study was conducted to assess the knowledge, attitudes, and behaviour of participants towards ergonomics and to determine the extent of ergonomic hazards among meat inspectors at selected high throughput red meat abattoirs in the Western Cape. The data collected were integrated, related, or mixed at various stages during the research process. The quanti-qualitative study was used to help build on the strengths of both quantitative (positivist) and qualitative (interpretivist) approaches and to explore different views and discover relationships between different research objectives (Shorten and Smith, 2017).

3.3 Project participation

Written permission to conduct the project was requested and obtained from facilities, meat inspection personnel, abattoir managers, and industry role players. Participants were requested to sign the consent letter (Appendix A) before taking part in the study. Participants were also informed that their involvement in the project were completely voluntary and highly confidential and that they had the right to withdraw from the project when they deemed necessary.

3.4 Data sources

The research project focused on data sources that were generated and collected during the field investigation (conducted as part of the research experiment). The methods used to collect data comprised of questionnaires, interviews, naturalistic observations, and field notes. The data collected contained information relating to the individuals and facilities that were included in this study as well as non-parametric and parametric sources. The non-parametric data included nominal and ordinal data, while parametric data involved the use of numbers on an interval scale or discrete values on a discontinuous scale (Nayak and Singh, 2015).

3.5 Population, sampling technique, and sample size

3.5.1 Population

The population applicable to this study included abattoirs, meat inspection personnel, abattoir managers, and stakeholders that were either directly or indirectly involved in the production of safe meat at selected abattoirs. The target population applicable to this investigation therefore included:

(a) all high throughput red meat abattoirs in the Western Cape including all single, double, or triple species slaughtering facilities governed by the same set of regulatory requirements;

(b) all registered inspectors who, governed by the same regulatory requirements, performed meat inspection at all high throughput red meat abattoirs in the Western Cape;

(c) all abattoir managers who were responsible for managing high throughput red meat abattoirs in the Western Cape irrespective if they slaughtered single, double, or triple species.

(d) representatives from industry and government (involved in regulating the red meat abattoir industry).

Thus, the total target population applicable to this study included 19 high throughput red meat abattoirs, 59 meat inspectors, 21 abattoir managers, and 4 participants from stakeholders.

3.5.2 Sampling techniques

A representative sample was selected from the total population mentioned in section 3.5.1 above. The sample included a designated number of abattoirs, the number of inspectors at these abattoirs, the number of abattoir managers at these abattoirs and a few representatives from stakeholders. The sample was deemed to be representative of the population because it represented a set of attributes and characteristics that were applicable to the whole population (Mweshi and Sakyi, 2020). A sampling strategy was used to increase the feasibility, the effectiveness and the accuracy with which data and the project was managed. For this study, the researcher opted to use non-probability sampling techniques and applied the purposive sampling method.

Non-probability sampling allowed the researcher to select samples based on his subjective judgement and provided a cost effective and swifter approach to sampling. Purposive sampling permitted the researcher to select a sample based on his knowledge of the population, its fundamentals as well as the purpose of the study (Sharma, 2017). The sample of abattoirs included in the study were selected subject to the conditions set out in section 3.5.3.1 under the inclusion and exclusion criteria. The inclusion and exclusion criteria were selected to answer various questions about the population under investigation (Kothari, 1990). Furthermore, purposive sampling allowed the researcher the opportunity to focus on those characteristics or representative attributes of the population that was deemed important to this investigation (Nayak and Singh, 2015). The sampling techniques selected used two distinct sampling strategies, i.e., homogeneous, and heterogeneous strategies. In terms of homogeneous sampling, the sample population applicable to meat inspection personnel and abattoir managers comprised of individuals who practiced in the field of meat inspection and those who worked within the abattoir industry. These participants shared a common set of characteristics applicable to their line of work and a working environment that were governed by a specific set of guidelines. In heterogeneous sampling the population that was under investigation exhibited very distinct differences in areas such as: age, gender, physical heights, weights, physical ability, experience, and competencies (Laerd dissertation, 2012).

3.5.3 Sample size

The size of the study population had an impact on the size of the sample. The population size was relatively small, which prompted the researcher to select a larger sample to limit the occurrence and the risk of sampling errors (Nayak and Singh, 2015). A larger sample provided the project with sufficient opportunity to enhance the relevance and the accuracy of the conclusions drawn about the target population. The selection of samples was done with the highest level of impartiality and unbiasedness.

3.5.3.1 Selection of abattoirs

Abattoirs were selected based on: (a) throughput; (b) the size of the establishment; (c) the type or number of animal species slaughtered; (d) the number of inspectors; and (e) the distance of each abattoir from Elsenburg. The abattoirs that were selected provided the researcher the opportunity to investigate the different conditions under which meat inspectors performed their duties. A total of 10 out of 19 high throughput red meat abattoirs were selected to be included in this study. These abattoirs made up approximately 52% of the total number of high throughput red meat abattoirs registered with the Department of Agriculture for the 2020/21 registration cycle in the Western Cape. The selected abattoirs had a combined production output that was comparatively high in relation to the total production capacity for all high throughput red meat abattoirs in the Western Cape.

Each abattoir was allocated a code that comprised of a letter from A to J followed by a subscripted numerical value that indicated the different species of animals that were slaughtered at that particular abattoir e.g., A_2 – referred to an abattoir which was allocated a code A that slaughters only two of the three species of animals that are most commonly referred to in the red meat category, B_1 - referred to an abattoir allocated a code B that slaughters only one species of animals (South Africa, 2004).

Abattoirs were included or excluded based on the following criteria:

Inclusion criteria:

a) High throughput red meat abattoirs situated within a 200 km radius from Elsenburg.
b) Abattoirs that slaughtered any combination of cattle, sheep, or pigs.
c) Single specie pig slaughtering abattoirs.
d) Abattoirs that expanded in terms of their structural as well as their production capacities over the last five to ten years.
e) New high throughput red meat abattoirs.

f) Number of meat inspectors at a plant.

Exclusion criteria:

a) Abattoirs that met the requirement of the study but were excluded because they were not located within the required 200 km radius from Elsenburg.
b) Single species sheep slaughtering abattoirs.
c) Abattoirs that slaughtered both cattle and sheep, but with low production outputs.
d) Abattoirs whose registration certificates were suspended or withdrawn.

The selected abattoirs slaughtered different species of animals applicable to the study and ranged from single species to multi species abattoirs.

3.5.3.2 Determination of sample size for meat inspectors, abattoir managers, and stakeholders

The total population for this project, as indicated in section 3.5.1, were between two population sizes. The projected sample fell between: (a) a population size of 50 participants, the suggested sample percentage was estimated at 64%, which amounted to 32 participants; and (b) a population size of 100 participants, the suggested sample percentage was estimated to be 45%, which amounted to 45 participants that needed to be sampled (Table 3.1).

Table 3.1: Guidelines for sampling (Strydom and Venter, 2002 as adopted from Stoker, 1985)

Population	Percentage suggested	Number of respondents
20	100%	20
30	80%	24
50	64%	32
100	45%	45
200	32%	64
500	20%	100
1 000	14%	140
10 000	4.5%	450
100 000	2%	2 000
200 000	1%	2 000

The researcher calculated the sample using a projected population size of 84. The calculations were therefore conducted for x = 84, where x_1 = 50, x_2 = 100, y_1 = 32, and y_2 = 45. The following formula was used: $(y - y_1) = [(y_2 - y_1) / (x_2 - x_1)] * (x - x_1)$. If we used the values in Table 3.1, we get:

$$x = 84: \quad (y - 32) = [(45 - 32) / (100 - 50)] * (x - 50)$$

$$(y - 32) = (13/50)(x - 50)$$

$$(y - 32) = 0.26(84 - 50)$$

$$(y - 32) = 0.26(34)$$

$$y = 0.26(34) + 32$$

$$y = 40.84$$

Thus, interpolating between n = 50 and n = 100 for x = 84, the total number of respondents should be 40.84, which comprised of a suggested sample percentage of 48.6% of the total population as indicated above (Stroud and Booth, 2013).

The total number of participants in the selected sample were as follows [as set out in Table 3.2: The selected abattoirs across different District Municipalities (not applicable to stakeholders)]:

a) Meat inspection staff – 39;
b) Abattoir managers – 12;
c) Stakeholders – 4 (not indicated in Table 3.2 below);

However, based on the number of respondents that participated in completing the questionnaires and those involved in the interviews, the selected sample was estimated at 65.5% (55/84 x 100 = 65.47%) of the total population.

Table 3.2: The selected abattoirs across different District Municipalities

Selected abattoirs	Sample Detail			No. of Participants
	Species and throughput	Participants	Gender	
1. Abattoir B_{1*}	throughput: high species: one	inspectors, abattoir managers	male = 8 female = 4	12
2. Abattoir A_{2*}	throughput: high species: two	inspectors, abattoir managers	male = 4 female = 0	4
3. Abattoir G_{2*}	throughput: high species: two	inspectors, abattoir managers	male = 3 female = 0	3
4. Abattoir H_{3*}	throughput: high species: three	inspectors, abattoir managers	male = 2 female = 2	4
5. Abattoir J_{2*}	throughput: high species: two	inspectors, abattoir managers	male = 2 female = 1	3
6. Abattoir C_{1*}	throughput: high species: one	inspectors, abattoir managers	male = 3 female = 0	3
7. Abattoir D_{2*}	throughput: high species: two	inspectors, abattoir managers	male = 6 female = 1	7
8. Abattoir E_{1*}	throughput: high species: one	inspectors, abattoir managers	male = 6 female = 1	7
9. Abattoir F_{2*}	throughput: high species: two	inspectors, abattoir managers	male = 3 female = 0	3
10. Abattoir I_{3*}	throughput: high species: three	inspectors, abattoir managers	male = 4 female = 1	5

* Abattoir code indicated by a letter from A to J, each letter is subscripted by a numerical value indicating the different species of animals slaughtered

NB! Throughput as indicated on the registration certificates issued by Department of Agriculture

3.6 Methods of data collection – tools, techniques, and strategies

As stated above, the data applicable to this investigation were collected using questionnaires, semis-structured interviews supported by participant observations and field notes collected during site visits. The data collection tools were selected to address several variables important to this study, namely: (a) determination of type of hazards present; (b) evaluation of effects of hazards; and (c) assessment of the extent of hazards.

Prior to the commencement of the project an e-mail correspondence was sent to facilities to follow up and confirm their availability and participation in the study. The responses received from facilities endorsed the request for site visits as well as the completion of the questionnaires. Site visits to different facilities were combined to allow for a maximum of two facilities to be visited on the same day. Following the receipt of confirmation from facilities, the researcher drafted a visit schedule (Appendix B) to assist in the planning of site visits to selected abattoirs. The dates for visits were communicated to the respective facilities. The schedule made provision for a minimum of two hours per site visit to each of the selected abattoirs.

3.6.1 Questionnaires

The questionnaires formed part of a set of research instruments used in this study. It contained well-defined questions designed to collect information from the group of selected meat inspectors as well as abattoir managers who participated in the survey. Separate questionnaires were developed for meat inspection personnel (Appendix C) and abattoir managers (Appendix D).

The questionnaires were used as the main data collection tool. The design, layout, and content of questionnaires were influenced by the literature review process. The questionnaires were administered to 51 participants (i.e., 39 meat inspection personnel and 12 abattoir managers or supervisors) who worked at ten abattoirs located in four district municipalities of the Western Cape.

3.6.1.1 Structure and design of questionnaires

Questionnaires were methodically structured and divided into different sections (i.e., demographic and content based) to assess specific knowledge and concepts significant to the field of ergonomics. The make-up of each questionnaire provided for a set of definite and pre-determined questions, each comprising of the same wording and order. Each questionnaire was designed to reduce or limit the risk of nonsampling errors and made provision for a sequence of questions about a specific topic or a phenomenon (Nayak and Singh, 2015).

The cultural heterogeneity of the sample population (with specific reference to language) posed some challenges to the design and development of these questionnaires. Due to the complexity and the difficulty of designing questionnaires or interpreting responses in the participants' preferred languages, the researcher elected to design and administer the questionnaires in English. Questionnaires subsequently allowed respondents to reply to the same set of questions and kept the responses to questions in the respondents' own words to a minimum. Each questionnaire consisted of questions that made provision for participants to indicate their levels of agreement, disagreement, or uncertainty by either indicating "yes" or "no" or "do not know" (Nayak and Singh, 2015; Kothari, 1990).

The design of questionnaires made provision for adequate question-sequencing, which allowed for clear relationships to exist between questions within the different sections and in relation to the overall research objectives. Question-sequencing enabled the researcher to develop questions that evolved from the general to the more specific. Sufficient space was provided for the answering of questions and to assist with editing and tabulation of responses (Kothari, 1990). The questionnaires were developed, coded, and scaled to contain a combination of scaling approaches. Each questionnaire made provision for dichotomous responses, nominal responses, open-ended and closed-ended multiple responses, as well as ordinal and interval-level (5-point Likert scale questions) response type questions (Nayak and Singh, 2015).

3.6.1.2 Completion and collection of questionnaires

The questionnaires were hand delivered to participants at each of the selected abattoirs. The researcher supervised and administered the completion of questionnaires. Participants were given an overview of the project objectives and an outline of the content and layout of each questionnaire. The completion of questionnaires (for meat inspection personnel) was conducted in a group setting (where the entire team or part of the team of inspectors were present as dictated by their work setting). Each participant completed their own questionnaire, and each questionnaire was collected immediately after its completion and on the same day of the site visit. The researcher facilitated the process and clarified any uncertainties that participants had in relation to the answering of specific questions. Participants were not allowed to consult with or to enquire from fellow participants to prevent them from influencing each other during the completion of questionnaires.

3.6.2 Interviews

Interviews provided the researcher the opportunity to gather information from industry stakeholders on the existence and impact that ergonomics may have on meat inspectors. Each interview was systematically planned and arranged with stakeholders i.e., meat inspection service providers and the government department. An interview schedule (Appendix E) was developed and used during interview sessions. The inference thereof was overseen and administered by the researcher (Kothari, 1990). The researcher selected a total of four participants to participate in the interview process.

3.6.2.1 Type and structure of interviews

Semi-structured interviews were scheduled and conducted with participants. Due to some challenges (the Covid-19 pandemic) as well as logistical reasons only one interview (one-to-one or face-to-face) was conducted in person, while the remainder of the interviews were conducted using one of the virtual platforms available at the time (i.e., Skype). A meeting request was sent to all stakeholders (i.e., for one face-to -face setting and the remainder of the participants were sent invitations for one-on-one interviews using Skype). The one-on-one (face-to-face setting) interview was conducted in the interviewee's office (a neutral office space) at Department of Agriculture's head office. The researcher assured all participants that the information provided will be handled with the utmost confidence and that they will remain anonymous. In addition, the researcher provided participants with a brief overview of the procedures that were followed in conducting these interviews. The researcher (also the interviewer) took on the role of a facilitator during each interview. Each respondent was encouraged to respond and voice their own opinion. The researcher remained impartial and unbiased towards participants and their views (Mafuwane, 2011).

The semi-structured interviews provided a degree of flexibility to the participants as provisions were made for open-ended answers that allowed the interviewees to further elaborate on points of discussion. The interview schedule was drafted in English and participants were given the opportunity to answer questions either in English or Afrikaans (as most participants were conversant in both languages). Subsequently, all participants indicated that they were comfortable with conducting the interviews in English. Permission was obtained from participants to record the proceedings. The interviews lasted approximately 30 minutes each. Due to technical reasons (or errors) only three of the four interviews could be recorded (i.e., audio recordings). However, the researcher captured additional notes during interviews to facilitate the data collection process.

Upon completion of interviews, the audio recordings (of the three interviews) and notes were reviewed, and transcripts compiled. All quotes that were applicable or related to the research objectives (set out for this study) were highlighted and coded. The audio recordings and the transcripts were saved on the researcher’s computer and on an external hard drive for future referencing.

3.6.3 Observations

A key objective of this study was to observe meat inspectors in their actual work setting. This involved the systematic noting and recording of activities, events, and behaviour of participants. Observations were recorded as field notes in a detailed, non-judgemental, and descriptive manner by the researcher.

3.6.3.1 Type and nature of observations

Direct observations allowed the researcher the opportunity to collect data by observing inspectors’ behaviour and their physical characteristics in a natural setting. Indirect observations highlighted the results of interactions, processes, or behaviours. The principles of overt observation were applied to all settings as the presence of the researcher, as an observer, was known to the participants (Nayak and Singh, 2015).

Field notes were taken and used to compile a detailed record of observations. The focus areas during the site visits involved all areas where meat inspectors performed their duties. These included designated as well as non-designated areas or workstations. Dimensions of working areas and workstations or platforms where meat inspectors performed working activities were recorded and was supported by simple diagrams or pictures. The dates, names, observations, diagrams, or pictures were recorded for ease of reference. The observations focussed solely on the extent of the study and not on meat safety compliance or the lack thereof. The scope of observations at each abattoir focussed on: (a) the type and use of hand tools; (b) the working postures adopted by inspectors during the performance of meat inspection; (c) the pace of work; (d) height and reach requirements for different working activities; (e) dimensions, design, and layout of workstations or platforms; (f) existence of job or task rotation systems; (g) existence of rest or recovery breaks; (h) number of inspectors; and (i) the scope of activities performed by meat inspectors.

Observations were supported by pictures and video clips taken of participants performing meat inspection and related activities. The researcher requested and obtained the necessary consent and approval from abattoirs and participants to take pictures and video clips in support of the observations made. The pictures and video clips allowed the researcher the opportunity to conduct secondary assessments of observations made during fieldwork to improve the data collection process. These secondary assessments were mainly conducted as a desktop study using the Rapid Entire Body Assessment (REBA) tool. The REBA tool was chosen because it was easy to use and did not require a formal qualification in ergonomics. Although REBA was not specifically used or applied during the site visits, it provided the researcher the opportunity to conduct further assessments. These assessments focussed on the risks of whole-body postural disorders as well as work related hazards associated with the performance of various tasks (during meat inspection). The desktop study assisted the researcher to understand the type of postures and the working activities of a few different inspectors at each of the different workstations during the day. The researcher conducted an in-depth study of the step-by-step guidelines on the use and application of the REBA tool prior to conducting the assessments. The aim was to ensure that the researcher applied the highest level of consistency in the application and use of the checklist during the assessments (Middelsworth, 2023a).

3.7 Methods of data analysis

The process of statistical analysis facilitated the review, the evaluation, and the interpretation of data. It allowed the researcher the opportunity to identify patterns, themes, and relationships and assisted to determine the extent to which these may be applicable to the broader study population.

The data analysis process also assisted to discover trends and to find the facts that were considered important to this investigation (Pandey and Pandey, 2015). It aimed to provide answers to the research question and research objectives (Kothari, 1990).

3.7.1 Data processing

Each questionnaire was checked and assessed at the end of each day, with limited field editing conducted during visits. The completed questionnaire was marked with a reference code during the checking process. The reference code comprised of the letter and the species number allocated to each abattoir (as previously issued by the researcher) together with a new numbering code for each inspector or supervisor. The numbers that were used to record the inspectors’ questionnaires varied based on the number of inspectors that were designated to each abattoir (i.e., if there were three inspectors at abattoir A_2, the numbering codes constituted of additional numbers 1 to 3 and were: A_2 – 1 for first inspector, A_2 – 2 for second inspector and A_2 – 3 for the third inspector). An additional reference code was generated for abattoir managers i.e., A_2 – 4 sup aba (aba is first three letter of the word abattoir and is used to refer to a supervisor or manager at a selected abattoir). After the collection of all the questionnaires, time were set aside to assess, classify, and code the information. Coding was conducted in small batches to enhance the effectiveness and efficiency of data processing. The data were labelled and grouped into categories to assess and compare the data. The headings and sub-headings in the questionnaires were used as initial categories into which the data were arranged. These categories provided a brief overview of the applicable data segments and ultimately aided in the sorting and processing of the data.

The field notes were organized into a tabular format that provided an overview of the designations and dimensions applicable to meat inspection areas (for each species of animal at each of the selected abattoirs). Video and photographic material were exported to the researcher's laptop where it was saved in a folder developed for each abattoir. The Microsoft Photo Editor application was used to edit selected video and photographic material to protect and ensure the anonymity of abattoirs and participants.

The audio recordings of the interviews were transferred to a selected folder on the researcher's laptop and later saved on a separate hard drive. The transcripts of each of the recordings were replayed and the data was recorded by the researcher using Microsoft Word. The completed transcript was saved in a designated file or folder. Participant responses were clustered and tabulated in accordance with the headings and sub-headings contained in the interview schedules.

The responses of participants (for both questionnaires and interviews) were linked to the research objectives and colour coded accordingly.

3.7.2 Data analysis

During data analysis the codes and data classes were used to identify, categorise, and determine if similarities existed. The scales of measurement used were nominal, ordinal, and interval scales. These scales provided a description of the properties of each of the numbers used in the research design. The researcher used tables, charts, and graphs to describe and interpret the data generated during this study. The relationships that existed and those that were identified between the variables assisted the researcher to make deductions about the total population. These deductions were based on the observations made in terms of the sample population (Dawson and Trapp, 2004), but assisted the researcher to predict, compare, and generalise what the impact of these observations may be on the general population of meat inspectors (Sharma, 2017).

The data from the questionnaires were entered into an electronic data base and an electronic workbook was created using Atlas.ti 8 for Windows. Each questionnaire was scanned and saved into the data base (using the codes allocated to each questionnaire according to the identification criteria set out in paragraph 3.5.3 and 3.7.1). The researcher processed participant responses in line with the headings and sub-headings in questionnaires. The responses to the questionnaires were administered separately, one for meat inspectors and one for abattoir managers. These data sets were exported to a Microsoft Excel spreadsheet. Each of the data sets (for meat inspectors and abattoir managers) were further analysed using Statistical Package for Social Sciences (SPSS), Version 27 (IBM Corporation, Armonk, NY, USA). The data were arranged into a concise, logical, and orderly arrangement of columns and rows. Columns were used to classify the variables while the rows were used to enter the responses from participants (Kothari, 1990). The data set represented different types of statistics classified into either categorical or continuous data and representing both dependent and independent variables (Adams, 2008). The measures of central tendencies and the measures of variability were calculated using demographic data (age, gender, height, weight, experience). The Pearson's chi-square test of independence was selected to determine if relationships existed between different variables.

The data from interviews and field notes were assessed to identify any similarities or differences. The researcher also identified and developed different categories, which were used to process and arrange the types of data.

3.7.3 Validity and reliability of data

The face validity of the questionnaires was assessed with the assistance of the supervisors and biostatistician to determine if the questionnaires measured what it intended to measure. The content validity of the questionnaires was assessed in determining if the study contained questions that included all aspects associated with ergonomic hazards applicable to meat inspection personnel (Mafuweni, 2011).

The researcher used different methods and different data sources in studying ergonomics to provide an all-inclusive understanding of ergonomic hazards among meat inspectors. These included: (a) participants who completed the meat inspector questionnaire; (b) participants who completed the abattoir manager or supervisor questionnaire; and (c) stakeholder representatives who participated in the semi-structured interviews. Participants were also male and female, each from different community backgrounds, working at different abattoirs, having different levels of experience as well as competency levels, which provided various sources of information to the researcher.

3.8 Pilot study

A pilot study was scheduled and conducted at a pre-identified abattoir. The pilot study sample consisted of three respondents (two meat inspection staff, and one abattoir supervisor) at a randomly selected high throughput red meat abattoir. The aim of the pilot study was to: (a) assess the viability of the study; (b) check the validity and reliability of the questionnaires; (c) evaluate the dependability with which respondents completed questionnaires (which was important for the data collection process); and (d) establish if the questionnaires were clear, logical, and functional as a research instrument. The pilot study revealed that the questionnaire (the main data collection instrument) did not contain any unclear questions and respondents did not experience significant challenges in completing it.

The questionnaires were also tested to ensure that any potential errors or mistakes were identified and corrected. The scheduled interview could not be conducted during the pilot study. Staged interviews (informally set up) were used to prepare for one-on-one interviews to test the validity of questions.

In addition, any ambiguous, leading, or vague questions that could result in non-comparable, biased, or unclear responses from participants were identified and eliminated. The pilot study assessed whether participants could complete the questionnaires within a maximum of 20 minutes. Each of the participants took between 25 to 30 minutes to complete the questionnaires. The outcome of the pilot study therefore recommended that the time frame for completing the questionnaire should be increased to 30 minutes as a lesser time frame may pose challenges to some workers and could negatively impact on the validity of the data collection process.

Finally, the pilot study did not form part of the sample of abattoirs selected for participation in the main study. The outcomes of the pilot study did not form part of the overall investigation.

3.9 Ethical consideration

The researcher is an employee of the Department of Agriculture: Western Cape. The researcher did not conduct the research as an official of government but purely as a researcher and a student. Adequate control measures were put in place to ensure that the position of the researcher did not compromise the investigation. The researcher received the necessary permission from the Department to conduct the investigation and to commence with the data collection process (Appendix F). Permission and approval for this study was also obtained from the Cape Peninsula University of Technology's ethics committee (Appendix G). In addition, a consent letter, requesting permission to participate in the study, accompanied each questionnaire as well as each request for an interview. The researcher endeavoured to maintain the confidentiality and the anonymity of participants throughout the investigation i.e., data collection, analysis, and report writing. The purpose of protecting the anonymity of participants was done to limit any association between participants and their responses. The hard copies of completed questionnaires and field notes were filed and kept in a safe and secure place at the researcher's property. Hard copies were scanned and emailed to the researcher's e-mail address. The data was only used for the purpose stated and intended in this study and was stored on the researcher's laptop as well as on a separate external hard drive. The data was password protected on both the laptop and external hard drive. Backup copies were stored on the dedicated CPUT data repository using the eSango data management tool, which is also password protected.

CHAPTER FOUR
RESULTS

4.1 Introduction

Meat inspection plays a pivotal role in the production of safe meat in South Africa. Meat safety is therefore regarded as a key part of the entire production process and not only as an end-product inspection procedure (Olivier, 2004). The current practices involved in meat inspection predominantly focusses on the application of macroscopic inspection techniques, which require an inspector to visually examine, palpate, and incise organs or carcasses in assessing the safety of meat and meat products (Hill *et al.,* 2013). This study was aimed at evaluating the conditions under which meat inspection was performed to assess the occurrence and the scope of ergonomic hazards in abattoirs. The primary tools used in data collection comprised of well-structured questionnaires, interviews, and naturalistic observations, including photo and video graphic analysis.

This section provides information on the classification of data as well as the reliability assessments conducted. It also includes an outline of the demographic profile of participants based on age, gender, height, education, and employment. The data obtained from the questionnaires, interviews, and observations will be presented under separate headings.

In the event where a participant omitted to answer a question (either by choice or by default), such omissions were categorized as “not selected”. Items identified as “not selected” were still deemed part of the overall sample population, N = 39 for meat inspection personnel and N = 12 for abattoir managers. However, the omissions did not form part of the “response results”. The designated alpha value or the level of significance were set at 10% (p-value of 0.1) for this study.

4.2 Data classification

The data presented in this section serves as the basis for the information generated in the study, which includes words, figures, tables, photographs, video recordings, and voice recordings. During data analysis, the data were classified according to the NOIR system (i.e., Nominal, Ordinal, Interval, and Ratio) (Adams, 2008). Table 4.1 provides a brief description of the application of these categories.

Table 4.1 NOIR system used for the classification of data categories

NOIR system used in the classification of data types		
Variable	Data type	Description
Categorical	Nominal	Categories are named with no implied order
	Ordinal	Categories are ordered but the differences between categories are not necessarily equal
Continuous	Interval	Distances between values are equal but the zero point is arbitrary
	Ratio	The same as for interval and a meaningful zero; data may be obtained by measurement

(As adopted from Adams, 2008)

4.2.1 Data reliability assessments

Reliability assessments were conducted on both sets of questionnaires. Questionnaire responses were assessed separately (i.e., for meat inspectors and abattoir managers) as well as in a combined data set. The Cronbach's alpha reliability coefficients were calculated using both SPSS and Microsoft Excel.

4.2.2 Inter-item correlation analysis

Inter-item correlation analysis was conducted to determine the extent to which items on a scale assessed the same subject matter (Cortina, 1993). The "Summary Item Statistics" section in Table 4.2, in the first column, shows the mean of the number of correlations calculated for "Occupational Health and Safety (OH&S) Management System" in the questionnaires as 0.312 which indicates that the items were reasonably homogenous.

Table 4.2: Inter-item analysis of OH&S management system

Summary item statistics	Item-Analysis Occupational Health and Safety Management System						
	Mean	Min	Max	Range	Maxi / Min	Variance	No. of items
Item Means	0.616	0.220	1.280	1.060	5.818	0.142	9
Item Variances	0.480	0.175	1.510	1.335	8.625	0.168	9
Inter-Item Correlations	0.312	-0.572	1.000	1.572	-1.750	0.206	9

Table 4.3 shows the inter-item correlation analysis of several items in this study and reflects on the homogeneity of selected items.

Table 4.3 Inter-item correlation analysis of selected sections

Summary item list	Mean	Number of items
OH&S Management system	0.312	9
OH&S training and awareness	0.481	15
Meat inspection areas	0.052	12
Meat inspection platforms	0.076	7
Hand tools used in meat inspection	0.132	8
Common approaches to OH&S and Ergonomics	0.039	13

4.2.3 Cronbach's alpha reliability coefficient

The Cronbach's alpha test was used to assess item responses in each questionnaire as well as the levels of internal consistency within these data sets (Vaske *et al.,* 2017). The coefficient of reliability calculated for "occupational health and safety (OH&S) management system" was 0.750. Table 4.4 provides a breakdown of the Cronbach's alpha values for different items.

Table 4.4: Cronbach's alpha reliability coefficient for OH&S management system

	Scale mean if item deleted	Scale variance if item deleted	Corrected item-total correlation	Cronbach's alpha if item deleted
Management system - MI# & AM*	4.26	14.604	-0.401	0.843
System supported by H&S policy AM	5.32	10.467	0.851	0.690
H&S policy clearly defined AM	5.32	10.467	0.851	0.690
H&S policy clearly displayed AM	5.18	8.844	0.834	0.652
H&S representative designated MI & AM	4.66	10.841	0.385	0.733
H&S inspections done AM	5.28	10.124	0.835	0.682
H&S inspections conducted AM	4.94	6.956	0.691	0.681
Control measures to prevent hazards MI	4.70	11.561	0.291	0.746
Reporting system	4.66	11.086	0.302	0.747

 # MI – meat inspector's questionnaire responses

*** AM – abattoir manager's questionnaire responses**

Table 4.5 provides information on the outcomes of additional Cronbach's alpha reliability assessments conducted and show that the coefficient of reliability of the selected items varied substantially (using a combined data set).

Table 4.5: Cronbach's alpha reliability coefficients calculated for both questionnaires

Variable	Cronbach's alpha	Number of items
OH&S training and awareness	0.887	15
Meat inspection areas	0.644	12
Meat inspection platforms	0.462	7
Hand tools used in meat inspection	0.549	8
Common approaches and attitudes to OH&S and Ergonomics	0.249	13

If the number of items were increased, the alpha values for each questionnaire delivered higher reliability scores (Tavakol *et al.,* 2011).

4.3 Demographic characteristics

The demographic profile of participants is hereby presented to provide an overview of the composition of the sample population.

4.3.1 Age

Figure 4.1 presents the age distribution of inspectors and shows that most inspectors were spread across two main categories, i.e., 42.1% between 26 – 35 years and

26.3% between 36 - 45 years. The data also revealed that almost 71.0% of participants were younger than 45 years of age and approximately 86.8% of participants younger than 55 years of age.

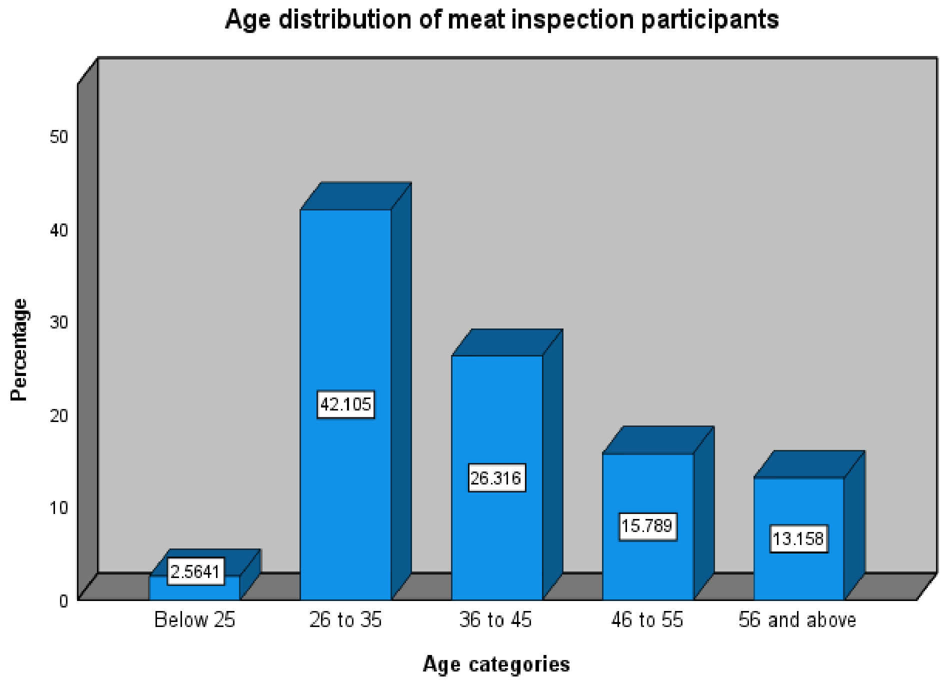


Figure 4.1 Age categories of meat inspection personnel

Most managers, like inspectors, were spread across two main categories with none older than 56 years of age.

4.3.2 Gender

Figure 4.2 shows the gender distribution of male and female inspectors. The total number of male participants were approximately three times greater than female participants.

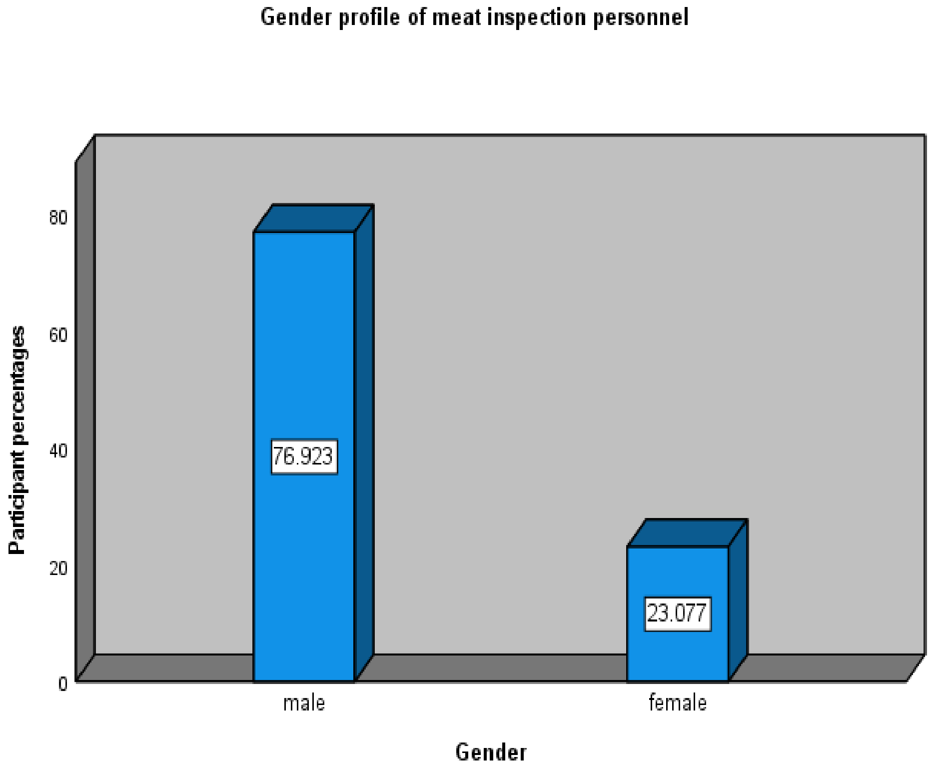


Figure 4.2 Gender distribution of meat inspection personnel

The data also showed that most abattoir managers who participated in the study were predominantly male.

4.3.3 Height

The individual heights of inspectors were not measured, but inspectors selected heights from predefined categories provided in the questionnaires. The average height of meat inspection personnel varied considerably; however, the majority of participants (89.2%) were between 1.5 m to 1.8 m tall as indicated in Table 4.6.

Table 4.6 Average height categories of meat inspection personnel

	less than 1.5 m	1.5 m to 1.6 m	1.6 m to 1.7 m	1.7 m to 1.8 m	>1.8 m
Average height	5.4%	29.7%	24.3%	35.1%	5.4%

4.3.4 Weight

Table 4.7 shows the weights of inspectors with most participants falling into the 61 kg to 70 kg category. Approximately 12.9% of respondents reported average weights of more than 90 kg.

Table 4.7 Average weight categories of meat inspection personnel

Average weight distribution of inspectors				
		Frequency	Percentage	Cumulative percent
Weight	less than 60 kg	1	2.6	2.6
	61 kg to 70 kg	16	41.0	43.6
	71 kg to 80 kg	8	20.5	64.1
	81 kg to 90 kg	9	23.1	87.2
	95 kg	2	5.1	92.3
	96 kg	1	2.6	94.9
	90 to 100 kg	1	2.6	97.4
	110 kg	1	2.6	100.0
	Total	39	100.0	

4.3.5 Education

Figure 4.3 indicates that 64.1% of inspectors obtained a tertiary education, i.e., National Diploma or BTech degree. The remaining number of participants obtained a Meat Examiner Certificate (in addition to their grade 12).

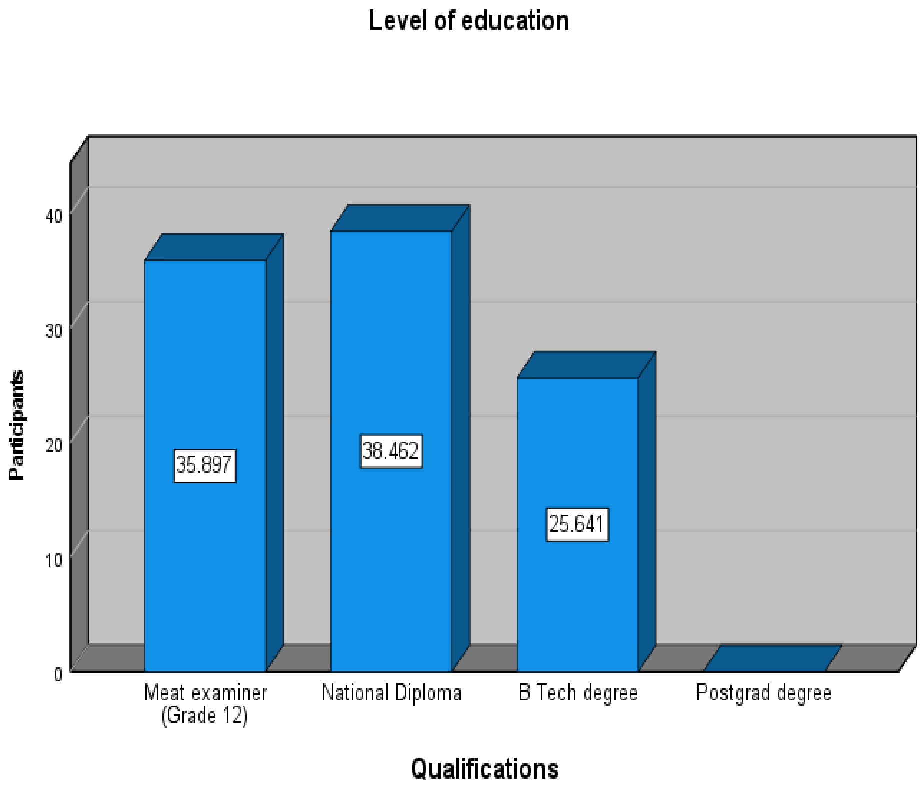


Figure 4.3 Level of education obtained by inspection personnel

Most abattoir managers obtained a tertiary education, i.e., National Diploma, while the remainder of the managers obtained a minimum of grade 12.

4.3.6 Employment experience

According to Figure 4.4, 41.7% of inspectors had extensive experience (more than 10 years), while 58.3% of participants had less than 10 years' working experience. Of these (i.e., 58.3%), 38.9% had less than 5 years' experience.

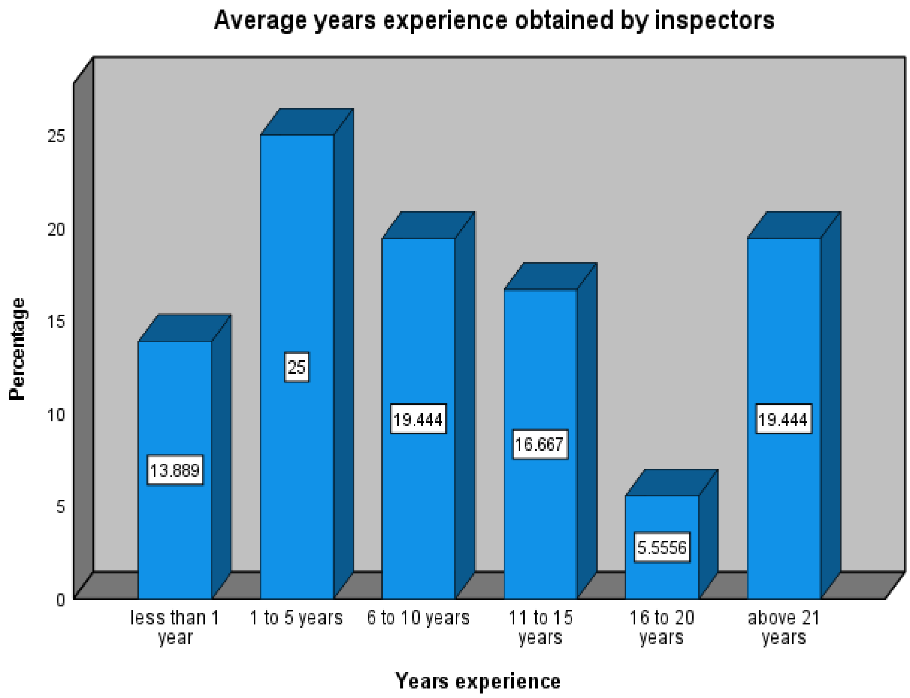


Figure 4.4 Number of years' experience obtained by inspection personnel

Furthermore, most managers had extensive experience in the abattoir industry, with 45.5% of them having more than 21 years' experience, while 72.7% of all managers worked in the abattoir industry for more than 10 years.

In addition, the data shows that most inspectors (77.8%), indicated that they worked at the selected abattoirs (the abattoir at which they were based during this study) for less than 5 years, while only 54.5% of managers worked at the selected abattoirs for less than 5 years.

4.4 Approaches to statistical analysis

4.4.1 Descriptive statistics

Statistical analysis, including the measures of tendency were conducted. The following section provides a summation of the methods used as well as the information applicable to the calculation of the sample mean, median, mode, interquartile range, standard deviation, and variance of grouped data.

4.4.1.1 Measures of central tendency

A variety of calculations were conducted on the age, height, weight, experience, and the number of years that inspectors spent at an abattoir as shown in Table 4.8.

Table 4.8: Statistics on measures of central tendency – applicable to meat inspectors

	Mean	Median	Mode	Standard Deviation	Variance	Skewness*	Kurtosis*
Age	39.98	38	33	10.99	120.78	0.604	- 0.710
Years' experience	10	9	4	7.93	62.83	0.328	-1.221
Years at abattoir	3.6	2	5	3.82	14.56	1.200	1.598
Height	1.66m m	1.66 m	1.73 m	0.1	0.01	- 0.174	- 0.967
Weight	76 kg	74 kg	67.5 kg	11.21	125.58	0.301	- 1.237

* Skewness and kurtosis values were derived from SPSS and not calculated using Excel

4.4.1.2 Interquartile range

The interquartile range (Table 4.9) as well as the values for quartiles 1 and 3 were calculated.

Table 4.9: Statistics on interquartile ranges for meat inspectors

Descriptive statistics IM	Quarter 1(Q_1)	Quarter 3 (Q_3)	Range ($Q_3 - Q_1$)
Age*	30.8	48	17.2
Height	1.57 m	1.74 m	0.17 m
Weight	65.9 kg	85.2 kg	19.3 kg
Years' experience*	3.2	15.5	12.3
Years at abattoir*	3.6	4.9	1.3

* Unit of measurement in years

4.4.1.3 Measures of dispersion

Standard deviation and variance were calculated as shown in Table 4.8 and are deemed measures of dispersion or variability. Their focus is to determine the measures of change or the difference in distance or variation between a data point and the mean (central measure of tendency). The coefficient of variation, shown in Table 4.10, applicable to "years' experience" and "years at abattoir" were wider dispersed from their means than that of the other variables.

Table 4.10: Statistics on coefficient of variation for meat inspectors

Coefficient of variation of inspectors	
Age	0.27
Height	0.06
Weight	0.15
Years' experience	0.79
Years at abattoir	1.06

4.4.2 Assessment of key relationships between demographic variables

An assessment of the relationship between demographic variables were conducted to determine the level of dependence or independence (amongst selected variables).

4.4.2.1 Age and experience of inspectors

A comparison drawn between the age and the experience (Table 4.11) indicates that of the 89.7% of responses received, approximately 57.1% (i.e., inspectors across all age categories) of inspectors had less than 10 years' experience.

Table 4.11: Cross-tabulation of age vs experience of inspection personnel

		Cross-tabulation of age vs years' experience of inspectors													
		less than 1 year		1 to 5 years		6 to 10 years		11 to 15 years		16 to 20 years		more than 21 years		Total	
		N	%	N	%	N	%	N	%	N	%	N	%	N	%
Age	Below 25	0	0.0%	1	12.5%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	1	2.9%
	26 to 35	3	60.0%	4	50.0%	5	71.4%	1	20.0%	0	0.0%	0	0.0%	13	37.1%
	36 to 45	1	20.0%	1	12.5%	2	28.6%	4	80.0%	1	50.0%	1	12.5%	10	28.6%
	46 to 55	1	20.0%	2	25.0%	0	0.0%	0	0.0%	0	0.0%	3	37,5%	6	17.1%
	above 56	0	0.0%	0	0.0%	0	0.0%	0	0.0%	1	50.0%	4	50.0%	5	14.3%

An analysis of the relationship between age and experience revealed a Chi-square statistic of 34.430 with a p-value of 0.023 and a Pearson's R of 0.644.

4.4.2.2 Gender and experience of inspectors

An evaluation of the relationship between gender and experience (Table 4.12) provides a summary of the number of male and female participants per "experience" category. Most inspectors (both male and female) practiced meat inspection for less than 10 years (totalling 58.3% - 21 out of 36 - for both male and female participants).

Table 4.12: Cross-tabulation of gender vs experience of inspectors

		Cross-tabulation of gender vs years' experience of inspectors													
		less than 1 year		1 to 5 years		6 to 10 years		11 to 15 years		16 to 20 years		more than 21 years		Total	
		N	%	N	%	N	%	N	%	N	%	N	%	N	%
Gender	male	4	80.0%	5	55.6%	5	71.4%	3	60.0%	2	100.0%	8	100.0%	27	75.0%
	female	1	20.0%	4	44.4%	2	28.6%	2	40.0%	0	0.0%	0	0.0%	9	25.0%

Table 4.13 provides a breakdown of information on the number of male or female participants in each category as a percentage of the total number of male or female participants involved in the project.

Table 4.13: Cross-tabulation of experience vs gender of inspectors

Cross-tabulation of years' experience vs gender of inspectors		Male		Female		Total	
		N	%	N	%	N	%
Years' experience gained	less than 1 year	4	14.8%	1	11.1%	5	13.9%
	1 to 5 years	5	18.5%	4	44.4%	9	25.0%
	6 to 10 years	5	18.5%	2	22.2%	7	19.4%
	11 to 15 years	3	11.1%	2	22.2%	5	13.9%
	16 to 20 years	2	7.4%	0	0.0%	2	5.6%
	more than 21	8	29.6%	0	0.0%	8	22.2%
Total		27	100.0%	9	100.0%	36	100.0%

An assessment of the relationship between gender and experience revealed a Chi-square statistic of 5.862, a p-value of 0.320 and Pearson's R of - 0.277.

4.4.2.3 *Gender and average height of inspectors*

An assessment of gender and the average height (Table 4.14 - applicable to inspectors) shows that on average female participants were significantly shorter than their male counterparts.

Table 4.14 Cross-tabulation of gender vs average height of meat inspection personnel

Cross-tabulation of gender vs average height of inspectors		less than 1.5 m		1.5 m to 1.6 m		1.6 m to 1.7 m		1.7 m to 1.8 m		1.9 m		Total	
		N	%	N	%	N	%	N	%	N	%	N	%
Gender	male	0	0.0%	6	54.5%	7	77.8%	13	100.0%	1	100.0%	27	75.0%
	female	2	100.0%	5	45.5%	2	22.2%	0	0.0%	0	0.0%	9	25.0%
											Total	36	100.0%

An evaluation of the relationship between gender and average height showed a Chi-square statistic of 13.158, a p-value of 0.011 and a Pearson's R of - 0.577.

4.5 An analysis of the physical environment of meat inspectors

An assessment of the physiological and biomechanical aspects of meat inspection were conducted as well as the interactions of inspectors with the different elements of the meat production system (and may apply to the mental workload, decision-making, skilled performance, and work-related stress) (IEA, no date).

4.5.1 Field Investigation

The production and processing of at least one species of animals were observed at each of the selected abattoirs. The performance of meat inspection was assessed across a variety of different work settings applicable to this study.

4.5.1.1 *Measurement of inspection areas, platforms, and equipment*

The scheduled visits to participating abattoirs allowed the researcher the opportunity to identify and assess meat inspection areas (all areas where meat inspection was performed), whether designated or non-designated. The estimated floor space available for the performance of meat inspection as well as the dimensions of working platforms or stands were measured and recorded in:

a) Appendix H: Assessment of the work environment of meat inspectors during sheep slaughter;
b) Appendix I: Assessment of the work environment of meat inspectors during cattle slaughter; and
c) Appendix J: Assessment of the work environment of meat inspectors during pig slaughter.

Single species abattoirs (pigs slaughtering abattoirs) were equipped with dressing lines that measured 3 m above the floor level. The two and three species abattoirs had dressing lines that measured between 2.30 m and 2.45 m for sheep and approximately 3.40 m high for cattle and pigs (where applicable). Each abattoir had an expected minimum of three meat inspection areas or points. As stated earlier, it was determined that meat inspection areas were not clearly identified or demarcated at abattoirs. Likewise, no uniformity existed amongst abattoirs in terms of the size, layout, and design of these areas. The average floor space applicable to inspection areas varied from abattoir to abattoir with a minimum of 0.450 m^2 measured at abattoir I_3 and a maximum of 11.106 m^2 measured at abattoir B_1.

Apart from the differences identified in terms of meat inspection areas, the study revealed that discrepancies also existed in the design and the type of working platforms used for or dedicated to meat inspection. The average floor space available for meat inspection personnel (on platforms) at abattoirs ranged between 0.396 m^2 to 3.960 m^2, respectively. The maximum heights used in the design of working platforms differed greatly between facilities and was measured between 0.80 m and 1.60 m from ground level (measured from ground level to the height of the highest flat working surface). Platforms did not adequately accommodate or provide for the differences in heights of individual inspectors.

Finally, the slaughter practices among abattoirs also differed from facility to facility. Many abattoirs used different length equipment such as shackles, pulleys, hooks, or chains during their slaughter and dressing processes. Each of these items ultimately affected the levels of elevation at which meat inspection were performed. Furthermore, abattoirs made use of conveyor tables upon which inspection of rough offal (and in only one other case, red offal) were performed. The height of these conveyor tables varied between 0.78 m to 1.10 m and the width between 0.47 m to 1.02 m.

4.5.1.2 *Assessment of the activities involved in the performance of meat inspection*

The researcher developed an "Ergonomics work activity checklist" (Appendix L) to assess the performance of meat inspection at selected abattoirs. In addition to the observations made during the site visits, the researcher took pictures and video clips of inspectors performing inspection activities.

The performance of meat inspection requires inspectors to conduct their duties in a standing position. Inspectors adopted different stances depending on the working activity involved. Participants often flexed one or both knees and lifted their heels when stretching to perform routine meat inspection activities. Furthermore, at some abattoirs where meat inspection duties were performed at a conveyor table, inspectors often adopted a balanced stance (legs apart). However, in the case of a mechanical conveyor inspectors often had to move along the conveyor table to keep up with line speed. Thus, individuals frequently rotated between stationary positions and moving along the line. This resulted in a participant (i.e., an inspector) often standing with one leg straight and the other flexed, shifting their body weight between legs from time to time.

Inspectors rotated their upper and lower arms between different levels of elevation as well as at different positions and angles in relation to their bodies. It was common practice for inspectors to work with their arms just below or above shoulder level. Apart from working with their arms in an elevated position (Appendix P), inspectors also performed duties that required them to perform work using their arms in an abducted position (away from the body's midline) (Appendix Q).

Except for the inspection of red offal in cattle in which case hooks were used, inspectors normally used their supporting hand to hold and keep products while their dominant hand operated the knife. In performing these duties, participants performed short repetitive motions, i.e., upward, and downward movements of their hands, wrists, and forearms. These supinated (palm facing upwards) and pronated (palm facing downwards) movements formed part of each inspection cycle (performed throughout the day). In addition to the above, it was also observed that inspectors used a variety of different hand grips when holding the knife or hook. Variations in handle design of hooks greatly influenced the type of grip used, which in most cases could be classified as "unconventional" (Appendix R). However, when it came to gripping their knives, most inspectors used the power grip or a combination of the power grip and the precision grip (forefinger or thumb stretched across the back of the blade).

Meat inspection also require inspectors to adopt different neck and body positions. Participants repeatedly flexed and extended their necks while performing routine inspections (Appendix O). However, the extension of the neck was more common practice in cases where inspection personnel did not use working platforms (witnessed during pig carcass inspections conducted at abattoirs) or where there were significant deviations in terms of the height requirements of platforms and that of individual inspectors. Furthermore, inspectors bent their backs at varying degrees of angles, which ranged from less than 20° to close to 90° (Appendix N). However, it was noticed that at some abattoirs inspectors bent their backs at angles greater than 90°, with one abattoir where an inspector adopted a squatting position while doing inspection (i.e., sheep carcasses and red offal inspection). In addition to the above, inspectors often rotated and flexed their backs in side-ways positions when bending forward (abattoirs A_2 carcass inspection, F_2 carcass, red offal, and cattle head inspection).

Table 4.15 provides a summary of the observations made and outlines the number of abattoirs at which such activities were observed.

Table 4.15: Summary of work activity assessments conducted at selected abattoirs

Ergonomics work activity assessment summary at abattoirs								
Body#	Activity	aba.*	Activity	aba.*	Activity	aba.*	Activity	aba.*
Head	Straight	10	tilted back	10	bent sideways	8	rotated sideways	1
Neck	bent forward	10	tilted back	10	bent sideways	10	rotated sideways	2
Body	bent forward	10	bent backward	0	tuned sideways	10	Rotated	7
Shoulders	faced forward	10	tilted sideways	9	left side higher & right side lower	9	right side higher & left side lower	9
Arms	bent at elbow	10	lower than shoulder	10	higher than shoulder	10	reaching or stretching	10
Hands	grip type	10	repetitive movement	10	radial deviation	10	ulnar deviation	10
Wrist	pronated position (palm down)	10	supinated position (palm up)	2	extended or flexed (bent - sideways or up and down)	9	radial or ulnar deviation (twisted or turned wrist)	10
Legs	apart (balanced stance)	10	weight shifted to one leg	10	one leg bent	10	both legs bent	9
Feet	Flat	10	heels lifted	5	standing on toes	0	standing for long periods	10

items aligned to assessment criteria used in REBA analysis tool (https://ergo-plus.com/wp-content/uploads/REBA.pdf)

* number of abattoirs (out of 10) at which activity was observed

4.5.2 Rapid Entire Body Assessment (REBA)

The pictures and videos taken of inspectors conducting meat inspection also assisted the researcher in conducting additional assessments using the REBA tool (Appendix M). The REBA tool was used in a desktop exercise to provide additional information on the existence of potential risks, which may occur in the work environment of meat inspection personnel. The outcomes of each assessment served as an estimation of the level of risk to which participants were exposed and may therefore warrant further investigations. The researcher assessed the working activities of different individuals at several different workstations. For this investigation, a minimum of two to three different REBA assessments were conducted on the evidence collected from each abattoir. The scoring criteria used in determining the level of risk, constituted of the following: 1 = negligible risk; 2 - 3 = low risk (change may be needed); 4 - 7 = medium risk (further investigate and change soon); 8 - 10 = high risk (investigate and implement change); and 11+ = very high risk (implement change) (Middelsworth, 2023a). Table 4.16 provides a summary of the information applicable to each assessment.

Table 4.16: REBA analysis of meat inspection activities at various inspection points

Abattoir	Inspection point	Risk rating	Risk classification
A_2	carcass inspection	12	very high risk
	head inspection	9	high risk
	red offal inspection	9	high risk
B_1	carcass inspection	12	very high risk
	head inspection	10	high risk
	red and rough offal	5	medium risk
C_1	carcass inspection	11	very high risk
	head inspection	12	very high risk
	red offal inspection	9	high risk
	red and rough offal inspection	9	high risk
D_2	carcass inspection	11	very high risk
	red offal inspection	11	very high risk
E_1	carcass inspection	10	high risk
	head inspection	12	very high risk
	red offal inspection	10	high risk
	rough offal inspection	10	high risk
F_2	carcass inspection	13	very high risk
	head inspection	12	very high risk
	red offal inspection	12	very high risk
	tongue inspection	10	high risk
G_2	carcass inspection	12	very high risk
	head inspection	11	very high risk
	red offal inspection	12	very high risk
H_3	carcass inspection	12	very high risk
	head inspection	13	very high risk
I_3	carcass inspection	11	very high risk
	head inspection	12	very high risk
	red offal inspection	11	very high risk
	carcass inspection	12	very high risk
	red offal inspection	10	high risk
J_3	carcass inspection	11	very high risk
	red offal inspection	12	very high risk

4.5.3 Significance of physical ergonomics

Inspection areas, working platforms, and other supporting equipment needed in the performance of meat inspection varied considerably from abattoir to abattoir. Meat inspection areas were not clearly identifiable and had no defined or minimum requirements in terms of size or layout. In assessing the importance of ergonomics at abattoirs, it is essential to understand the role and the effect that meat inspection areas, working platforms, the use of hand tools, repetitive work, and the type of body postures had on the existence of ergonomic hazards (Vieira and Kumar, 2004).

An analysis was conducted to determine if a relationship existed between the existence of ergonomic hazards and “meat inspection areas”, “working platforms”, the “use of hand tools”, “repetitive work”, and the “type of body postures” adopted.

4.5.3.1 Meat inspection areas

With specific reference to meat inspection areas, 92.3% of inspectors indicated that abattoir layouts made provision for dedicated areas. All abattoir managers supported this statement.

According to Table 4.17, 64.1% of inspectors stated that abattoir layout provided for the effective use of meat inspection areas and 48.7% indicated that they had enough floor space to do their work. Less than 50% of inspectors always performed their tasks at a comfortable height and most of them kept up with production line speeds and completed their tasks in time. On the other hand, participants were divided on whether the number of inspectors allocated to each abattoir was sufficient or not. With specific reference to job or task rotation, 89.7% of inspectors indicated that they frequently rotated between tasks or inspection points.

Table 4.17: Responses of meat inspectors with regards to inspection areas

Meat inspection areas	Always	Seldom	Never
Layout provide for effective use of areas	64.1%	30.8%	5.1%
Sufficient space necessary to perform meat inspection	48.7%	35.9%	15.4%
Perform tasks at a comfortable height	46.2%	53.8%	0.0%
Keep up with the line speed or pace of work	61.5%	35.9%	2.6%
Perform necessary tasks within the required time	63.2%	34.2%	2.6%
Number of inspectors sufficient for abattoir	38.5%	25.6%	35.9%

According to 58.3% of abattoir managers meat inspection areas were clearly identifiable in abattoirs. Most managers (91.7%) affirmed that inspectors had sufficient floor space available to do their work, while the majority felt that these areas could accommodate more than one inspector at a time.

In an analysis of the relationship between the availability of designated areas for meat inspection and the effective use of such areas, the data revealed a Chi-square statistic of 8.486, a p-value of 0.014 and Pearson’s R of 0.454. In determining whether a relationship existed between the variables having “dedicated areas” available and having “sufficient floor space” for meat inspection, the data revealed a Chi-square statistic of 3.431, a p-value of 0.180 and Pearson’s R of 0.273.

Table 4.18 provides a breakdown of the Chi-square assessments conducted using dedicated areas for meat inspection together with several other variables.

Table 4.18: Chi-square test for dedicated areas and other variables

Variables	Test statistics	df	Asymptotic significance (2-sided)	Observation	Decision	Pearson correlation
Dedicated areas and keep up with pace of work	0.103	2	0.987	0.987 > alpha = 0.1	Not significant. Do not reject null hypothesis. No association (there is Independence	- 0.041
Identified areas and sufficient floor space	1.527	1	0.217	0.217 > alpha = 0.1	Not significant. Do not reject null hypothesis. No association (there is Independence)	0.357
Sufficient floor space and accommodate more than one inspector	12.000	1	0.001	0.001< alpha = 0.1	Significant Reject null hypothesis There is association (no independence)	1.000

Table 4.19 provides data on the calculations used in the probability assessments applicable to meat inspection areas at selected abattoirs.

Table 4.19 (a): Statistics on meat inspection areas used in probability calculations

Statistics on meat inspection areas – inspectors						
	Always responses			Seldom responses		
	N	Percent	Percent cases	N	Percent	Percent cases
Layout provide for effective use of areas	25	19.8%	64.1%	12	14.4%	30.8%
Sufficient space necessary to perform meat inspection	19	15.1%	48.7%	14	16.8%	35.9%
Perform tasks at a comfortable height	18	14.3%	46.2%	21	25.3%	53.8%
Keep up with the line speed or pace of work	24	19.1%	61.5%	14	16.8%	35.9%
Perform necessary tasks within the required time	24	19.1%	63.2%	13	15.7%	34.2%
Number of inspectors sufficient for abattoir	15	11.9%	38.5%	10	12.1%	25.6%

The information in Table 4.19 (a), used in probability calculations show that there is a 31.2% likelihood that abattoirs will make provision for the effective use of inspection areas as well as for sufficient floor space available to inspectors. Subsequently, there is a 29.6% likelihood that inspectors will perform tasks at a comfortable height and that they will be able to keep up with the pace of work. Table 4.19 (b) provide additional probability statistics applicable to meat inspection areas.

Table 4.19 (b): Additional probability statistics applicable to meat inspection areas

Probability statistics on meat inspection areas that indicate the likelihood that:	Probability
the layout of areas will provide for effective use and provide sufficient space	31.2%
inspectors will work at comfortable height and keep up with pace of work	29.6%
inspectors will perform necessary tasks and keep up with pace of work	38.9%
the number of inspectors will not be sufficient for abattoir	61.5%

4.5.3.2 Meat inspection platforms

According to Table 4.20 (inspector responses), 89.7% of participants deemed the use of platforms as important, a concept supported by 91.7% of abattoir managers. Consequently, 59.0% of inspectors (supported by 63.6% of abattoir managers) felt that platforms (Appendix T) provided sufficient walk-length. According to 72.7% of managers, platforms provided for height differences of individuals.

Table 4.20: Responses of meat inspectors with regards to inspection platforms

Meat inspection platforms	Yes	No
Working platforms necessary to perform tasks	89.7%	10.3%
Sufficient walk-length	59.0%	41.0%
Height differences of individual inspectors	44.7%	55.3%
Adequately distanced from the line	84.6%	15.4%
Fitted with side rails	79.5%	20.5%
Safe to work on	66.7%	33.3%

An assessment of the relationship between “working platforms” and “working at a comfortable height” revealed a Chi-square statistic of 0.897, a p-value of 0.344 and a Pearson’s R of 0.154. Furthermore, an analysis of the relationship between “working platforms” and “height differences” of individual inspectors showed a Chi-square statistic of 1.656, a p-value of 0.198 and a Pearson’s R of - 0.209. Likewise, the relationship between “platforms providing for the height differences of inspectors” and “sufficient floor space” based on the data from abattoir managers revealed a Chi-square statistic of 1.637, a p-value of 0.201 and a Pearson’s R of 0.386. Additional assessments of the relationships between working platforms and working conditions were conducted and are presented in Table 4.21.

Table 4.21: Comparison between working platforms and working conditions

Variables	Test statistics	df	Asymptotic significance (2-sided)	Observation	Decision	Pearson correlation
Working platforms and stretch or reach tasks	3.609	2	0.165	0.165 > alpha = 0.1	Not significant Do not reject null hypothesis No association (there is independence)	0.301
Working platforms and tasks elevated arms	4.175	2	0.124	0.124 > alpha = 0.1	Not significant. Do not reject null hypothesis. No association (there is Independence)	0.055
Working platforms and require to bend	2.549	2	0.280	0.280 > alpha = 0.1	Not significant. Do not reject null hypothesis. No association (there is Independence)	0.258
Tasks at comfortable height and require to bend	2.283	2	0.319	0.319 > alpha = 0.1	Not significant. Do not reject null hypothesis. No association (there is Independence	- 0.191
Tasks at comfortable height and arms elevated	1.690	2	0.430	0.430 > alpha = 0.1	Not significant. Do not reject null hypothesis. No association (there is Independence	0.169
Tasks at comfortable height and stretch or reach	0.488	2	0.783	0.783 > alpha = 0.1	Not significant. Do not reject null hypothesis. No association (there is Independence)	- 0.065

Table 4.22 provides data on the calculations used in the probability assessments applicable to working platforms at selected abattoirs.

Table 4.22: Statistics on meat inspection platforms used in probability calculations

Statistics on meat inspection platforms						
	Inspector responses			Manager responses		
	N	Percent	Percent cases	N	Percent	Percent cases
Sufficient walk-length	23	17.7%	59.0%			
Height differences of individual inspectors	17	13.1%	44.7%	8	32%	72.7%
Adequately distanced from the line	33	25.4%	84.6%			
Fitted with side rails	31	23.8%	79.5%	10	40%	90.9%
Safe to work on	26	20.0%	66.7%			
Sufficient workspace for inspectors				7	28%	63.6%

From the information provided in Table 4.22, it was concluded that there is a 26.4% likelihood that an abattoir will provide working platforms that provide sufficient walk-length and that will accommodate for the differences in height of inspectors. Table 4.23 highlights additional probability calculations applicable to working platforms at abattoirs.

Table 4.23: Additional probability statistics on calculations applicable to working platforms

What is the probability that meat inspection platforms will have:	Probability
Sufficient walk-length and provide for height difference	26.4%
Sufficient walk-length and sufficient workspace	34.4%
Fitted side rails and safe to work on	53.0%

4.5.3.3 Hand tools

Almost 89.7% of inspectors and 91.7% of managers, considered the type of hand tools (Appendix S) used during meat inspection as adequate and specific set of hand tools, while 84.6% of inspectors believed that hand tools were well designed and comfortable to grip. Likewise 75% of managers believed that hand tools were well designed and comfortable to use and further 75% of managers believed that hand tools allowed for a comfortable grip.

With specific reference to the use of hand tools, 82.1% of inspectors indicated that they used their hand tools for the entire duration of their working day, while 17.9% of respondents indicated that they used their hand tools for most part of the day. In Table 4.24, a considerable number of inspectors (94.7%) believed that the design of hand tools had an impact on the type of grip used. In addition, they felt that hand tool design could affect grip strength and stated that knife sharpness affected the efficiency with which they performed their duties.

Table 4.24: Responses of meat inspectors on the effects of hand tools

Effects of hand tools	Yes	No
Design impact on type of grip used	94.7%	5.3%
Design impact on grip strength	100%	0.0%
Knife sharpness affect task performance	89.7%	10.3%

Inspectors used a variety of knife types, each different in shape and distinct in size. Most inspectors, approximately 87.1% indicated that they used a single knife while 12.9% used a two-knife system. According to Table 4.25, 25.6% of inspectors used the 12.7 cm straight boning knife and another 25.6% used the 12.7 cm curved boning knife, while 46.2% of inspectors indicated that they used a larger knife type or a combination of larger knife types.

Table 4.25: Types and sizes of knives used by inspectors

Knives used by inspectors	Straight boning knife (12.7cm)	Curved boning knife (12.7 cm)	Beef skinning knife (15.24 cm)	Butcher's knife (25.4 cm)	Straight boning and curved boning knives	Straight boning and beef skinning knives	Curved boning and beef skinning knives
Type and size of the knife	10 25.6%	10 25.6%	6 15.4%	8 20.5%	1 2.6%	1 2.6%	3 7.7%

An assessment of the relationships between "hand tools" and several related variables were conducted as depicted in Table 4.26. According to the data, statistical relationships existed between "hand tools" and the application of a "comfortable hand grip" as well as the "type of grip used". It was also found that there was a statistical relationship between "hand tools" and the "strength of the grip" used by inspectors.

Table 4.26: Comparison between adequate hand tools and other variables

Variables	Test statistics	df	Asymptotic significance (2-sided)	Observation	Decision	Pearson correlation
Adequate set of hand tools and comfortable grip	12.000	2	0.002	0.002 < alpha = 0.1	Significant Reject null hypothesis There is association (no independence)	0.806
Adequate hand tools and well design and comfortable to use	12.000	2	0.002	0.002 < alpha = 0.1	Significant Reject null hypothesis There is association (no independence)	0.806
Adequate hand tools and its use in day-to-day activities	0.150	1	0.698	0.698 > alpha = 0.1	Not significant. Do not reject null hypothesis. No association (there is Independence)	0.062
Grip type and knife sharpness	5.147	1	0.023	0.023 < alpha = 0.1	Significant Reject null hypothesis There is association (no independence)	0.368
Grip type and comfortable grip	0.396	1	0.529	0.529 > alpha = 0.1	Not significant. Do not reject null hypothesis. No association (there is Independence)	- 0.102
Adequate set of hand tools and comfortable grip	4.103	1	0.043	0.043 < alpha = 0.1	Significant Reject null hypothesis There is association (no independence)	0.324

Table 4.27 provides data on the calculations used in the probability analysis applicable to the use of hand tools at selected abattoirs.

Table 4.27: Statistics on the effects of hand tools used in probability calculations

Statistics on the effects of hand tools						
	Inspector responses			Manager responses		
	N	Percent	Percent of cases	N	Percent	Percent of cases
Well designed for comfortable grip	33	23.2%	84.6%			
Design impact on type of grip used	36	25.4%	94.7%			
Design impact on grip strength	38	26.8%	100%			
Knife sharpness affect task performance	35	24.6%	89.7%			
Well designed and comfortable to use				9	50%	75%
Provide comfortable grip				9	50%	75%

The probability calculations show that there is an 80.1% likelihood that hand tools will be well-designed and that it will affect the type of grip used during meat inspection. Table 4.28 highlights additional probability assessments applicable to hand tools used at abattoirs.

Table 4.28: Additional probability statistics on the use of hand tools at abattoirs

What is the probability that the following will affect the use of hand tools?	Probability
Well-designed and impact on grip type	80.1%
Well-designed and impact on grip strength	84.6%
Grip strength and grip type	94.7%

4.5.3.4 Body postures

Most of the inspectors in Table 4.29, [92.3% (35.9% always + 56.4% seldom)] and 90.9% of the managers (27.3% always + 63.6% seldom) were of the view that stretching or reaching activities were performed during meat inspection. Both inspectors and managers confirmed that participants worked with their arms in elevated positions (Appendix P) and conducted activities that required them to bend forward (Appendix N).

Table 4.29: Body postures adopted by meat inspectors when performing inspection activities

Working activities performed during meat inspection	Always	Seldom	Never
Stretch or reach to perform tasks	35.9%	56.4%	7.7%
Perform tasks with arms in elevated position	38.5%	56.4%	5.1%
Required to bend forward	39.5%	44.7%	15.8%

The data (applicable to inspectors) also revealed that a statistical relationship existed between “stretching or reaching” and working with “arms in an elevated position”. A Chi-square statistic of 32.839, a p-value of 0.001 and a Pearson’s R of 0.508 was determined. Subsequently, an analysis conducted on the responses from abattoir managers on “stretching or reaching” and working with “elevated arms”, revealed a statistic value of 12.000, a p-value of 0.002 and a Pearson’s R of 0.891. In addition to the above, an assessment of meat inspector responses on the independence of the variables “stretching or reaching” and “bending forward” discovered a Chi-square statistic of 8.072, a p-value of 0.089 and a Pearson’s R of 0.007. Likewise, the results from abattoir managers also indicated that independence existed between stretching or reaching and forward bending. A Chi-square statistic of 9.061, a p-value of 0.060 and a Pearson’s R of 0.692 was calculated.

According to the information provided in Table 4.30, there is a 90.9% probability that an inspector will perform work that involve stretching or reaching activities. Table 4.30 provides a summary of these probability calculations according to abattoir managers.

Table 4.30: Statistics on body postures adopted by inspectors according to abattoir managers

What is the probability that an inspector will adopt the following body postures during meat inspection:	Probability
Stretch or reach to perform tasks	90.9%
Perform tasks with arms in elevated position	100%
Required to bend forward	83.3%

4.5.3.5 Repetitive work

Most participants, 97.1% of inspectors and 100.0% of managers, was of the view that meat inspection was deemed a standard and prescribed function (Appendix K). The data indicated that most meat inspection personnel rotated between workstations of which almost 55.6% rotated hourly, about 27.8% rotated every half an hour and only 11% rotated every 45 minutes.

The data provided by inspectors showed that there was a 79.5% probability that an inspector will perform repetitive work and according to abattoir managers there was a 91.7% probability that meat inspection involves repetitive work. Table 4.31 provides a summary of the activities involved in the performance of meat inspection at abattoirs.

Table 4.31: Total number of incisions, observations and palpations performed in a working day by meat inspectors at selected abattoirs

Minimum activity per meat inspection procedure at selected abattoirs

Porcine (p)

Abattoir	Red & rough offal			Head			Carcass			Total			Total physical activities
Repetitions per inspection procedure per	I*	O	P	I*	O	P	I*	O	P	I*	O	P	I*+O+P
	p-16	p-11	p-2	p-18	p-4	p-0	p-20	p-7	p-0	p-54	p-22	p-2	
B_1 # (x daily units)	20800	14300	2600	23400	5200	0	26000	9100	0	70200	28600	2600	101400
C_1 # (x daily units)	1152	972	144	1298	288	0	1440	504	0	3888	1584	144	5616
E_1 # (x daily units)	8000	5500	1000	9000	2000	0	10000	3500	0	27000	11000	1000	39000

Bovine (b) & Ovine (o)

Abattoir		Red & rough offal			Head			Carcass			Total			Total physical activities
Repetitions per inspection procedure per item		I*	O	P	I*	O	P	I*	O	P	I*	O	P	I*+O+P
		b-17, o-6	b-12, o-12	b-2, o-6	b-24, o- 0	b-5, o-7	b-1, o-6	b-26, o- 0	b-6, o-7	b-1, o-7	b-67, o-6	b-23, o-26	b-4, o-19	
A_2 # (x daily units)	b	1700	1200	200	2400	500	100	2600	600	100	6700	2300	400	9400
	o	3600	7200	3600	0	4200	3600	0	4200	4200	3600	15600	11400	30600
D_2 # (x daily units)	b	2125	1500	150	3000	625	125	3250	750	125	8375	2875	500	11750
	o	4500	9000	4500	0	5250	4500	0	5250	5250	4500	19500	14250	38250
F_2 # (x daily units)	b	1360	960	160	1920	400	80	2080	480	80	5360	1840	320	7520
	o	2880	5760	2880	0	3360	2880	0	3360	3360	2880	12480	9120	24480
G_2 # (x daily units)	b	850	600	100	1200	250	50	1300	300	50	3350	1150	200	4700
	o	3240	6400	3240	0	3780	3240	0	3780	3780	3240	14040	10260	27540
J_2 # (x daily units)	b	1700	1200	200	2400	500	100	2600	600	100	6700	2300	400	9400
	o	3600	7200	3600	0	4200	3600	0	4200	4200	3600	15600	11400	30600

Bovine (b), Ovine (o) & Porcine (p)

Abattoir		Red & rough offal			Head			Carcass			Total			Total physical activities
Repetitions per inspection procedure per item		I*	O	P	I*	O	P	I*	O	P	I*	O	P	I*+O+P
		b-17, o-6, p-16	b-12, o-12, p-11	b-2, o-6, p-2	b-24, o-0, p-18	b-5, o-7, p-4	b-1, o-6, p-0	b-26, o-0, p-20	b-6, o-7, p-7	b-1, o-7, p-0	b-67, o- 6, p-54	b-23, o-6, p-22	b-4, o-19, p-2	
H_3 # (x daily units)	b	1105	780	130	1560	325	65	1690	390	65	4355	1495	260	6110
	o	2340	4680	2340	0	2730	2340	0	2730	2730	2340	2340	7410	12090
	p	2080	1430	260	2340	520	0	2600	910	0	7020	2860	260	10140
I_3 # (x daily units)	b	2720	1920	320	3840	800	160	4160	960	160	10720	3680	640	15040
	o	5760	11520	5760	0	6720	5760	0	6720	6720	5760	5760	18240	29760
	p	5120	3520	640	5760	1280	0	6400	2240	0	17280	7040	640	24960

*- multiple incisions only applicable to lymph node incisions and for this study means a minimum of three incisions
I – incision; O – observation; P – palpation
- represent the daily slaughter capacity indicated on the facility's registration certificate

4.5.4 Working conditions

An assessment of the working conditions at abattoirs were conducted to determine what type of hazards affected meat inspectors in the performance of their duties.

4.5.4.1 Daily working activities

The working activities involved in the performance of meat inspection are depicted in Table 4.32 (responses from inspectors only).

Table 4.32: Different daily working activities involved in the meat inspection process according to inspectors

The type of daily activities involved in meat inspection				
		Responses		Percent of cases
		N	Percent	
Type of working activities	Repetitive work	30	16.3%	76.9%
	Handgrip	34	18.5%	87.2%
	Elevated arms	23	12.5%	59.0%
	Reach or stretch	21	11.5%	53.9%
	Variable line speed	26	14.2%	66.7%
	Bending back and neck	29	15.8%	74.4%
	Vibration	7	3.8%	18.0%
	Lifting	10	5.5%	25.6%
	Pulling and pushing	3	1.6%	7.7%
	Total	183	100.0%	

Table 4.33 provides a breakdown of probability scores applicable to various working activities relevant to the performance of meat inspection.

Table 4.33: Statistics on the probability that meat inspection may involve the following daily activities

What is the probability that the following working activities are involved in meat inspection:	Probability
Repetitive work and hand grip	67.1%
Repetitive work and working with elevated arms	45.4%
Repetitive work and bending of back or neck	57.2%
Working with elevated arms and reaching or stretching	31.8%
Working with elevated arms and variable line speeds	39.4%
Repetitive work and variable line speed	51.3%

4.5.4.2 Nature of work

In an assessment of the nature of work involved in the performance of meat inspection, Table 4.34 identified several activities associated with the type of work performed in an abattoir. The two activities identified with the highest percentage values were physically demanding work (59%) and long working hours (61.5%).

Table 4.34: Nature of work performed by inspectors during meat inspection

Nature of work performed by inspectors		Responses N	Responses Percent	Percent of cases
Nature of work involved in inspection	Physically demanding tasks	23	23.47%	59.0%
	Long hours	24	24.5%	61.5%
	No rest or recovery breaks	6	6.1%	15.4%
	No rotation	7	7.1%	18.0%
	Awkward stance or working postures	19	19.4%	48.7%
	Highly paced activities	19	19.4%	48.7%
	Total	98	100.0%	

Approximately 75% of managers felt that meat inspection was physically demanding in nature and 50% believed that it constituted of extensively long working hours. Only 25% of managers stated that meat inspection was conducted in a highly paced work environment and 41.7% indicated that inspectors often adopted awkward working postures when performing inspection tasks.

The data provided in Table 4.34, show that there is a 59% probability that an inspector will perform physically demanding work, a 61.5% probability that the work involved in meat inspection will constitute of long working hours, a 48.7% probability that an inspector will adopt an awkward stance or posture and a 48.7% probability that meat inspection at an abattoir will be associated with highly paced working activities.

Table 4.35 also provides a breakdown of the probability scores applicable to a combination of variables relating to the nature of work performed during meat inspection.

Table 4.35: Statistics on probability calculations relating to the nature of work performed

What is the probability that the nature of work performed by inspectors will include:	Probability
Physically demanding work and long working hours	36.3%
Physically demanding work and adopting awkward postures	28.7%
Highly paced working activities and long working hours	29.9%
Physically demanding work and highly paced activities	28.7%
Highly paced activities and adopting awkward postures	23.7%

4.5.4.3 Muscular discomfort

The kind of discomfort experienced by inspection personnel are shown in Table 4.36 below. It was indicated by 76.9% of inspectors that they experienced back discomfort during their work. Participants also reported some distress in the neck, shoulders, hands, and wrists. Subsequently abattoir managers highlighted back (41.7%), and shoulder (41.7%) discomfort as key concerns reported by meat inspection personnel.

Table 4.36: Multiple response analysis of types of discomfort experienced

Discomfort associated with the performance of meat inspection		Responses		Percent of cases
		N	Percent	
Discomfort experienced	back	30	25.86%	76.92%
	hand	22	18.97%	56.41%
	neck	16	13.79%	41.03%
	shoulder	24	20.07%	61.54%
	wrist	24	20.07%	61.54%
Total		116	100.0%	

An analysis was conducted to determine if a statistical relationship existed between ergonomic hazards and its impact on the well-being of inspectors. According to the data provided by inspectors (Table 4.36), there is a 76.9% probability that an inspector will experience back discomfort, a 56.4% probability that an inspector will experience hand discomfort, a 41.0% probability that an inspector will experience neck discomfort, and a 61.5% probability that an inspector will experience shoulder and wrist discomfort respectively.

In assessing the relationship between "back' and 'neck' discomfort, the data revealed a Chi-square statistic of 12.353, a p-value of 0.001 and a Pearson's R of 0.787. In addition to the above, Chi-square tests were also conducted on several other variables related to the types of discomfort experienced by inspectors. The details of the assessments are captured in the Table 4.37.

Table 4.37: Summary of Chi-square test for the different types of discomfort

Variables	Test statistics	df	Asymptotic significance (2-sided)	Observation	Decision	Pearson correlation
Back discomfort and neck discomfort	12.353	1	0.001	0.001< alpha = 0.1	Significant Reject null hypothesis There is association (no independence)	0.767
Back discomfort and shoulder discomfort	11.185	1	0.001	0.001 < alpha = 0.1	Significant Reject null hypothesis There is association (no independence)	0.697
Back discomfort and wrist discomfort	5.831	1	0.016	0.016 < alpha = 0.1	Significant Reject null hypothesis There is association (no independence)	0.503
Hand discomfort and wrist discomfort	14.603	1	0.001	0.001 < alpha = 0.1	Significant Reject null hypothesis There is association (no independence)	- 0.797
Hand discomfort and shoulder discomfort	9.900	1	0.002	0.002 < alpha = 0.1	Significant Reject null hypothesis There is association (no independence)	- 0.671
Neck discomfort and shoulder discomfort	10.978	1	0.001	0.001< alpha = 0.1	Significant Reject null hypothesis There is association (no independence)	0.760

Table 4.38 provides a breakdown of probability calculations applicable to a combination of discomfort experienced during meat inspection.

Table 4.38: Statistics on the probability that an inspector may experience a combination of discomfort at abattoirs

What is the probability that an inspector may experience the following discomfort:	Probability
back and neck	31.5%
back and shoulders	47.3%
shoulders and neck	25.2%
shoulders and wrist	37.8%
hand and wrist	34.7%

Table 4.38 shows that an inspector may experience some levels of discomfort in different parts of his or her body because of the type of work involved in the performance of meat inspection.

4.6 An analysis of the organisational environment of meat inspectors

An assessment of the organisational environment, policies, and processes in which meat inspection functioned was conducted in terms of the design of work, the design of working times and participatory design (IEA, no date).

4.6.1 Key elements of occupational health and safety management systems

According to Table 4.39, 70.3% of inspectors believed the selected abattoirs had health and safety management systems in place. Of these (the “yes” responses) 84% indicated that abattoirs had designated health and safety representatives appointed, while most respondents felt that abattoirs had control measures in place to manage and report hazards.

Table 4.39: Occupational health and safety management at abattoirs

Occupational Health and Safety Management System	Yes	No	Do not know
OH&S system exist	70.3%	16.2%	13.5%
Health and safety representative designated	84.0%	12.0%	4.0%
Control measures to prevent hazards	84.6%	15.4%	0.0%
System to report hazards	80.8%	11.5%	7.7%

Approximately 91.7% of abattoir managers stated that abattoirs had a health and safety management system in place. A further 100.0% held the view that abattoirs had a suitable health and safety policy, and that this policy was clearly defined. Only 36.4% of managers indicated that the health and safety policy was adequately displayed in abattoirs. A total of 83.3% of managers felt that abattoirs had designated health and safety representatives appointed, while 91.7% stated that health and safety inspections were conducted.

In assessing whether a relationship existed between the existence of an “OH&S system” and having a “designated OH&S representative”, the results indicated a Chi-square statistic of 0.218, a p-value of 0.640 and a Pearson's R of - 0.135. Likewise, an analysis of the relationship between having "control measures" in place and having a "system for the reporting" of hazards indicated a Chi-square statistic of 9.722, a p-value of 0.008 and Pearson's R of 0.526.

Table 4.40 provides a summary of the data on OH&S management systems at abattoirs and shows that there is a 70.3% probability that an abattoir will have an OH&S system in place.

Table 4.40: Statistics on the existence of OH&S management systems at abattoirs

Statistics on Occupational Health and Safety Management System						
	Inspector responses			Manager responses		
	N	Percent	Percent of cases	N	Percent	Percent of cases
OH&S system exist	26	29.0%	70.3%	11	25.0%	91.7%
Health and safety representative designated	21	23.3%	84.0%	10	22.7%	83.3%
Control measures to prevent hazards	22	24.4%	84.6%	12	27.3%	100%
System to report hazards	21	23.3%	80.8%	11	25.0%	91.7%
Total	90	100.0%		44	100%	

An analysis of the likelihood that a randomly selected abattoir (one having an OH&S system), will have control measures in place to prevent and report hazards, indicated that there is a 41.9% likelihood that an abattoir, having an OH&S management system, will have control measures in place and have a suitable reporting structure.

4.6.2 The extent of occupational health and safety training and awareness

Thirty-five point nine percent (35.9%) of inspectors stated that abattoirs conducted health and safety training, while 51.3% indicated the opposite. According to 91.7% of abattoir managers, abattoirs had health and safety training programmes in place and 83.3% of managers stated that health and safety training were often conducted at abattoirs. A total of 64.3% of inspectors indicated that they took part in training and awareness programmes at abattoirs.

According to inspectors the following items were included during training and awareness at abattoirs: bending, variable line speed, and lifting of products (all scored 4 out of 9) which ranked as the most frequently identified aspects. Awkward postures, grip force, and repetitive work (all scored 3 out of 9) were ranked as the second most frequently identified items reported. On the other hand, abattoir managers (Table 4.41) revealed that bending (83.3%), repetitive work (75%), and awkward postures (66.7%) were some of the important items.

Table 4.41: Items covered by training and awareness according to abattoir managers

OH&S training and awareness – abattoir managers	Yes	No
awkward postures	72.7%	27.3%
bending	90.9%	9.1%
grip force	50.0%	50.0%
repetitive work	81.8%	18.2%
variable line speed	63.6%	36.4%
vibration	40.0%	60.0%
lifting	90.9%	9.1%
training improve health and safety awareness	91.7%	8.3%

An assessment of the impact of training on the overall health and safety at abattoirs, indicated that 87.5% of inspectors (7 out of 8 participants who selected to answer this question) felt that training improved overall health and safety, while 91.7% (11 out of 12) of abattoir managers thought it did.

Of the inspectors who indicated that they participated in training at abattoirs, Table 4.42 revealed that 75% strongly agreed and 25% agreed that training contributed to better health and safety management at abattoirs. Most inspectors felt that training reduced occupational health risks and enhanced the reporting of occupational hazards at abattoirs.

Table 4.42: OH&S training and awareness statements by inspectors

OH&S training and awareness:	Strongly agree	Agree	Unsure	Disagree	Strongly disagree
Contribute to better health and safety management	75.0%	25.0%	0.0%	0.0%	0.0%
Reduce health and safety risks	71.4%	28.6%	0.0%	0.0%	0.0%
Enhances reporting of health and safety hazards	71.4%	28.6%	0.0%	0.0%	0.0%

In addition to the above, 100% of abattoir managers (i.e., 58.3% strongly agreed and 41.7% agreed) supported the statement that training contributed to better health and safety management. All managers (i.e., 66.7% strongly agreed and 33.3% agreed) also stated that training reduced occupational risks and 83.3% (i.e., 58.3% strongly agreed and 25.0% agreed) indicated that it enhanced the reporting of hazards at abattoirs. In assessing if a relationship existed between the existence of an "OH&S system" and the implementation of a suitable "training programme", the data revealed a Chi-square statistic of 0.099, a p-value of 0.753 and a Pearson's R of - 0.091.

Table 4.43 provides a summary of the Chi-square statistics for a few variables relating to the training and awareness variables.

Table 4.43: Chi-square test for OH&S training and other variables

Variables	Test statistics	df	Asymptotic significance (2-sided)	Observation	Decision	Pearson correlation
OH&S system and OH&S training conducted (Inspectors)	12.581	4	0.014	0.014 < alpha = 0.1	Significant Reject null hypothesis There is association (no independence)	0.329
OH&S system and OH&S training conducted (Managers)	0.218	1	0.640	0.640 > alpha = 0.1	Not significant. Do not reject null hypothesis. No association (there is Independence	- 0.135
OH&S representative and conducting OH&S training	7.957	4	0.093	0.093 < alpha = 0.1	Significant Reject null hypothesis There is association (no independence)	0.236
Participation in training and reporting system	4.200	1	0.040	0.040 < alpha = 0.1	Significant Reject null hypothesis There is association (no independence)	0.548

Table 4.44 provides data on the calculations used in determining the probability assessment applicable to health and safety training at selected abattoirs.

Table 4.44: Statistics on OH&S training and awareness

Statistics on Occupational Health and Safety training and awareness at abattoirs						
	Inspector responses			Manager responses		
	N	Percent	Percent of cases	N	Percent	Percent of cases
Awkward postures	3	17.6%	33.3%	8	20.5%	66.7%
Bending	4	23.5%	44.4%	10	25.6%	83.3%
Grip force	3	17.6%	33.3%	5	12.8%	41.7%
Repetitive work	3	17.6%	33.3%	9	23.1%	75.0%
Variable line speed	4	23.5%	44.4%	7	18.0%	58.3%
Total	17	100.0%		39	100%	

Probability statistics show that there is a 0.72% likelihood that if one of the selected abattoirs have an OH&S training programme in place, that such a training programme will cover awkward postures, bending, grip force, repetitive work, and variable line speed.

Table 4.45 provides a breakdown of additional probabilities applicable to training and awareness programmes at a randomly selected abattoir, which is included in this study.

Table 4.45: Additional probability statistics on OH&S training and awareness

What is the probability that OH&S training and awareness will include:	Probability
Awkward postures and bending	14.8%
Grip force and repetitive work	11.1%
Repetitive work and variable line speed	14.8%
Variable line speed and bending	19.7%

4.6.3 Common approaches to ergonomics and occupational health and safety

In the data provided by meat inspection personnel, 86.8% of respondents indicated that they knew whom to report health and safety hazards to. Figure 4.5 provides an outline of the responses from inspectors. The reporting of health and safety hazards to the different role players were not investigated and can therefore not be verified as part of this study. However, none of the respondents considered reporting health and safety hazards to the Department of Labour.

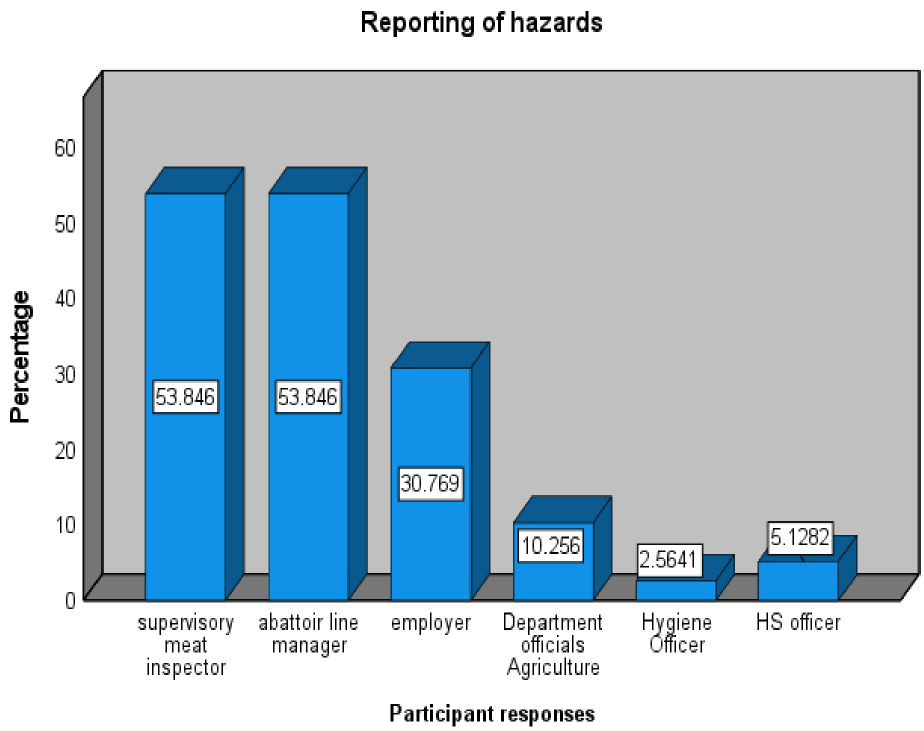


Figure 4.5 Role players to whom health and safety hazards were reported as indicated by inspectors

Participants identified and reported health and safety hazards in their workplace as indicated in Figure 4.6. A total of 64.1% of inspectors identified and reported hazards in an abattoir. This statement was supported by 58.3% of abattoir managers who shared the same views and 41.7% who did not.

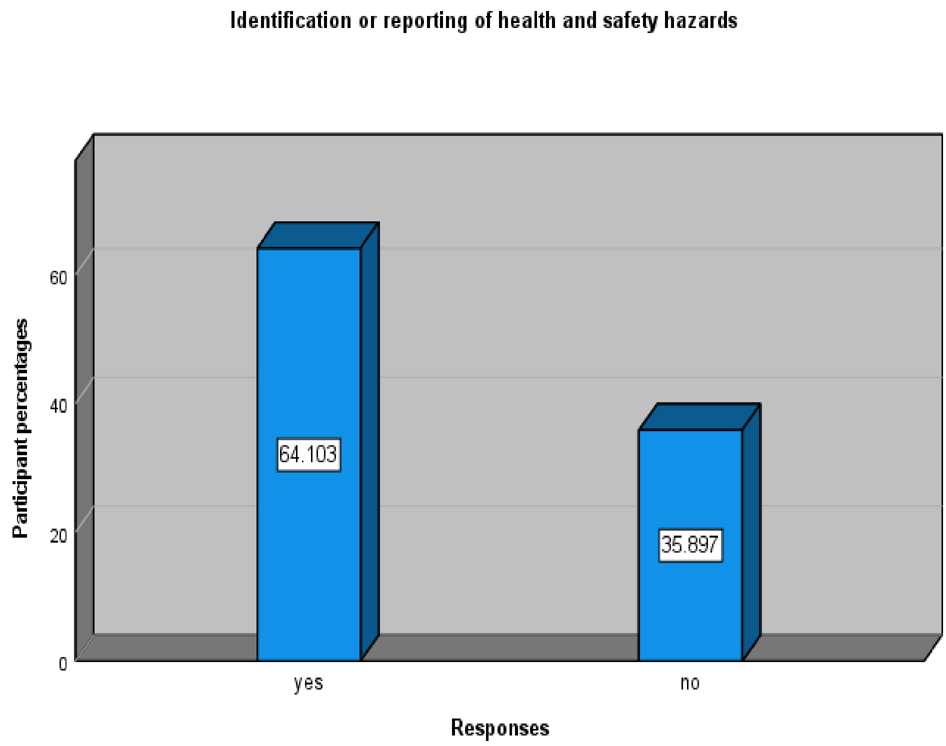


Figure 4.6 Identification or reporting of health and safety hazards by inspectors

In an assessment of the common approaches to ergonomics and OH&S at abattoirs, the data (Table 4.46) shows that 94.9% of inspectors indicated that they had a good understanding of ergonomics. Most of them viewed reducing health and safety hazards in an abattoir as important. They also considered addressing ergonomic hazards in an abattoir as part of their responsibility and held the view that ergonomics also applied to tool and equipment design.

Table 4.46: Approaches to ergonomics and OH&S

Approaches to ergonomics	True	False
Understanding of ergonomics	94.9%	5.1%
Reducing hazards are important	94.9%	5.1%
Ergonomics applies to tool and equipment design	79.5%	20.5%
Ergonomic hazards are my concern	60.5%	39.5%

Apart from those inspectors who disagreed or who were unsure about the relevance of training, around 77% (i.e., 46.2% strongly agreed and 30.8% agreed) of inspectors thought training conducted at abattoirs were relevant to the field of ergonomics. Abattoir managers on the other hand, agreed that an abattoir's occupational health and safety programme included ergonomics (i.e., 41.7% of managers strongly agreed and 50% agreed). On the issue of the relevance of training, 83.3% (i.e., 33.3% strongly agreed and 50% agreed) of managers indicated that training was relevant to ergonomics.

Table 4.47 provides an illustration of a Pearson's R correlation analysis conducted on the relationships between the variables applicable to measuring the approaches of inspectors towards ergonomics and OH&S at abattoirs.

Table 4.47: Correlation analysis on approaches to ergonomics and OH&S based on the data collected from inspectors

Correlation analysis with regards to ergonomics and OH&S		1	2	3	4	5	6
1. Know who to report health and safety hazards to	Pearson Correlation	1					
	Sig. (2-tailed)						
	N	38					
2. Identify or report health and safety hazards	Pearson Correlation	0.025	1				
	Sig. (2-tailed)	0.879					
	N	38	39				
3. Understanding of ergonomics	Pearson Correlation	0.257	0.311	1			
	Sig. (2-tailed)	0.119	0.054				
	N	38	39	39			
4. Reducing hazards are important	Pearson Correlation	- 0.092	0.068	- 0.054	1		
	Sig. (2-tailed)	0.584	0.679	0.744			
	N	38	39	39	39		
5. Ergonomics applies to tool and equipment design	Pearson Correlation	- 0.201	- 0.248	- 0.118	- 0.118	1	
	Sig. (2-tailed)	0.226	0.128	0.474	0.474		
	N	38	39	39	39	39	
6. Ergonomic hazards are my concern	Pearson Correlation	- 0.145	0.053	- 0.190	0.292	0.243	1
	Sig. (2-tailed)	0.391	0.753	0.252	0.075	0.141	
	N	37	38	38	38	38	38

4.6.4 Attitudes towards ergonomics

Regarding the question, whether the field of ergonomics was concerned with people and their work, 89.7% of inspectors believed that it did. With specific reference to whether workspace and equipment design played a vital role in ergonomics, 100% of inspectors stated that it did. Concerning the question if or not the principles of ergonomics could be incorporated into the initial planning and design of abattoirs, 94.9% of inspector participants thought that it could be incorporated into the initial planning and design of abattoirs. All the abattoir managers (100%) agreed with the statements in this section.

Table 4.48 provides an outline of a Pearson's R correlation analysis conducted on the relationships between the variables applicable to measuring the attitudes of inspectors towards the field of ergonomics at abattoirs.

Table 4.48: Correlation analysis on attitudes towards ergonomics based on the data collected from inspectors

		Correlation analysis on attitudes towards ergonomics		
		1	2	3
1. Training is relevant to the field of ergonomics	Pearson Correlation	1		
	Sig. (2-tailed)			
	N	39		
2. Concerned with people and their work	Pearson Correlation	0.225	1	
	Sig. (2-tailed)	0.169		
	N	39	39	
3. Planning and design of abattoirs	Pearson Correlation	0.105	- 0.074	1
	Sig. (2-tailed)	0.525	0.655	
	N	39	39	39

4.7 Interviews with Industry stakeholders

Interviews were conducted using a combination of face-to-face settings (one face-to-face) and Skype Business (three using the virtual platform due to the Covid-19 pandemic). The researcher opted for a semi-structured approach which allowed the participants some level of freedom in their responses to questions. The interview schedule followed the same themes as the questionnaires and focussed on the key points mentioned below which were deemed important to this investigation (Annexure E).

On the role and the importance of occupational health and safety and ergonomics, most participants felt that abattoirs understood what health and safety were. However, concerns were raised about the fact that health and safety systems fell short in addressing the health and safety concerns of meat inspection personnel. The reason for this was mainly because inspectors were not employed by abattoirs, but by external service providers. With reference to whether ergonomics was adequately provided for at abattoirs, the general view was that it was not treated with the necessary level of importance and that it should play a more meaningful role during the design and development of abattoirs.

With specific reference to the work environment of inspectors, participants agreed that the layout of abattoirs made provision for meat inspection areas. However, they were divided on whether the floor space, currently provided for at abattoirs, were sufficient in terms of meat inspection requirements. According to participants, adequate provisions (i.e., for line speed, height, space, product, and process efficiency, etc.) should be made within the work environment of inspectors to ensure that abattoir layout is adequate for performing meat inspections.

Participants agreed that the workload and work patterns applicable to meat inspection were greatly affected by the highly paced work setting and physically demanding activities required for extensively long periods. According to one participant, meat inspection was synonymous with repetitive work, which exposed inspectors to several risks (including decreased quality of work). Subsequently, participants felt that long working hours were also affected by peak production cycles, i.e., monthly, annual, or seasonal peaks.

Regarding the monitoring and reporting of ergonomic hazards at abattoirs, the responses from participants were diverse. Some felt that abattoirs had systems in place for monitoring and reporting of hazards, while others indicated that abattoirs addressed general health and safety issues and not ergonomics *per se*.

On the question whether abattoirs had done enough to reduce their liability in terms of ergonomics, participants believed a lot still needs to be done. All participants were of the view that the challenges faced by abattoirs in terms of ergonomics could only be adequately addressed through cooperative efforts by all stakeholders involved.

CHAPTER FIVE
DISCUSSION

5.1 Introduction

Ergonomic hazards have become one of the main concerns within the meat industry and according to the International Labour Organisation (ILO) training was identified as one of the fundamental requirements necessary to adequately address these hazards (Tomoda, 1997). The hazards applicable to meat inspectors may include working postures, the use of hand tools, repetitive movements, workplace layout, and safety and health (Vieira and Kumar, 2004).

The field of ergonomics is primarily divided into three main areas i.e., physical, cognitive, and organisational ergonomics (IEA, no date). With reference to this study, physical ergonomics involve aspects such as the anatomy of inspectors as well as the physiological and biomechanical characteristics of the work they perform. Cognitive ergonomics, on the other hand, focuses on the mental processes that an inspector have to work through. It includes aspects such as the reasoning and motor responses of inspectors and their interactions with different elements of the meat production system and may include mental workload, decision-making, skilled performance, and work-related stress. The field of organisational ergonomics deals with the impact that the organisational structure, policies, and processes have on an inspector's working environment in terms of the design of work, the design of working times, and participatory design (IEA, no date).

The objectives of this study was firstly, to establish if ergonomic hazards existed and to identify the type of hazards that occurred within the work environment of meat inspectors. Secondly, to determine the effects of ergonomic hazards, and thirdly to determine the extent and impact of ergonomic hazards on meat inspectors.

5.2 Ergonomic risk factors present during meat inspection

The performance of meat inspection was greatly influenced by variations in the workplace, the workspace as well as the physical diversities of meat inspection personnel. The working environment, tools, equipment, and working systems applicable to abattoirs could affect the physical, biomechanical, physiological, and psychological capabilities of inspectors (Fernandez, 1995).

At present meat inspection is performed in an environment that evolved over time and abattoirs and meat inspection personnel had to adapt to these changes. This section aims to discuss how the physical design requirements of the occupational environments in abattoirs affected the physiological performance and capabilities of inspectors.

5.2.1 Repetitive work

An inspection task as indicated in Table 4.31, is a set of sequential steps that requires an inspector to examine a carcass or its organs and to determine if it was safe for human or animal consumption. Inspectors are therefore required by law to follow a specific set of inspection procedures for each carcass and its accompanying parts (Regulations No. 1702 of 17 September 2004) (South Africa, 2004).

The time it takes to complete an inspection procedure, may be defined as work cycle time or standard cycle time (Taifa and Vhora, 2019; Lean Strategies International LLC, 2022). An assessment of the work cycle times applicable to the performance of meat inspection, revealed that an inspector has a minimum of 15 to 30 seconds to complete a set of inspection procedures. A reduction in work cycle times could increase the physical intensity of meat inspection activities. Consequently, an increase in the pace of work as well as the repetitiveness of meat inspection activities could result in greater physiological demands on inspectors, which may increase the level of fatigue or strain in their bodies (Zadry *et al.,* 2011). Furthermore, if inspectors performed the same repetitious movements for the entire duration of the day or shift, the "repeated motion patterns" followed during meat inspection can be defined as repetitive work (Al-Otaibi, 2001). Although the muscular discomfort experienced by inspectors may be affected by the type and the extent of working activities involved, repetitive work may cause or may aggravate damage to muscular tissues or tendons which could affect the neck, upper limbs, and the back of those practicing meat inspection (Al-Otaibi, 2001).

A test of independence conducted on the relation between the two variables "keeping up with line speed or pace of work" and "perform necessary task within required time" was not significant [$X^2(4, N = 38) = 5.420$; $p = 0.247$]. The data showed that no relationship existed between the two variables. An increase in production line speeds or any fast-paced working activities could therefore influence an inspector's ability to perform all the necessary tasks. A series of assessments conducted on different types of variables, revealed that the relation between "repeating tasks during meat inspection" and "hand-, wrist-, arm-, shoulder-, neck-, and back discomfort" were not statistically significant. The data showed that no relationships existed between the different combinations of variables. However, with reference to the type of working activities involved in the performance of meat inspection, the data indicated that the variable “repeating tasks during meat inspection” could present a considerable risk to inspectors.

5.2.2 The use of hand tools

Most of the respondents (section 4.5.3.3 – 89.7% of inspectors and 91.7% of managers) were in agreement that inspectors had an adequate set of hand tools. However, the use of the term “adequate”, did not reflect on any quality related aspects, but rather on whether hand tools were suitable or appropriate for use during meat inspection.

Several hooks consisted of steel rod handles (rectangular and t-shaped) and cylindrical shaped handles (such as screwdriver or other types of handles) (Appendix S). The majority of the steel rod handles were quite difficult to grasp, and an inspector’s hand or fingers could not be fully wrapped around it. The contact area between the hand and handle were greatly reduced in steel rod handles, which may increase the level of strain on the hand and fingers (Mital and Kilbom, 1992). In general, the difference in the design of hand tool handles may have affected the type and the comfort of grips used during meat inspection. An assessment of the independence of the two variables “designed for comfortable grip” and “grip type used” was not significant [$X^2(1, N = 38) = 0.396$; $p = 0.529$] and no statistically significant relationship existed between the variables. The data showed that a selection of hand tool designs did not make adequate provision for comfortable gripping techniques.

Inspectors used a combination of knives (i.e., beef skinning knife, butcher’s knife, straight boning knife, and curved boning knife). The beef skinning knife and the butchers’ knife consisted of wide, flat, thick curved blades with rounded tips. These knives consisted of heavier blades, which allowed inspectors to easily cut through tougher meats. The straight or curved boning knives (used by 51.2% of inspectors), consisted of sharp, narrow straight blades with pointed tips, designed for precision work during deboning operations (Table 4.25). The use of deboning knives could substantially increase the level of strain on the wrist of meat inspectors as it was not designed to cut through tougher meat (Price, 2023). Inspectors may adopt non-neutral hand, wrist, and arm positions during cutting operations. These non-neutral positions could reduce an inspector’s wrist and grip strength (as indicated in Figure 2.10) and increase the level of tension in the hand or wrist. The increased levels of tension in the hand and wrist may give rise to tendon and tissue disorders (Bobjer *et al.,* 1993). Subsequently, knife sharpness may also affect an inspector’s ability to complete tasks and may trigger changes in gripping techniques. A reduction in knife sharpness may result in inspectors (especially noticeable amongst newer or inexperienced inspectors) struggling to complete the necessary tasks or to keep up with the pace of work (Szabo *et al.,* 2001). It could also result in an increase in the cutting force requirements in the hand or wrist (McGorry *et al.,* 2003; McGorry *et al.,* 2005). A test of independence conducted to determine the relation between "grip type" and "knife sharpness" revealed the two variables was statistically significant [$X^2(1, N = 38) = 5.147$; $p = 0.023$]. The data showed that a positive relationship existed between the two variables and that knife sharpness was more likely to affect the type of grip used by inspectors.

5.2.3 Working platforms

Platforms play an integral part in the performance of meat inspection. Rail heights were fixed and not adjustable and therefore did not accommodate for the physical diversities of individual inspectors. The level of elevation at which carcasses hung were influenced by the height of the rail, the size of the carcass, the length of the pulleys, gambrels, shackles, or chains used. These ultimately impacted on the height or elevation at which meat inspection was performed. A test of independence conducted to determine the relation between "working platforms" and "performing work at a comfortable height" revealed that the two variables were not significant [$X^2(1, N = 38) = 0.897$; $p = 0.344$] and no statistically significant relationship existed between the variables. The shortfalls in the design and layout of working platforms were more likely to prevent inspectors from performing meat inspection at a comfortable height. Working platforms (Appendix T) may force inspectors to adopt a range of arm and shoulder positions (Appendices P & Q) that could increase the degree of muscular activity in their bodies (Hellig *et al.,* 2018).

The common perception amongst respondents (Table 4.20) were that platforms were necessary. However, they were divided on whether platforms made sufficient provision for the height differences of inspectors. Most inspectors felt that platforms did not make adequate provision for height differences, whereas the majority of managers felt that it did. An assessment of platforms revealed that most platforms were fixed structures and was either too high or too low. The widths or depths of the walking surfaces were found to be inadequate in terms of floor surface requirements. The type, design, and level of elevation applicable to these platforms ultimately affected the ease with which meat inspectors performed their duties (Appendix N). A test of independence conducted to assess the relation between the two variables "working platforms" and "height differences of inspectors" revealed that the two variables was not significant [$X^2(1, N = 38) = 1.656; p = 0.198$] and showed that no statistically significant relationship existed between the variables. The level of elevation applicable to working platforms together with the height differences of individual inspectors were more likely to have an impact on an inspector's ability to perform meat inspection.

While most inspectors and managers (Table 4.20) felt that platforms provided sufficient walk-lengths, only 20% of the selected abattoirs had platforms with a walk-length greater than 1 m in length. Platforms did not provide inspectors with sufficient space to manoeuvre themselves and were fitted with hand washbasins and sterilizers which were necessities required in terms of the relevant regulations (South Africa, 2004). These necessities reduced the minimum space available to inspectors. The lack of sufficient workspace on working platforms caused inspectors to adopt a variety of different but awkward working positions, which forced them to overexert themselves and to perform work outside of their comfort zones (Harmse *et al.,* 2016).

5.2.4 Working areas

Meat inspection areas made provision for the continuous and dynamic interactions between inspectors and their working environments. Several key risk factors may exist in working areas that could trigger physiological and psychological responses of inspectors. These responses might impact on the comfort, the performance, and the well-being of meat inspectors (Dianat *et al.,* 2016). The workload of meat inspectors could be affected by the layout of inspection areas, the nature of inspection activities as well as the type of equipment or hand tools used during meat inspection (Vieira and Kumar, 2004).

While meat inspection areas existed at selected abattoirs, it lacked attention to detail in terms of its design and layout. The work performed during meat inspection was scientifically and theoretically different from the work performed during slaughtering and dressing. Meat inspection therefore required specific and dedicated areas within abattoirs. An assessment of meat inspection areas indicated that inspection areas were hugely inadequate in terms of its location, its dimensions and floor sizes (Appendices H, I, and J). A test of independence indicated that the relation between the two variables "dedicated areas" and "effective use of areas" was significant [$X^2(2, N = 39) = 8.486; p = 0.014$]. It showed that a moderate positive relationship existed between the variables and that the provision of meat inspection areas was more likely to influence the extent to which inspectors effectively used these areas to perform and complete the inspection activities.

Inspectors were divided on whether they had enough space to perform their duties (Table 4.17). Most managers (91.7%) were of the opinion that abattoirs provided sufficient floor space and that these areas could accommodate more than one inspector at a time. Nonetheless, the dimensions applicable to these areas indicated that nearly one third of inspection areas consisted of lengths greater than 2.0 m, while none consisted of widths equal to or greater than 1.85 m. The insufficiencies in floor space resulted in slaughter and dressing activities interfering with the performance of meat inspection. Such interferences reduced the time and space that inspectors had available to complete prescribed tasks. The lack of adequate space contributed to inspectors adopting poor and strained working postures (in confined spaces). A test of independence revealed that the relation between the two variables "dedicated areas" and "sufficient floor space" was not significant [$X^2(2, N = 39) = 3.431$; $p = 0.180$]. No statistically significant relationship existed between the variables. The provision of "dedicated" working areas at selected abattoirs therefore did not give any assurance that meat inspection areas will have sufficient floor space available for meat inspectors to conduct the necessary inspection duties.

The inadequacies in the design and layout of meat inspection areas were considered a key risk factor that could contribute to inspectors adopting awkward body postures and overexerting themselves during the performance of meat inspection (Carayon and Smith, 2000).

5.3 Significance of ergonomic risk factors to meat inspectors

This section reflects on the physical task requirements as well as the working practices, which may be key in determining the presence of ergonomic hazards to meat inspectors. Inspectors constantly adopted both static and awkward body positions, which included extreme shoulder movements, significant elbow activity, and a variety of wrist and hand movements. All of these were considered key risk factors during the performance of meat inspection.

Several psychosocial risk factors may also exist that could further contribute to an inspector's fatigue and discomfort. These include a lack of control over work, limited social support structures (i.e., from co-workers, supervisors, or employers), long working hours, fast paste working activities, and tiresome work (Al-Otaibi, 2001). The mechanical load, level of exertion, and level of repetition may also impact on the occurrence of occupational risk factors (Marras, 2000). Meat inspectors could develop muscular fatigue due to extensive periods of physical activity, which may limit their ability to perform certain tasks. If an inspector becomes exhausted, he or she may ultimately experience reduced muscular strength, which may lead to muscle pain and discomfort that could give rise to work-related disorders (Filus and Okimorto, 2012).

A common sign of muscle strain may be associated with the feeling of pain or the perception of pain or discomfort in the human body. An assessment of the presence and the existence of discomfort as experienced by inspectors could therefore be seen as a “direct measure” of the impact of meat inspection (Delgado, 1990). The survey results indicated that several types of muscular disorders may be associated with the performance of meat inspection, which could affect the hands, wrists, shoulders, neck, and back of those involved.

5.3.1 Hand and wrist discomfort

5.3.1.1 Physical task requirements

The performance of meat inspection requires the use of knives (using the dominant hand), hooks (using the supporting hand), and the use of a steel (using the supporting hand to sharpen knives from time to time). Inspectors used the power grip or a combination of the power and precision grip. The power grip was used due to the amount of force that may be needed during cutting activities (using the dominant hand) and to operate hooks (using the supporting hand). The precision grip was seldom used. Not all meat inspection duties required the use of a hook (in the supporting hand). In many cases the supporting hand was used (without the use of a hook) to assist in completing the required inspection activities such as the inspection of sheep carcasses, intestines of all species, and the plucks of sheep and pigs. Inspectors conducted the examination of sheep carcasses using both hands, with the dominant hand loosely holding the knife while the fingers were used to palpate the carcass. In conducting meat inspection on plucks (i.e., sheep and pigs) the supporting hand was used to palpate, hold, and turn these organs in order to visually inspect it and to make the necessary incisions (if and where applicable using the knife in the dominant hand). The remainder of the organs (i.e., heads of sheep, the intestines of all species, and the feet of both cattle and sheep) were only observed and visually inspected. These items were either placed on a stand or conveyor table where it awaited the performance of meat inspection.

The work involved in meat inspection required inspectors to constantly adopt different hand and wrist positions (Appendix Q). The hands and wrists were repeatedly bent (i.e., flex or extend) from side to side (in both directions), while the wrists were moved in an upwards and downwards direction (radial or ulnar deviation). Inspectors rotated their hands and wrists in short repetitive cycles with palms facing upward (supination), and inward and/or downward (pronation). They conducted fast paced movements and continuous grasping of organs while also operating their hooks and/or knives during meat inspection. In using these hand tools, the hands and forearms were aligned while adopting different hand and wrist positions during cutting or tool handling operations. Inspectors performed these hand and wrist postures to help them exercise control over their work and to operate their hand tools with precision.

5.3.1.2 Factors contributing to hand and wrist discomfort

The outcomes of this study (Table 4.36) revealed that more than half (56.4%) of the inspectors experienced some discomfort of the hand, and an even greater percentage (61.5%) experienced some discomfort of the wrist.

Hand sizes varied considerably amongst inspectors particularly between male and female inspectors (Sancho-Bru *et al.,* 2003). A handle should permit the thumb to cover the end of the index and middle fingers (Patkin, 2001) to allow an inspector's hand to make a 120° curve around it (Drury, 1980). In practice, knife handles, and a number of hook handles appeared to be comfortable to use. However, a selection of hooks consisted of handles that were constructed of different materials and constituted of mixed designs (Appendix S). The designs did not always allow an inspector's hand to fully curve around the handle and required inspectors with smaller hands to apply awkward gripping techniques. These awkward gripping techniques could ultimately affect the level of comfort inspectors experienced (McDowell *et al.,* 2012). The reduced levels of comfort could increase muscular fatigue in the hands and forearms (Lewis and Narayan, 1993), which may lead to injuries to the nerves, tendons, or tendon sheaths (Tichauer, 1966; Armstrong and Chaffin, 1979). A test of independence revealed that the relation between the two variables "adequate hand tools" and "designed for comfortable grip" was significant [$X^2(1, N = 39) = 4.103$; $p = 0.043$] and showed that a positive relationship existed between the variables. Thus, the type of hand tools used during meat inspection was likely to influence the level of comfort with which inspectors performed their duties (i.e., gripping their hooks and knives).

The design, the shape, and the size of handles may also affect the strength of an inspector's grip (Grant *et al.,* 1992; McDowell *et al.,* 2012). The grip force applied by inspectors could be defined as the force with which hand tools are clamped when the hand is enclosed (Dong *et al.,* 2008). Most handles were of suitable size (Table 4.25 and section 5.2.2) but varied in diameter. The steel rod handles, and cylindrical handles did not fit comfortably into the width of an inspector's hand (Patkin, 2001), which could ultimately affect their grip strength (Grant *et al.,* 1992). Subject to individual hand size, an average handle diameter of around 32 mm may allow for optimum grip strength (Sancho-Bru *et al.,* 2003). Optimum grip strength could be achieved using handle diameters that was at least 10 mm smaller than the inside grip diameter of an inspector's hand. The higher the variation between handle diameter and grip diameter, the greater the tension in the hands or wrists. Subsequently, the muscular effort generated in the forearm may also be affected by variability in handle diameters (Grant *et al.,* 1992). Thus, greater forces in the hand or wrist may increase the risk of injuries, which could reduce an inspector's overall strength and endurance (Habibi *et al.,* 2013). An increase in duration and the extent of the workload during meat inspection (Table 4.31 & section 5.4.1.1) may decrease grip strength and increase the level of fatigue and strain in the hands, wrists, and arms (Habibi *et al.,* 2013). This, together with the use of inadequate hand tools, could further contribute to the level of fatigue and injury in the hands and wrists that could eventually give rise to muscular disorders (McGorry *et al.,* 2005).

Although the level of friction (of all handle types used) were not measured, the knives and several hooks consisted of handles that provided limited levels of friction. Some handles (i.e., screwdriver handles, and steel rod handles) allowed for very low levels of friction, which could, especially if used in wet conditions, significantly increase the slipperiness of hand tools. Increased slipperiness could eventually require inspectors to apply additional gripping force in the hand. The increased levels of force in the hand and wrist may put inspectors at risk of causing damage to the tendons or tissues (Bobjer *et al.,* 1993).

Continuous micro trauma to the hand or wrist could cause ganglion cysts, tendonitis, or tenosynovitis and may also include the loss of sense or feeling in the fingers, wrist pain or discomfort, loss of grip or grip strength, swelling in the hand or arm, and muscular weakening or degeneration (Ross, 1994). The use of hand tools and the working activities conducted by inspectors required them to constantly and continuously bend, flex, or rotate their hands, wrists, and arms. These different hand, wrist, and arm positions may be considered key risk factors could contribute to the effects of ergonomic hazards on meat inspectors.

5.3.2 Shoulder discomfort

5.3.2.1 Physical task requirements

The working environment in abattoirs caused inspectors to conduct certain tasks using their hands and arms in elevated positions (Appendix P). The heights at which meat inspection was performed varied and inspectors were divided on whether they performed their duties at a comfortable height or not (46.2% of respondents indicated always and 53.8% seldom). The working activities involved in meat inspection required the use of both the hands, wrists, elbows, and shoulders in non-neutral positions (Appendices Q & R). Meat inspectors conducted working activities that involved a wide range of shoulder activities at different degree angles performed across all three planes i.e., the coronal, sagittal, and transverse planes.

Inspectors performed work using their arms and shoulders positioned away from their bodies in the coronal plane. The elbows of both arms were constantly flexed and extended during cutting and hooking activities (where applicable). Subject to the inspection activity performed, both shoulders were abducted at different degree angles, which ranged between an estimated 0° to 90°. Likewise, inspectors also adopted back angles that ranged between 0° to 80°. A few inspectors were observed performing working activities with shoulders abducted at angles marginally greater than the above mentioned 90°. The work performed in the sagittal plane, often required the use of flexed shoulder angles that ranged between 30° to 120° when compared to the Ovako Working Posture Analysis System (OWAS) (Hellig *et al.,* 2018). Inspectors frequently flexed and extended their forearms when performing duties at shoulder angles less than 30° (in sagittal plane). A considerable amount of work was performed using shoulder angles that ranged between 60° and 120°, the sagittal plane’s “painful arc” (ProHealth, 2022). With specific reference to the transverse plane, inspectors conducted working activities that required shoulder angles between 0° and 90° in a horizontally abducted direction (from left to right). Similarly, they performed tasks that required them to adopt shoulder angles between 15° to 30° in a horizontally adducted direction (from right to left).

In addition, inspectors when examining items placed on a stand or conveyor table, conducted inspection activities that required them to rotate the shoulders in a medial or lateral direction. The work performed on a stand or conveyor table required inspectors to adopt back angles between 20° to 80° while they maintained shoulder angles that ranged between 60° to 120° in accordance with OWAS (Hellig *et al.,* 2018).

5.3.2.2 *Factors contributing to arm and shoulder discomfort*

In principle, participants agreed that shoulder discomfort may be of concern to meat inspectors (61.5% of inspectors and 41.7% of managers).

The height clearances applicable to working areas in abattoirs required inspectors to work with their arms in elevated positions. The results of a test of independence conducted, revealed that the relation between the two variables applicable to meat inspector responses "stretching or reaching to perform tasks" and "working with elevated arms" was significant [$X^2(4, N = 38) = 32.839$; $p = 0.001$] and showed that a statistically significant relationship existed between the two variables. The reaching or stretching activities conducted during meat inspection was more likely to prompt inspectors to perform tasks that required them to work with their arms in elevated positions. Thus, considering the level and duration of the static load as well as the level of upper body activity involved in the performance of meat inspection, working activities could significantly increase the risk of shoulder discomfort amongst inspectors. Subsequently, the performance of meat inspection required inspectors to conduct working activities using different shoulder angles (i.e., angles between 30° to 120°) (Sporrong *et al.,* 1996). Inspectors often worked with their arms abducted at angles greater than 30° for the entire duration of their day or shift. These working activities could give rise to the development of shoulder pain, which may develop due to the build-up of pressure within the affected tissue. Such pressure may increase if inspectors continuously perform work that required them to move their arms from the neutral position (0°) to 90° in both flexion and abduction directions (Vieira and Kumar, 2004).

With 53.9% of inspectors less than 1.7 meters tall, inspection areas may play a significant role in determining if inspectors performed their duties at a comfortable height or not. The test of independence conducted, revealed that the relation between two variables "dedicated areas" and "performing tasks at comfortable height" was not significant. It showed that no relationship existed between the two variables. The provision of dedicated areas at selected abattoirs did not contribute to meat inspectors performing their tasks at a comfortable height. The nature of these working activities could increase the levels of strain in the arms and shoulders, which may increase the level of exhaustion and discomfort within one hour after they started working (Sundelin and Hagberg, 1992). The intensity with which inspectors gripped their hand tools were also deemed to be directly related to the level of muscular activities in the shoulders (Sporrong *et al.,* 1996). Thus, adopting awkward working positions as well as applying greater forces when gripping hand tools, might decrease the strength in the arms and shoulders. An increased level of fatigue in the arms and shoulders may limit an inspector's ability to do lightweight manual tasks (Garg and Kapellusch, 2009).

A total of 84.6% of inspectors viewed platforms as being adequately distanced from overhead rails. Based on a test of independence conducted, the results revealed that the relation between the two variables "working platforms" and "adequately distanced from line" was not statistically significant [$X^2(1, N = 39) = 0.317$; $p = 0.574$]. It showed that no relationship existed between the two variables. The setting of working platforms in selected abattoirs therefore actually increased the extent of vertical and lateral movements applicable to meat inspection. The lateral distances applicable to the setting of platforms varied from abattoir to abattoir and had a huge influence on the horizontal and vertical transfer distances (as well as force requirements) applicable to meat inspection. These horizontal and vertical transfer distances played a key part in forcing inspectors to adopt different shoulder angles. Each shoulder angle could increase the level of muscular activity in areas of the back, shoulders, and arms (Hellig *et al.,* 2018). Likewise, if inspectors performed work with the arms in a flexed position, it might increase the risk of damage to the ulnar nerve or the tendons (Sporrong *et al.,* 1996) responsible for mobility of the shoulders. Thus, if the ulnar nerve or tendons were damaged, it could lead to the loss of feeling in the hands and arms of inspectors (Ross, 1994). Inspectors may also be exposed to the risk of developing disorders such as rotator cuff syndrome and tendinitis commonly associated with work involved in abattoirs (Leclerc *et al.,* 2004). The continued performance of pronation and supination activities when using the hands and arms during meat inspection may also put inspectors at risk of developing epicondylitis (O'Sullivan and Gallwey, 2002).

Working with the arms and shoulders in elevated positions, required inspectors to adopt a variety of different hand, arm, and shoulder angles. These hand, arm, and shoulder angles may be considered key risk factors that could contribute to the development of ergonomic hazards amongst inspectors.

5.3.3 Neck discomfort

5.3.3.1 Physical task requirements

Visual observational techniques played an integral part in the use and application of meat inspection methodologies. The movement of carcasses or organs along production lines compelled inspectors to rotate their heads, necks, and trunks from left to right and vice versa (Appendices N & O). Detailed visual inspections accompanied the performance of every incision and palpation. Visual inspections also required inspectors to examine and observe the outside and inside surfaces of carcasses and organs. With specific reference to cattle and pigs, inspectors visually examined carcasses at heights ranging between 0.8 m to 2.5 m. For sheep, inspectors visually examined the carcasses at heights between 0.5 m to 1.6 m. Inspectors visually examined carcasses along its length, which required significant head and neck movements up and down to view the entire surfaces of carcasses. The methods used to make red offal (cattle and sheep, and cattle heads) available to inspectors, differed considerably from abattoir to abattoir. Each of these methods influenced the level of elevation at which inspection activities were performed. With specific reference to the inspection of items made available on stands or conveyor tables (i.e., red, or rough offal inspection), many inspectors adopted a static posture with their upper bodies, with the head and neck slightly leaning forward.

The performance of inspection activities required inspectors to constantly move their heads and necks upwards, downwards, side-ways, and rotate it to the left or right (at different degree angles using REBA – Appendix M). The head and neck angles adopted ultimately determined an inspector's optimum viewing area. The viewing angles applicable to meat inspection varied depending on the inspection activity as well as the individual inspector's viewing capabilities. The dynamic nature of meat inspection forced inspectors to perform inspection activities that may constantly exceed optimum viewing angles (Nilsson, 2017).

5.3.3.2 Factors contributing to neck discomfort

The results in Table 4.36 showed that 41% of inspectors experienced neck discomfort as a direct result of the work they performed, while 50% of managers thought neck discomfort were not a concern for inspectors.

Certain occupations or occupational classes may be more closely associated with neck pain or neck disorders (Ariëns *et al.,* 2000). The working activities involved in meat inspection could contribute to the risks associated with neck pain or neck discomfort. Assessing the relation between two variables (applicable to responses of managers), a statistically significant relationship existed between "stretching and reaching to perform tasks" and "working with elevated arms" [$X^2(2, N = 12) = 12.000$; $p = 0.002$]. As indicated in this study, meat inspection involved reaching or stretching activities that could prompt an inspector to work with his or her hands or arms in elevated positions. When working with their arms in elevated positions, inspectors adopted non-neutral hand and arm positions, which could ultimately contribute to the occurrence of neck and shoulder discomfort.

Inspectors also performed working activities that required them to lean forward with the head and upper body. The observed angles at which inspectors flexed their necks (section 4.5.2 – REBA) were conservatively estimated to be between 10° to 20° based on the angles depicted in the REBA assessment tool. The height differences of inspectors may contribute to the occurrence of neck disorders. Shorter inspectors extended their necks (backward bending) further than taller inspectors to observe and complete the necessary inspection procedures. Likewise, taller inspectors flexed their necks (forward bending) further than shorter inspectors when conducting their inspection procedures.

The inconsistencies in the levels of elevation, the differences in height of inspectors as well as the dynamic nature of meat inspection were key considerations that could influence an inspector's ability to perform the required observations, i.e., optimum viewing area and viewing angle. Inspectors performed their assessments across a range of eye and neck angles. This allowed inspectors to observe the entire length and width of the carcass or its organs (internally and externally) during each inspection cycle. Subject to the pace of work as well as the level of interaction by inspectors, it may be difficult to determine an ideal viewing area and viewing angle for meat inspection. According to Nilsson (2017) an optimal viewing area was estimated to be between 0° to 30° (in a downwards direction) and an optimal viewing angle was between 24° to 27° (also in a downward direction). Nilsson was of the view that the bending or flexing of the neck at an angle greater than 25°, would require the neck muscle to work harder to keep the head up. Research indicates that the constant flexing of the neck at angles above 15° for the duration of the day or shift could significantly increase the risk of muscular disorders in the neck (Vieira and Kumar, 2004; Mukhopadhyay and Khan, 2015). Furthermore, meat inspectors constantly performed work using their arms in elevated positions at angles of 45° to the vertical, which could affect the glenohumeral joint and may also affect the neck and shoulders (Quansah, 2005). The responses from inspectors revealed that the relation between the two variables "neck discomfort" and "shoulder discomfort" was significant [$X^2(1, N = 19) = 10.978$; $p = 0.001$]. This indicated that a strong positive relationship existed between the two variables and that the existence of neck discomfort were also more likely to give rise to the development of shoulder discomfort amongst inspectors.

Another assessment of the relation between the two variables "years' experience" and "neck discomfort" was not significant [$X^2(5, N = 21) = 6.183$; $p = 0.289$]. It showed that no statistically significant relationship existed between the two variables and that the incidence of neck discomfort may not be contingent on the years of experience gained by inspectors. One may conclude that the working activities such as the constant and continuous bending, flexing, or rotating of the head and neck in quick succession over short cycles of repetitive work, may be some of the primary causes of neck discomfort amongst inspectors (Ariëns *et al.,* 2000).

5.3.4 Back discomfort

5.3.4.1 Physical task requirements

Inspectors examined carcasses and organs that were suspended from dressing rails. Dressing rail heights varied subject to the species of animals being slaughtered as well as the unique practices applicable to each abattoir (section 4.5.1.1). In order to complete the required inspection activities, inspectors adopted static but dynamic working postures. The type and range of working postures adopted were influenced by the nature of meat inspection activities involved as well as the layout of inspection areas. Production line speed and the pace of work determined the work cycle times for each inspection activity. During each cycle, inspectors altered their body positions several times. A single inspection procedure required inspectors to stretch, bend, and twist their bodies (Appendix N) while adopting awkward hand, wrist, arm, and shoulder positions.

Subject to the working activities performed, inspectors adopted a range of back angles between 0° to 80° when compared to OWAS (Hellig *et al.,* 2018). These back angles were adopted for every carcass or its organs (whichever was applicable). Back angles were also accompanied by a variety of neck movements (i.e., flexing, extending, and rotating). Neck angles varied depending on the inspection requirements (angles using REBA – section 4.5.2). Irrespective of whether a mechanized or manual production system was used, inspectors frequently moved along production lines to keep up with line speeds or the pace of work. They often shifted their weights from one leg to another, with one or both legs slightly bent when completing inspection activities (mostly applicable to carcass inspection as many inspection points for organs were provided for at a single point).

5.3.4.2 Factors contributing to back discomfort

The working postures adopted by inspectors may expose them to constant and cumulative loading of the spine and the lower extremities. According to 76.9% of inspectors back discomfort (highest percentage of responses from inspectors on any type of discomfort experienced) were common among them, while around 41.7% of managers highlighted back discomfort as a concern among inspectors.

A subsequent evaluation of the relation between the two variables “average height” and “back discomfort” was not significant [$X^2(4, N = 32) = 4.673$; $p = 0.323$]. It showed that no statistically significant relationship existed between the two variables and that back discomfort were more likely to develop irrespective of the individual heights of inspectors. Although the population demographics may affect the level of exposure to back discomfort, the working activities would be considered of foremost importance. However, the elevation levels or height clearances applicable to the performance of meat inspection required inspectors to frequently adopt bent, cramped, and crouched working postures. Inspectors were confined to working areas that had limited space and spent most of their working time in a standing position. Though 40.6% of inspectors were taller than 1.7 m, the data showed that the average height of inspectors may not be considered a primary risk in terms of the incidence or the development of back discomfort. As stated previously, the back angles observed were between 0° to 80° in the transverse plane and the shoulder angles ranged between 30° to 120° at varying degrees of back angles (Hellig *et al.,* 2018). Together these back and shoulder angles may be considered key risk factors that could contribute to the existence or the development of muscular disorders amongst inspectors. The incidence of back injuries depended on the biomechanical loading, tissue tolerance levels, and the muscular structure of the spine (Marras, 2000; Vieira and Kumar, 2004).

Another test of independence highlighted that a strong relationship existed between neck and back discomfort [$X^2(1, N = 21) = 12.353$; $p = 0.001$]. Thus, the existence of neck discomfort was also more likely to contribute to the development of back discomfort among inspectors. The demands of meat inspection (external in nature) on the body of an inspector, produced an internal force in the affected muscle which in turn created a load that acted on the spine. If the tolerance levels in the spine were exceeded, as a result of continuous and repetitive loading, it may result in cumulative trauma to the back (Davis and Jorgensen, 2005). The repeated trauma to the back could lead to permanent scarring or weakening of the ligaments, disks, muscles, or tendons (Ross, 1994). The biomechanical loading of the back could result in muscular contractions. If the muscle of the back were contracted for more than 15% to 20% of their maximum capacity, it could lead to the development of tissue ischemia. Tissue ischemia may result in delays in the removal of metabolites and thus increases the physiological stresses in the body (Kroemer, 1989). Performing work in a standing position or adopting awkward working postures for long periods could therefore generate a static load in the affected muscle, which could significantly contribute to discomfort in the lower back as well as the level of risk to inspectors (Hoogendoorn *et al.,* 1999).

A subsequent test of independence revealed that the relation between the two variables "years' experience" and "back discomfort" was not significant [$X^2(5, N = 31) = 6.565$; $p = 0.255$] and showed that no relationship existed between the two variables. Based on the outcomes of this study, it can be concluded that the incidence of back discomfort was not solely contingent on the years that an inspector has been working. However, apart from adopting static working postures, the working activities involved in the performance of meat inspection required inspectors to constantly adopt different back angles in a fast-paced working environment. These back angles may therefore be considered key risk factors that could contribute to the existence of ergonomic hazards amongst inspectors (Hellig *et al.,* 2018).

5.4 Prevalence and impact of ergonomic risk factors to meat inspectors

The two key aspects that may give effect to the occurrence of ergonomic hazards at abattoirs were associated with the occupational conditions to which inspectors were exposed. These involved the type of daily working activities that inspectors were involved in as well as the nature of the work that they performed.

In assessing the existence and the extent of ergonomic hazards, it is vital to recognize how the daily working activities and the nature of work influenced the level of risk to which meat inspectors were exposed. In doing so, it is important to determine if the work performed were dynamic or static and whether it involved manual handling and repetitive work. Meat inspection required inspectors to regularly bend or rotate their backs and to repeat these working activities for the duration of their shift or day. The body postures adopted, and the movements executed during meat inspection may therefore pose a considerable risk to the health and safety of inspectors (Das and Sengupta, 2000; Vieira and Kumar, 2004).

5.4.1 Daily working activities

The daily working activities (Table 4.32) involved in the performance of meat inspection may be considered some of the main contributors to the development of muscular discomfort amongst inspectors. The following is a summary of key working activities and the impact that it may have on meat inspection personnel.

5.4.1.1 *Repetitive work*

The efficiency of meat inspection depended on an inspector's ability to perform a sequence of tasks or to complete a set of inspection procedures within a limited time frame. The working activities involved in the performance of meat inspection were physically intense and highly repetitive and could ultimately reduce muscle strength or increase the levels of exhaustion amongst inspectors (Hägg *et al.,* 2012). Increased levels of fatigue could give rise to the development of discomfort or pain, which may lead to injuries or muscular disorders (Filus and Okimorto, 2012).

Working activities that comprised of a minimum of 25 and 33 repetitions per minute for the duration of a shift or day were deemed to be sufficient to cause tendon disorders (Tirloni *et al.,* 2020). With specific reference to meat inspection, the least number of repetitions performed during a single inspection activity, was conducted on sheep (heads and carcasses) (Table 4.31). These inspection activities required that a minimum number of repetitions i.e., 13 repetitions on heads and 14 repetitions on carcasses, be conducted. If inspectors had 30 seconds to complete an inspection procedure, it would require inspectors to perform 26 repetitions on heads and 28 repetitions on carcasses per minute (head-neck-eye movements as well as hand-, arm-, wrist- and shoulder movements). If, inspectors had 15 seconds to complete an inspection procedure, it would require inspectors to perform 52 repetitions on heads and 56 repetitions on carcasses per minute (head-neck-eye movements as well as hand-, arm-, wrist- and shoulder movements).

Subsequently, the highest number of repetitions performed, were conducted on cattle red & rough offal and carcasses. The inspection activities required that a minimum of 31 repetitions on red & rough offal and 33 repetitions on carcasses be conducted. Accordingly, if inspectors had 30 seconds to complete an inspection procedure, it would require inspectors to perform 62 repetitions on red & rough offal and 66 repetitions on carcasses per minute (head-neck-eye movements as well hand-, arm-, wrist- and shoulder movements). If, inspectors had 15 seconds to complete an inspection procedure, it would require inspectors to perform 124 repetitions on red & rough offal and 132 repetitions on carcasses per minute (head-neck-eye movements as well hand-, arm-, wrist- and shoulder movements).

If an abattoir therefore slaughtered 300 sheep, it could require inspectors to conduct a minimum of 7 800 repetitions on heads and 8 400 repetitions on carcasses per day at 30 second intervals. For 15 second intervals these could increase to 15 600 repetitions on heads and 16 800 repetitions on carcasses per day (head-neck-eye movements as well hand-, arm-, wrist- and shoulder movements). Alternatively, if an abattoir slaughtered 50 cattle, it could also require inspectors to conduct a minimum of 3 100 repetitions on red & rough offal and 3 300 repetitions on carcasses per day at 30 second intervals. At 15 second intervals these could increase to 6 200 repetitions on red & rough offal and 6 600 repetitions on carcasses per day (head-neck-eye movements as well as hand-, arm-, wrist- and shoulder movements). However, many two species abattoirs often slaughtered a combination of sheep and cattle. Thus, if an abattoir produced 300 sheep and 50 cattle, it would require inspectors to perform 10 900 repetitions (i.e., on both sheep heads and cattle red & rough offal) and 11 700 repetitions per day (i.e., on both sheep and cattle carcasses) at 30 second intervals. At 15 second intervals these repetitions could increase to 21 800 repetitions (i.e., on sheep heads and cattle red & rough offal) and 23 400 repetitions per day (i.e., on sheep and cattle carcasses).

The minimum number of repetitions where an abattoir slaughtered pig carcasses were 22 repetitions on heads and 27 repetitions on carcasses. Thus, if a carcass is presented every 30 seconds, inspectors were required to conduct 44 repetitions on heads and 54 repetitions on carcasses. These could increase to 88 repetitions on heads and 108 repetitions on carcasses at 15 second intervals. In the case where an abattoir slaughtered 80 pigs per day, inspectors may be required to conduct 3 520 repetitions on heads and 4 320 repetitions on carcasses per day at 30 second intervals. If, however, an abattoir slaughtered 1 350 pigs per day, inspectors may be required to conduct 59 400 repetitions on heads and 72 900 repetitions on carcasses repetitions per day at 30 second intervals. At 15 second intervals these repetitions could increase to 118 800 repetitions on heads and 145 800 repetitions on carcasses per day.

Consequently, if any abattoir therefore increased its production line speeds, it could significantly reduce the work cycle times that an inspector had available to conduct meat inspection activities. Any reduction in work cycle times, beyond the existing 15 to 30 seconds could further increase the risk of work-related injuries or muscular disorders amongst inspectors. This will eventually trigger higher repetitive rates, which could make meat inspection activities physically more intense and more hazardous (Arezes *et al.,* 2014).

5.4.1.2 *Gripping of hand tools*

The performance of meat inspection primarily required the use of hand tools. The design of hand tools ultimately influenced the type, the comfort, and the strength of the grip used. To grip or to hold their hand tools, inspectors needed to apply a certain degree of force in the hand and fingers (Dong *et al.,* 2008). The magnitude of the force may be influenced by the type of grip and the handle diameter (Grant *et al.,* 1992; Sancho-Bru *et al.,* 2003). Inspectors mainly used the power grip that could considerably increase the magnitude of the force in the hand and wrist by up to 25% compared to other grips (Stoy and Aspen, 1999). The use of the power grip or a grip similar to it (i.e., diagonal and transversal hand grip) could therefore generate forces of between 300 N to 400 N in the hand (Kadefors *et al.,* 1993). Inspectors often adopted the power grip using the thumb extended as reinforcement along the back of the blade. Likewise, some inspectors also used the forefinger extended at the back of the blade when the cutting force requirements were significantly reduced. The use of the thumb or the forefinger in these positions may put extra strain on the structure of the hand.

The dynamic and repetitive nature of meat inspection activities compelled inspectors to adopt a range of different hand, wrist, and arm movements (as indicated in section 5.3.1, 5.3.2, and 5.4.1.1). The fast past working activities performed over short repetitive cycles may not only increase the physical and biomechanical demands on inspectors, but also the risk of muscular disorders (Armstrong and Chaffins, 1978). Inspectors frequently adopted both neutral and non-neutral hand-wrist-arm positions, deviated their hands in the ulnar and radial direction, flexed or extended their wrists and rotated their hands-wrists-forearms in both pronated and supinated directions. They followed a precise sequence of repetitive movements during each inspection cycle of between 15 to 30 seconds, which could reduce the overall strength in the hand or wrist (Habibi *et al.,* 2013). The non-neutral hand-wrists movements as well as the awkward hand-wrist-arm positions adopted may not only reduce wrist strength (Figure 2.10) but may also increase the level of fatigue in the hands and arms (Mital and Kilbom, 1992).

With 55.3% of inspectors older than 36 years of age, the overall grip strength of an inspector may decrease because of age (Stoy and Aspen, 1999), which may considerably increase an inspector’s susceptibility to muscular disorders. Research has indicated that in most industries, workers between 18 and 35 years of age were most vulnerable to hand and wrist injuries (Mital and Kilbom, 1992). However, with specific reference to this study as well as the working activities involved in the performance of meat inspection, inspectors across all age groups may be at risk of increasing the level of strain on the tendons, joints and nerve endings in the hands, wrist, and arms. As stated earlier, increasing the level of force in the hand and wrist may reduce the strength capabilities of inspectors, which could intensify the levels of fatigue as well as the risk of injuries (Terrell and Purswell, 1976; Mital and Kilbom, 1992; Habibi *et al.,* 2013).

5.4.1.3 Hands and arms in elevated positions

The performance of meat inspection required inspectors to do their work in a standing position. They used their hands and arms in elevated positions and often away from their body's midline. Almost 60% of inspectors (Table 4.32) were of the opinion that working with the hands and arms in elevated positions were part of their day-to-day activities (a statement supported by the majority of managers). Notwithstanding the fact that inspectors performed work with their hands and arms in elevated positions, most of them (59.5%) were shorter than 1.7 m and might be at greater risk of developing muscular disorders. Of the 59.5% of inspectors, 23.1% were female inspectors who might be at even greater risk than their male counterparts. Inadequate elevation levels could lead to neck and back disorders among tall inspectors and too high elevation levels could lead to shorter inspectors having to overexert themselves in conducting their work (Quansah, 2005).

To most of the inspectors who were older than 36 years and who worked with the hands and arms in elevated positions in a highly paced working environment, the risk of muscular disorders may be substantially increased. Although the overhead structures in abattoirs were fixed, the level at which an inspector performed his or her duties differed from abattoir to abattoir. A common practice amongst inspectors was to constantly perform working activities with their hands and arms away from their body's midline in a 90° angle (i.e., abducted or flexed). Such working activities may cause damage or injury to the hands, wrists, arms, or shoulders (Vieira and Kumar, 2004).

Thus, based on the evidence presented, it might be reasonably safe to assume that the current practices involved in the performance of meat inspection may necessitate that an inspector frequently perform work with their hands and arms away from their bodies and in elevated positions.

5.4.1.4 *Reaching or stretching activities*

Apart from the work involved in meat inspection, the layout and design of abattoirs with specific reference to meat inspection areas often required inspectors to reach or stretch to complete routine inspection tasks. A key consideration with reference to platforms was the lateral transfer distances covered by inspectors during the performance of meat inspection. The lateral transfer distances were influenced by the height and reach of individual inspectors. Thus, shorter inspectors had a greater transfer distance and had to reach further when performing certain tasks that were dependent on different levels of elevation. According to 53.9% of inspectors and 66.7% of managers, the daily duties of meat inspectors involved reaching and stretching work. However, both inspectors and managers did not fully agree on the extent to which inspectors performed these "reaching or stretching" activities (i.e., how often – was it always or seldom). The data revealed that only 7.7% of inspectors and 9.1% of managers indicated that inspectors never stretched or reached to perform tasks during meat inspection. Based on this information it could therefore be concluded that the majority of inspectors and managers were in agreement that meat inspection involved a fair amount of reaching and stretching work.

Thus, unless the fundamental practices involved in the performance of meat inspection were changed, or unless innovative principles involved in the planning and design of abattoirs were introduced, inspectors will continue to perform tasks that require a great degree of reaching or stretching work during meat inspection.

5.4.1.5 *Variable line speed*

The production line speeds or the pace of work applicable to selected abattoirs had a significant impact on the time that an inspector had available to complete meat inspection procedures. With 55.3% of inspectors aged 36 or older, the variable line speeds or the pace of work may considerably contribute to the level of physical exertion experienced by inspectors. The level of physical exertion could be influenced by the body posture, working movements, repetitive work, and the duration of time spent working (Vieira and Kumar, 2004). The daily activities involved in meat inspection, according to 66.7% of inspectors and 58.3% of managers, involved work that were subjected to variable line speeds. Thus, only 61.5% of inspectors were able to keep up with the pace of work (while 35.9% indicated that they seldom did). Regarding the question whether inspectors were able to complete the required tasks within the allocated time frames, 63.2% of inspectors indicated that they were able to do so. One of the key factors that could impact on production levels at abattoirs was the economic environment within which abattoirs operated. An abattoir's profit margin is subject to the number of animals that it could slaughter. The daily throughput of an abattoir therefore influenced an abattoir's ability to maintain market access and supply local consumption levels (Luppnow, 2007). Daily throughput also influenced the pace and the speed of work, including production line speeds. Production line speeds varied based on daily, monthly, and seasonal production demands.

Thus, inspectors worked in an environment in which they may have little control over the production output, line speed, or the pace of their work as these factors were demand driven.

5.4.1.6 Back and neck bending activities

The daily working activities involved in the performance of meat inspection comprised of back and neck bending activities according to 74.4% of inspectors and 75% of managers. The basic posture adopted during meat inspection was static in nature. The inherent job requirements applicable to the performance of meat inspection required that inspectors constantly and continuously interacted with their working environment by adopting a range of different working postures. Participants were divided on whether inspection areas provided meat inspectors with sufficient space to perform their duties. Most managers (91.7%) were of the view that meat inspection areas were sufficient in terms of floor space and were confident that it could accommodate more than one inspector at a time. Although this view was supported by 48.7% of inspectors, it is important to understand that these areas played a pivotal role in determining and influencing the workload of inspectors (Vieira and Kumar, 2004). Thus, 46.2% of inspectors indicated that these areas affected the ease with which they performed their duties (i.e., comfortable height). The performance of meat inspection may therefore require inspectors to adopt awkward head, neck, and body postures when completing the required inspection procedures. Inspectors performed such duties on a daily basis and for extensively long periods of time. The lack of sufficient space (as highlighted in this study) may further contribute to inspectors having to adopt awkward and strained body positions during meat inspection.

A comparison between age and the reporting of back discomfort revealed that inspectors between the ages of 26 to 35 (totalling 48.2%) were at greater risk of developing back discomfort than each of the other age categories. However, the combined risk to those inspectors above the age of 36 also totalled 48.2%, which may indicate that those inspectors older than 36 were also at greater risk of developing back discomfort as a result of the work they do. The outcomes of this study may be supported by the results of Anderson (1997) as seen in Marras (2000) where individuals between the ages of 35 to 55 years were considered at greater risk in developing back disorders. However, in this study the data further highlighted that the risk of back disorders, with specific reference to meat inspection, could surface as early as between the ages of 26 to 35 years. Marras (2000) further highlighted that the highest incidence of back disorders for males were around the age of 40, while in the case of females it was between the ages 50 to 60 years. In this study with only 2.6% of inspectors younger than 25 and 13.2% older than 56, the data (M = 39.97 years, M_{dn} = 38 years and M_o = 33 years) showed that the majority of inspectors (97.4% and especially male inspectors) could be at risk of developing back discomfort. Unlike the outcomes of the study by Manchikanti (2000), which indicated that the incidence of back disorders may start during the mid-30s, this study revealed that those involved in meat inspection may experience back disorders as early as between the ages of 26 to 35 years (their mid-20s to mid-30s).

The highest averages in height for inspectors were distributed within three categories. The majority of inspectors comprised of height categories of 1.5 m to 1.6 m (29.7%), 1.6 m to 1.7 m (24.3%) and 1.7 m to 1.8 m (35.1%). The data further showed that there was a strong negative relationship (section 4.4.2.3 and Table 4.14) between gender and the average height of inspectors. According to the results, none of the female inspectors were taller than 1.70 m and only 5.4% of male inspectors were taller than 1.8 m. Table 4.14 showed that 45.5% of inspectors within the category of 1.5 m to 1.6 m and only 22.2% of inspectors within the category of 1.6 m to 1.7 m were females. Height and gender were two key factors in the development of back discomfort amongst inspectors in the category of 1.7 m to 1.8 m, with 100% of inspectors (males) being at risk of developing back disorders. Subsequently, in the 1.5 m to 1.6 m and 1.6 m to 1.7 m height categories, no relationship could be established between the two key elements (i.e., height and gender) and the occurrence of back discomfort. An estimated 70% of inspectors were at risk within the 1.5 m to 1.6 m height category, while 88.8% of inspectors were at risk in the 1.6 m to 1.7 m category. The results therefore revealed that although height and gender played a pivotal role in the occurrence of back discomfort within these categories, the type and extent of activities involved in the performance of meat inspection had a greater influence on the presence of back disorders among meat inspection personnel.

5.4.1.7 Pulling and pushing activities

A small percentage of inspectors indicated that pulling or pushing of carcases along the production line formed part of their daily tasks. In the case of the non-mechanical lines, inspectors conducted such activities to keep the line moving and to prevent a "bottleneck" of carcasses at inspection points. The pulling or pushing of carcasses were mostly conducted using the supporting hand (and often involved using the hook during pulling in the case of cattle and pigs).

The use of hooks in the supporting hand was necessary to exercise or to maintain control over the carcasses or organs during meat inspection activities. The hooks were used to hold, pull, or turn inspection items so that inspectors could complete the required observations, palpations, or incisions. Inspectors pulled carcasses, in non-mechanized systems, toward them to commence and complete the necessary inspection procedure. The pulling of carcasses, although not common at all selected abattoirs, happened over short distances not exceeding 1.0 m in length. Likewise, inspectors also pushed carcasses past inspection points (after completion of inspection activities) to create space for the next carcass. The magnitude of forces generated in the supporting hand during pulling or pushing activities could be significantly higher than the force in the dominant hand. The total force required to pull a carcass may be influenced by several factors such as the weight of the carcass, the weight of pulley or chain, resistance of the pulley (on the line) and the force of gravity that may be acting on the carcass, pulley, or chain. The pulling force may put strain on the supporting hand, wrist, arm, and shoulders.

The use of non-mechanical lines together with the high production demands created challenges in terms of the movement of carcasses along the production lines at selected abattoirs. The higher volumes produced at these abattoirs required additional pulling or pushing of carcasses along the production lines to keep or maintain production line speeds.

5.4.2 Nature of working activities

The nature and the type of work (Table 4.34) performed during meat inspection were key factors that could also contribute to the development of muscular discomfort among inspectors. The following is a summary of key factors associated with meat inspection that could have an impact on the total strength and the level of exertion of individual inspectors.

5.4.2.1 Physical demanding tasks

The work performed by meat inspectors were classified as physically demanding work by 59.0% inspectors and 75% managers. These tasks required inspectors to generate forces necessary to meet the work demands by considering the level of exertion, the repetitiveness as well as the duration of working activities (Westgaard and Winkel, 1997). The repetitiveness as well as the physically demanding nature of the work involved in meat inspection could significantly increase the level of muscular fatigue experienced by inspectors (Zadry *et al.,* 2011). The level of muscular fatigue could result in reduced performance (i.e., lack of task co-ordination or risk of errors) as well as an increase in the risk of tissue disorders (Wartenberg *et al.,* 2004).

In addition to the above, inspectors were not only exposed to physical and muscular fatigue, but also mental fatigue. The extent of mental fatigue might be linked to a number of factors such as: (a) the lack of independence and decision-making in terms of the performance of their work; (b) working under pressure (i.e., time and mental pressure); (c) fast-paced working activities; and (d) lack of an adequate organisational structure (including support structures). The level of mental exertion that inspectors were exposed to may only be visible over time as it may affect their efficiency, alertness, and attitude towards their work (Al-Otaibi, 2001; Wartenberg *et al.,* 2004).

5.4.2.2 Long working hours

Working activities within the abattoir industry may vary from abattoir to abattoir and an abattoir's production cycle may depend on its production capacity. According to 61.5% of inspectors and 50% of managers, the performance of meat inspection may be synonymous with long and extensive working hours. An abattoir's working hours may therefore increase depending on peak, monthly, and seasonal production cycles, which could be in excess of 8 hours per day (Hlasa, 2006). These long working hours may put inspectors at risk of injury or damage to muscle tissue as inspectors performed their duties in a standing position and remained standing for the entire duration of the day or shift. During these working hours, inspectors also adopted awkward body postures and constantly worked with their hands and arms above their shoulders. These static and awkward body postures further increased the risk for an inspector to develop muscular discomfort of the legs, hips, back, neck, or shoulder (Vieira and Kumar, 2004).

5.4.2.3 Rest or recovery breaks

The aim of any work-rest schedule should be to reduce the level of exposure and to limit the risk of injuries to meat inspectors (Mientjes, 2000). Notwithstanding the fact that only 15.4% of inspectors (and 0% of managers) stated that no rest or recovery breaks existed, the provision of work-rest schedules at abattoirs remained unclear and appeared to be least supported. The lack of adequate work-rest schedules made it difficult for abattoirs or service providers to control the time, duration, and impact of external forces on meat inspectors (Fransson-Hall and Kilbom, 1993).

At abattoirs where work-rest schedules were implemented, inspectors were required to work for a considerable amount of time before taking a recovery break. It is important for any work-rest schedule to consider the duration of work and to determine the frequency of recovery time applicable to meat inspection (Mientjes, 2000). The majority of inspection personnel were exposed to a higher work-to-rest schedule (i.e., the time an inspector worked before taking a break), which increased the risk and load on inspectors. The lack of more frequent or shorter breaks by inspectors could increase the risk of fatigue and may increase the muscular load on inspectors. This may also increase risks associated with lower extremity disorders, which may be caused by the extensive amount of time that inspectors spent working on their feet (Van Dieen and Oude Vrielink, 1998).

Peak production cycles or long working hours including inadequate staff capacities, may further limit the number of rest or recovery breaks during meat inspection (Park and Kim, 2020). Limited evidence existed at selected abattoirs to indicate that the workload of meat inspectors was effectively managed. Inspectors may not have been allowed sufficient recovery time between the different levels of exposures. Furthermore, little proof existed to indicate that the duration of exposure was adequately controlled or managed. If inspectors were exposed to low forces that were applied over a longer period, these low forces could cause more serious damage than the high forces applied over a shorter period of time (Fransson-Hall and Kilbom, 1993).

5.4.2.4 Rotation between tasks

The data indicated that 89.7% of inspectors frequently rotated between different tasks. Less than 20% of inspectors (18.0%) and managers (8.3%) indicated that no task rotation programmes existed at selected abattoirs. The majority of inspectors indicated that they rotated between inspection points every 60 minutes (27.8% every 30 minutes and 11.1% every 45 minutes).

The absence of a suitable job rotation programme effectively reduced an abattoir's ability to effectively mitigate the risks associated with fatigue and muscular tension to which inspectors were exposed. Those inspectors, who rotated between workstations, were required to conduct meat inspection using different inspection methodologies or approaches. However, these different inspection methodologies or approaches essentially required the use of the same muscle types, joints, and body parts (in exercising these duties). The use of the same muscle types, joints, or body parts at different workstations could therefore result in increased levels of exposure (Frazer *et al.,* 2003). Consequently, the over utilization of affected muscle types, joints, or body parts may cause higher levels of biomechanical stressors (Jorgensen *et al.,* 2005).

5.4.2.5 Awkward working postures

Less than 50% of inspectors (48.7%) and managers (41.7%) were of the view that adopting awkward working postures during meat inspection applied to meat inspectors. These non-neutral postures adopted by inspectors together with the load, the level, or the repetition of working activities may increase the risk of injuries (Marras, 2000). Inspectors' arms were often abducted, including horizontal abduction, adducted including horizontal adduction, and flexed. As stated earlier, the arms and shoulders were used in different ways in the coronal, sagittal, and transverse planes. They constantly performed work with the arms at or above their shoulders that increased the risk of developing tendonitis of the shoulders (Garg and Kapellusch, 2009).

As stated earlier, workstations, including working platforms, did not provide inspectors with sufficient floor space to accommodate for the adoption of dynamic postures (Thun *et al.,* 2011). In addition, insufficient floor space forced inspectors to adopt poor and awkward postures (Tappin *et al.,* 2008). These were key risk factors that could affect the overall occupational health and safety of inspectors at abattoirs (Carayon and Smith, 2000). Continuous forward bending and the rotation of the back during meat inspection, increased the risk of damage to ligaments, disks, muscles, and tendons (Ross, 1994; Davis and Jorgensen, 2005).

5.4.2.6 Highly paced working activities

Meat inspection, according to 48.7% of inspectors and 25% of managers, was performed in a highly paced working environment. An abattoir's production capacity depends on its daily- and hourly throughput. Daily- and hourly throughput were influenced by peak, monthly, and seasonal production demands. Each abattoir adjusted its production cycles to meet these capacity demands. Even though the responses from both inspectors and managers tended to indicate the opposite, the performance of meat inspection was subject to the variability of an abattoir's production cycle as well as variations in workflow patterns (Tappin *et al.,* 2008).

The operational demands applicable to an abattoir's production cycles, influenced the pace at which meat inspection was performed. Inspectors observed, palpated, incised, and judged if a carcass and/or its organs were fit for human or animal consumption within less than 30 seconds. In completing the above inspection activities, inspectors adopted a variety of body postures. Body postures (as indicated previously) involved (a) the constant movement, bending or rotation of the head and neck; (b) forward and sideways bending of the back; (c) flexing or bending of knees; (d) working with hands and arms in elevated positons; (e) using different hand and wrist movements; and (f) stretching or reaching activities. Each of these body positions were maintained for the required amount of time (which lasted a few seconds) and were then changed subject to the demands required by the specific inspection activity. The activities involved in the performance of meat inspection were fast-paced and involved short repetitive movements performed for the entire duration of the day or shift. Inspectors therefore not only had to ensure that they efficiently performed each of the sequential inspection procedures, but they also had to ensure that they keep up with the pace of work which required a stringent regimen of physically intense activities that needed to be performed.

5.5 Organisational ergonomics

An abattoir’s organisational structure, its policies, and its processes may have an impact on meat inspectors and their working environment. Each organisational structure may therefore influence the design of work and working times as well as an abattoir’s design strategies. Organisational ergonomics is therefore concerned with the layout of the workplace, the type of work that needs to be done, the use of technology, as well as defining the roles and responsibilities of those involved including effective communication and feedback strategies (IEA, no date).

5.5.1 Occupational health and safety (OH&S) management system

The data showed that health and safety management systems existed at selected high throughput red meat abattoirs. Most abattoir managers (91.7%) stated that the respective abattoirs had OH&S systems in place while 70.3% of inspectors supported this view. However, based on the results, both inspectors and managers agreed that OH&S management existed at high throughput red meat abattoirs, which was in line with the views shared by participants who participated in the interviews.

5.5.1.1 Health and safety policies

According to managers (100.0%) OH&S systems at abattoirs were supported by appropriate health and safety policies. Most managers believed that their abattoirs’ health and safety policies were clearly defined. Regarding the key requirement that an abattoir’s OH&S policy be communicated and accessible to employees (OSH Act

No. 85 of 1993) (South Africa, 1993), only a third of the managers felt confident that their abattoirs adequately displayed health and safety policies. An abattoir's inability to adequately display or communicate health and safety policies may deprive its employees (including meat inspection personnel) of the opportunity to gain insight and direction into the company's health and safety programmes (Maseko, 2016).

It was not clear if service providers had their own health and safety policies for their employees at abattoirs. However, the responsibility for health and safety at selected abattoirs was that of the abattoir owner. The concept of independent meat inspection may have created the belief that an abattoir may not exercise any control over the work or working activities of meat inspectors. Abattoirs were therefore very careful not to infringe on these requirements, as there were no clear guidelines on how the health and safety of meat inspectors should be addressed in relation to their "independence". As a result, meat inspection personnel may have been excluded from an abattoir's health and safety programme because they were not directly employed by abattoirs. This may have caused an abattoir's health and safety policy to fall short in addressing health and safety concerns specifically related to meat inspectors.

Most managers (91.0%) have been working at the selected abattoirs for more than one year while 41.7% of inspectors worked at these abattoirs for less than one year. Managers who were directly employed by abattoirs may have witnessed or participated in the implementation of OH&S policies because they worked there for more than one year. Meat inspectors, on the other hand, provided an outsiders' perspective on the management of OH&S at abattoirs. Many inspectors may not have witnessed or may not have been aware of the extent of or the implementation of OH&S, as many of them worked at these abattoirs for less than one year (at the time of the study). However, this may further raise questions on the scope of awareness to occupational health and safety policies at selected abattoirs.

According to the ILO, an abattoir should develop an OH&S framework that also incorporates the employees of service providers or contractors (ILO-OSH, 2001).

5.5.1.2 Health and safety reporting

OH&S policies, according to 84.6% of inspectors and 100% of managers, were supported by adequate control measures aimed at preventing the occurrence of hazards. Respondents across the board indicated that health and safety systems were supported by a suitable reporting system. Most managers agreed that inspectors were involved in the reporting of health and safety risks at abattoirs. It was however not clear what the type of hazards were nor if these hazards were specific to the work of meat inspectors.

Meat inspection service providers could possibly experience difficulty in directly affecting change in the work environment of its employees due to the fact that they do not have the necessary jurisdiction at abattoirs. Abattoirs, on the other hand, may struggle to fully incorporate meat inspectors into their operational and management structures as they do not directly employ inspectors. This was in line with the concerns raised by participants during interviews in which they indicated that meat inspection personnel were at risk of being excluded from an abattoir's health and safety programme as they were not regarded as "employees". In the absence of any clear guidelines on how hazards pertaining to meat inspectors need to be addressed, health and safety management of meat inspection personnel will remain a challenge.

An analysis of the relationship between the two variables "control measures" and "system for reporting" were statistically significant. The data revealed that there was a strong positive relationship between having control measures in place and having a system for the reporting of hazards at abattoirs. If, therefore, an abattoir had suitable control measures in place to prevent health and safety hazards, it will effectively improve the reporting of hazards among employees or their representatives. However, the data further showed that there was a less than 50% chance that an abattoir will have an OH&S system with suitable control measures and a system for reporting of hazards.

5.5.1.3 Health and safety representatives

Although the aim of this study was not to establish whether OH&S management was a recognized line-management responsibility (at the selected abattoirs), respondents indicated that most abattoirs had designated health and safety representatives in place. It is essential for a suitable line-management structure to exist in abattoirs to ensure that OH&S is practiced and accepted at all levels within the organisation (ILO-OSH, 2001). The absence of a suitable line-management structure could considerably influence the effectiveness of OH&S management at abattoirs. An analysis on the data from abattoir managers to determine the strength and the direction of the relationship between the variables "OH&S system" and "designated OH&S representative" were conducted. The data revealed that there was no statistical relationship between having an OH&S management system and having a health and safety representative at abattoirs. Thus, it may be possible for some abattoirs to have operated health and safety management systems without suitable line-management structures or health and safety representatives (ILO-OSH, 2001). On the issue of whether a relationship existed between "OH&S system" and "OH&S inspections", an analysis was conducted to determine the strength and direction of the relationship. No statistical relationship was found between having an OH&S management system in place and conducting health and safety inspections at abattoirs. Thus, the health and safety systems at selected abattoirs may not have been adequately supported by health and safety inspections.

5.5.2 Occupational health and safety training and awareness

Abattoir owners are required by law to provide employees with information and training necessary to ensure that health and safety are promoted within their organisations. Furthermore, employees are also assigned the task and responsibility to take care of health and safety at work. It therefore means that they must take care of their own as well as their co-workers' health and safety (OHS Act No. 85 of 1993) (South Africa, 1993). Training and awareness programmes form an essential part of any OH&S system and should be conducted regularly (ILO-OSH, 2001). Training educates employees to do their work within the scope of the organization's health and safety policy guidelines (Taderera, 2012). It helps to effectively reduce hazards in the workplace (Pouliakas and Theodossiou, 2010) and improve employee knowledge, which may help them to identify and report hazards by promoting a safer work environment (Cohen and Colligan, 1998).

According to 91.7% of managers, health and safety training systems existed at abattoirs. On the implementation of health and safety training programmes, almost all abattoir managers (83.3%) indicated that training was conducted at abattoirs. It was not clear to what extent inspectors were involved or whether their participation included attending or conducting training. If this training involved meat safety and regulatory control aspects, the execution of training by meat inspection personnel may be substantiated. However, if not, then it may be hard to understand how meat inspectors could be involved in conducting occupational health and safety training at abattoirs (when their primary responsibility was to perform meat inspection). Notwithstanding the importance of health and safety management, the most pressing issues in a normal working day for any abattoir would be to achieve its production targets and maintain adequate compliance levels (to the requirements of the Meat Safety Act, Act No. 40 of 2000) (South Africa, 2000). It is therefore difficult to expect that an abattoir would allow the employees of meat inspection service providers to take time out of their day to conduct health and safety training (something which abattoirs were mandated to do and something which abattoirs may struggle to do themselves).

On the question of whether abattoirs conducted health and safety training, the same concerns may apply. How do abattoirs, within a busy daily routine, incorporate health and safety training into their day-to-day activities? Do abattoirs set sufficient time aside for adequate health and safety training? Is this possible considering the long and extended production cycles at abattoirs? Not many employees would be interested in attending training during lunch or tea breaks as this is the only time they can take to "rest" from their highly paced working activities. Considering that the focus of an abattoir was meat production, it is questionable that health and safety at abattoirs received their full attention. Many abattoirs have only recently come to terms with the requirements of hygiene management systems as set out in the Meat Safety Act. A wide range of challenges remains in promoting adequate hygiene and hygiene management practices at abattoirs. These challenges are addressed through the implementation of adequate employee training programmes (i.e., abattoir hygiene related training). It is therefore not clear how it may be possible for an abattoir to find the "free" time to conduct both hygiene and health and safety training while maintaining production demands.

Abattoirs may take ownership and responsibility for the health and safety training of its own employees, but how would that apply to the health and safety training applicable to meat inspectors? Do health and safety training programmes of abattoirs fully cover all possible hazards applicable to conducting meat inspection? The most important items that should be covered during health and safety training included bending, repetitive work, awkward postures, grip force, and variable line speed. These items provide an indication of the items most closely associated with conducting meat inspection and are considered significant in terms of the level of risk applicable. Participants in this study were of the opinion that training had the potential to improve health and safety management at abattoirs. Participants agreed that training could assist in reducing health and safety hazards and improve its reporting as indicated by Cohen and Colligan (1998).

About 35.9% (14 out of 39) of inspectors indicated that they were aware that occupational health and safety training was conducted at abattoirs. Of these, 64.3% (i.e., 9 out of 14 inspectors) indicated that they participated in training and awareness at abattoirs. On the question whether the training conducted at abattoirs were relevant to the field of ergonomics, the data revealed that 30 out of 39 inspectors

(76.9%) and 10 out of 12 managers (83.3%) perceived that such training was relevant to the field of ergonomics. Moreover, inspectors that did not participate in training and awareness at abattoirs, concluded that such training (which they were never involved in) were relevant to the field of ergonomics. Finally, the fact that only 35.9% of inspectors highlighted that they were aware that health and safety training was conducted at abattoirs, raises concerns about the existence and relevance of health and safety training at selected abattoirs.

An analysis to determine the strength and the direction of the relationship between the variables having an "OH&S system" and having "training programmes" were conducted. The data derived from managers revealed that there was no statistical relationship between having an OH&S management system and implementing training programmes at selected abattoirs [$X^2(1, N = 12) = 0.099$; $p = 0.753$]. The results suggest that no guarantee existed that if an abattoir had a health and safety management system in place, that it would also conduct and implement training programmes. The data further indicated that it was highly unlikely that training programmes at abattoirs would include awkward postures, bending, grip force, repetitive work, or variable line speeds.

5.5.3 Common approaches to ergonomics and OH&S

Most participants indicated that they had a good understanding of occupational health and safety as well as of ergonomics. The general view of stakeholders interviewed were that the field of ergonomics were not treated with the necessary level of importance at abattoirs and that it should play a more meaningful role. Participating inspectors indicated that they knew whom to report health and safety hazards to but omitted to indicate if the Department of Labour (being the custodian of OH&S) had any role to play. According to the data, more than 80% of all reporting reached abattoirs and service providers. If the data proved to be correct and both abattoirs and service providers received reports from meat inspection personnel regarding the existence of ergonomic hazards at abattoirs, a lack of evidence existed on the efforts from abattoirs or service providers in addressing such hazards. The challenge faced by both abattoirs and service providers were the absence of clear guidelines on who takes responsibility for the health and safety of inspectors at abattoirs. This ultimately gave rise to a lack of effective cooperation between the two parties in addressing ergonomic hazards.

With 86.8% of inspectors indicating that they knew whom to report health and safety hazards to, only 64.1% indicated that they identified and reported health and safety hazards at abattoirs. Although 94.9% of inspectors indicated that they understood what ergonomics involved and that the reduction of health and safety hazards in an abattoir were important, only 60.5% of inspectors felt that ergonomics was their responsibility. Of the participating inspectors, 79.5% indicated that ergonomics had something to do with equipment and tool design. The internal consistency of the items measured within this section was questionable because a great deal of variability existed amongst the responses. From the responses, it appeared as though participants treated occupational health and safety and ergonomics as two separate aspects. By acknowledging that ergonomics had something to do with equipment and tool design, inspectors exhibited some degree of understanding on what ergonomics was all about. Apart from the fact that participants identified and reported health and safety hazards, 39.5% of inspectors believed that addressing ergonomic hazards outside of their work was not their concern. Being in contrast to the principles embedded in OHS Act No. 85 of 1993 (South Africa, 1993), it raises questions about the extent of occupational health and safety training and awareness at abattoirs. In as much as abattoirs were aware of their role and responsibility in terms of occupational health and safety, few abattoirs, if any, had systems in place to address all health and safety risks including ergonomic hazards. Furthermore, the extent to which health and safety systems incorporated meat inspection at abattoirs remains a challenge as the responsibility and accountability is shared between employer (service provider) and contractor (abattoir).

In the event where an abattoir had its own health and safety system, the question is to what extent it included the principles and practices of ergonomics? Furthermore, does it cover all risks applicable to meat inspection personnel? The researcher aimed to obtain an objective view from meat inspection personnel on the existence and management of health and safety at abattoirs. Firstly, because if an abattoir had an occupational health and safety system, then an inspector who has been working at that abattoir for a minimum of one year would have witnessed the implementation and existence of health and safety programmes. Secondly, if the abattoir had a system that explicitly managed and monitored risks that were specifically aimed at meat inspectors, it would be more objectively reported on by those included in this study.

CHAPTER SIX
CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The role of ergonomics within the local red meat abattoir sector have not been fully uncovered. The abattoir industry predominantly employs manual operations and the work performed is highly repetitive and physically demanding. This study therefore focussed on the interactions between meat inspectors and the organisational systems within which they performed their duties.

6.1.1 The existence of ergonomic hazards

In this segment, the first part of the research question is answered. It addresses the first research objective and identifies the types of ergonomic hazards that exist in abattoirs (applicable to meat inspection).

Based on the outcomes of this study, the repetitive work involved in the performance of meat inspection was identified as a risk to meat inspectors. The data showed that the applicable work cycle times could considerably increase the repetitiveness of meat inspection activities. Likewise, the short repetitive cycles performed in a highly paced working environment could further increase the load and the intensity of meat inspection.

The study also highlighted that the use of hand tools, for the entire duration or for most part of the day or shift, posed a considerable risk to inspectors. Although meat inspectors mainly used their hands and arms to perform inspection activities, the use of hand tools fundamentally influenced the type and the range of an inspector's hand, wrist, arm, or shoulder movements. These movements together with the deficiencies in the design of hand tools or the use of inadequate hand tools, could increase the level of strain and the risk of damage to the hands, wrists, arms, or the shoulders.

In addition to the above, the study further revealed that the body postures adopted during meat inspection also posed a risk to inspectors. Although the performance of meat inspection was dynamic in nature, inspectors often adopted awkward body postures due to deficiencies in the design and layout of meat inspection areas. These deficiencies forced inspectors to stretch and perform their duties in strained and difficult working positions. These body postures included bending forward, working with the arms in an elevated position, rotating their backs and trunks and bending the legs during meat inspection.

In summary, meat inspectors may be exposed to risks associated with the performance of physically intense and highly repetitive work. These may also include adopting awkward body postures using their hands, arms, and shoulders in elevated positions for extended periods. Furthermore, they constantly performed activities that required them to bend, rotate, extend, or flex their necks, backs, or legs during the executing of their duties.

6.1.2 Effects of ergonomic hazards

In this segment, the second part of the research question is answered. It addresses the second research objective and evaluates the perceived effects of ergonomic hazards.

The study showed that repetitive work could increase the physiological and biomechanical workload of inspectors. In doing so, it may result in muscular and tendon disorders and can affect the execution of meat inspection duties as well as an inspector's decision-making abilities. The use of hand tools could result in increased levels of force in the hand and wrist, which could increase the risk of damage to the muscles, nerves, tendons, or tendon sheaths of the hand, wrist, arms, and shoulders.

According to the outcomes of the study, any work conducted with the hands, arms, and shoulders in elevated positions, put additional strain on the arms, shoulders, neck, and back. It also raises the risk of developing nerve and tendon disorders that could cause rotator cuff syndrome, tendinitis, or epicondylitis. On the other hand, the constant and repetitive loading of the muscles in the neck and back, could therefore damage ligaments, disks, muscle, or tendons (Ross, 1994).

6.1.3 Prevalence and impact of ergonomic hazards

In this segment, the third part of the research questions is answered. It addresses the third research objective that assesses the extent and impact of ergonomic hazards.

Some of the elements that influenced the performance of meat inspection included the layout and design of inspection areas as well as the design and layout of dressing lines. These working conditions as well as the nature of meat inspection require inspectors to adopt postures and perform working activities that constantly change over short repetitive cycles in a highly paced work environment.

Apart from the physical intensity with which inspectors performed their duties, meat inspection required inspectors to use their skill, knowledge, and expertise to support their decision-making. The work involved in meat inspection is not only physical in nature but could give rise to work-related stress and mental fatigue. The level of mental exertion to which inspectors were subjected could ultimately affect their alertness, efficiency as well as the attitude towards their work.

Consequently, these risk factors were some of the key elements that contributed to the occurrence and the continuation of ergonomic hazards to meat inspectors in red meat abattoirs.

6.1.4 Barriers or opportunities to addressing hazards

In this segment, the answers to the fourth research objective are presented. It focusses on identifying the barriers or opportunities that abattoirs may face in addressing ergonomic hazards within the red meat abattoir industry.

The outcomes of the study revealed that the following barriers may limit abattoirs in addressing ergonomic hazards:

a) ergonomics not being fully integrated into OH&S management at abattoirs;
b) uncertainty on the roles and responsibilities of abattoirs and service providers in addressing ergonomic hazards to meat inspectors;
c) the lack of awareness programmes on ergonomic hazards within red meat abattoirs; and
d) the absence of control measures to assist in the identification and the reporting of ergonomic hazards.

In addition to the above, the study also highlighted some opportunities to addressing ergonomic hazards. These include opportunities to:

a) review the current approaches applicable to the design and layout of meat inspection areas;
b) incorporate ergonomics into the design and layout of working platforms and hand tools;
c) integrate ergonomics into existing OH&S systems at abattoirs and to establish a suitable line-management structure (where and if applicable);
d) develop suitably designed employee training programmes that includes ergonomics;
e) ensure that employees of service providers are also covered in the abattoir's OH&S management system;
f) assess the relevance and importance of rest-and-recovery programmes for inspectors;

g) develop and implement suitably designed job rotation programmes for meat inspectors;
h) reduce the impact of ergonomic hazards and the occurrence of work-related injuries.
i) reduce the risk and impact of worker's compensation claims; and
j) promote compliance to ergonomics within the red meat abattoir sector.

6.2 Recommendations

It is recommended that abattoirs (and service providers where applicable) consider to:

a) incorporate the use of ergonomically designed hand tools for meat inspectors;
b) eliminate the use of deboning knives during meat inspection;
c) ensure that meat inspection areas and working platforms adhere to the principles of ergonomics in terms of its design and layout;
d) implement adequate job rotation programmes to limit or reduce the level of exposure of meat inspectors to ergonomic hazards;
e) increase meat inspection capacities to adequately support job rotation programmes;
f) implement adequate rest-and-recovery programmes to allow for sufficient recovery time between the different levels of exposure;
g) develop and implement OH&S management systems that is inclusive of meat inspectors and ergonomic hazards;
h) establish OH&S as a recognized line management responsibility based on the size of each business;
i) ensure that OH&S training at abattoirs include the relevance and importance of ergonomic hazards to meat inspectors; and
j) make provision for the reporting of ergonomic hazards by meat inspectors to both abattoirs and service providers.

6.3 Future research

Although this study identified the types of hazards that may be present as well as the impact that it may have on inspectors, future research may be needed on the:

a) assessment of the physiological and biomechanical loading of working activities involved in the performance of meat inspection;
b) use and impact of job rotation programmes in reducing the impact of ergonomic hazards to meat inspectors;

c) role and significance of rest or recovery breaks in reducing the risks of muscular disorders to meat inspectors;

d) effects of mechanization on the incidence and the occurrence of ergonomic hazards within the red meat abattoir sector; and

e) type and impact of ergonomic hazards present in the working environment of slaughter personnel within the red meat abattoir sector.

REFERENCES

Abdullahi, A., Hassan, A., Kadarman, N., Junaidu, Y.M., Adeyemo, O.K., and Lua, P.L. 2016. Occupational hazards among the abattoir workers associated with noncompliance to the meat processing and waste disposal laws in Malaysia. *Risk Management and Healthcare Policy*. 9:157-163.

Adams, V. 2008. Introduction to data analysis. *Journal of Small Animal Practice*. 49(8):375-376.

Albert, S.L., and Spencer, J.B. 2003. "The Vertical". *NASA, Washington, Technology 2003: The Fourth National Technology Transfer Conference and Exposition*. 2:124-129.

Al-Otaibi, T. 2001. Repetitive strain injury. *Neurosciences Journal*. 6(2):90-94.

American Council on Exercise (ACE). 2017. Muscles that move the arm. https://www.acefitness.org/fitness-certifications/ace-answers/exam-preparation-blog/3535/muscles-that-move-the-arm/. [20 November 2022].

Anatomy QA. 2018. The superficial and deep palmer arch. https://anatomyqa.com/superficial-deep-palmar-arch-and-cutaneous-innervation-of-hand/. [03 September 2023].

Aptel, M., Claudon, L., and Marsot, J. 2002. Integration of ergonomics into hand tool design: principle and presentation of an example. *International Journal of Occupational Safety and Ergonomics*. 8(1):107-115.

Arciniega-Rocha, R.P., Erazo-Chamorro, V.C., and Szabo, G. 2023. The prevention of industrial manual tool accidents considering occupational health and safety. *Safety*. 9(3):51.

Arezes, P.M., Dinis-Carvalho, J., and Alves, A.C. 2014. Workplace ergonomics in lean production environments: A literature review. *Work (Reading, Mass.)*. 52(1):57-70.

Ariens, G.A., Van Mechelen, W., Bongers, P.M., Bouter, L.M., and Van Der Wal, G. 2000. Physical risk factors for neck pain. *Scandinavian Journal of Work, Environment & Health.* 26(1):7-19.

Armstrong, T.J., and Chaffin, D.B. 1979. Some biomechanical aspects of the carpal tunnel. *Journal of Biomechanics*. 12(7):567-570.

Banjo, T.A., Onilude, A.A., Amoo, A.O.J., Busari, A., Ogundahunsi, O.A., Olooto, W.E., Familoni, O.B., Amballi, A.A., Oyelekan, A.A.A., and Abiodun, O.A. 2013. Occupational Health Hazards Among Abattoir Workers in Abeokuta. *Academia Arena*. 5(10):29-36.

Barter, H.C. 2014. Slaughterhouse Rules: Declining Abattoirs and the Politics of Food Safety Regulation in Ontario. Master of Arts. University of Toronto. Toronto.

Bisht, D.S., and Khan, M.R. 2017. Anatomically shaped tool handles designed for power grip. In: *Research into Design for Communities, Volume 1: Proceedings of ICoRD.* Springer Singapore. 1:135-148.

Bobjer, O., Johansson, S., and Piguet, S. 1993. Friction between the hand and the handle - effects of oil and lard on textured and non-textured surfaces, perceptions of discomfort. *Applied Ergonomics*. 24(3):190-202.

Broadway, M.J., and Stull, D.D. 2008. "I'll do whatever you want, but it hurts": Worker safety and Community Health in Modern Meatpacking. *Labour Studies in Working-class History of the Americas*. 5(2):27-37.

Carayon, P., and Smith, M.J. 2000. Work organization and ergonomics. *Applied Ergonomics*. 31(6):649-662.

Cabrera, R., Cochran, M., Dangelmayr, L., D'Aguilar, G., Gawande, K., Lee, J., Speir, I., and Weigand, C. 2010. African capacity building for meat exports: Lessons from the Namibian and Botswana beef industry. https://bush.tamu.edu/wp-content/uploads/2020/02/Gawande_2007.pdf. [31 March 2024].

Chartered Institute of Ergonomics & Human Factors (CIEHF). 2023. What is ergonomics? https://ergonomics.org.uk/learn/what-is-ergonomics.html. [12 September 2023].

Cohen, A., and Colligan, M.J. 1998. Assessing occupational safety and health training - A Literature Review. https://stacks.cdc.gov/view/cdc/11254. [20 August 2023].

Cook, E.A.J., de Glanville, W.A., Thomas, L.F., Kariuki, S., de Clare Bronsvoort, B.M., and Fèvre, E.M. 2017. Working conditions and public health risks in slaughterhouses in western Kenya. *BMC Public Health*. 17:14(1-12).

Cortina, J.M. 1993. What Is Coefficient Alpha? An Examination of Theory and Applications. *Journal of Applied Psychology*. 78(1):98-104.

Curtis, R.I. 2001. Ancient Food Technology. *Brill Academic Publishers*. Leiden. Netherlands. Ancient Food Technology - Curtis - Google Books. [10 December 2020].

Das, B., and Sengupta, A.K. 2000. Evaluation of Low Back Pain Risks in a Beef Skinning Operation. *International Journal of Occupational Safety and Ergonomics*. 6(3):347-361.

Das, S. (no date). The Shoulder Exam. https://www.towsonsportsmedicine.com/wp-content/uploads/Shoulder-Exam-ppt-SDAS.pdf. [05 September 2023].

David, D., Giannini, C., Chiarelli, F., and Mohn, A. 2021. Text Neck Syndrome in Children and Adolescents. *International Journal of Environmental Research and Public Health*. 18(4):1565.

Davincenzo, K. 2018. How reach zones help manufacturing employees lead safer lives. https://www.work-fit.com/blog/how-reach-zones-help-manufacturing-employees-lead-safer-lives. [05 September 2023].

Davis, K.G., and Jorgensen, M.J. 2005. Biomechanical modelling for understanding of low back injuries: A systematic review. *Occupational Ergonomics*. 5(1):57-76.

Davis, K.G., and Marras, W.S. 2000. The effects of motion on trunk biomechanics. *Clinical biomechanics*, 15(10):703-717.

Davis, C.P. 2019. Drug-medical-dictionary. RxList. https://www.rxlist.com/drug-medical-dictionary/article.htm. [07 September 2023].

Dawson, B., and Trapp, R.G. 2004. Basics & Clinical Biostatistics. 4th edition. Lange Medical Books/McGraw-Hill. USA.

Delgado, E. 1990. An Ergonomic Study of Meat Processing Operations. Unpublished Master of Science. Western Michigan University. Michigan.

Dianat, I., Vahedi, A., and Dehnavi, S. 2016. Association between objective and subjective assessments of environmental ergonomic factors in manufacturing plants. *International Journal of Industrial Ergonomics*. 54:26-31.

Dolman, C. 1957. The Epidemiology of meat-borne diseases. Monograph Series. World Health Organisation. (33):11-108.

Dong, R.G., Wu, J.Z., Welcome, D.E., and McDowell, T.W. 2008. A new approach to characterize grip force applied to a cylindrical handle. *Medical Engineering & Physics*. 30(1):20-33.

Drury, C.G. 1980. Handles for manual materials handling. *Applied Ergonomics*. 11(1):35-42.

Dul, J., and Neumann, W.P. 2009. Ergonomics contributions to company strategies. *Applied Ergonomics*. 40(4):745-752.

Ebben, J.M. 2023. Wrists at Risk: *Awkward Postures to Avoid*. Source: https://www.iacindustries.com/get-started/ergonomics/wrists-at-risk. [04 September 2023].

Fagan, K.M., and Hodgson, M.J. 2017. Under-recording of work-related injuries and illnesses: An OSHA priority. *Journal of Safety Research*. 60:79-83.

Fakoya, A.O., Tarzian, M., Sabater, E.L., Burgos, D.M. and Marty, G.I.M. 2023. De Quervain's disease: A discourse on etiology, diagnosis, and treatment. *Curēus (Palo Alto, CA)*. [Online] 15(4):e38079-e38079.

Fayemi, P.O., and Muchenje, V. 2013. Maternal slaughter at abattoirs: history, causes and cases and the meat industry. *Springer Plus*. 2:125.

Feldhacker, D.R., Lohman, H., and Bracciano, A. 2021. A Topic Paper on Flexor Tendon Repair: A Theoretical and Evidence – Based Approach. *Rehabilitation Medicine*. 31(5):372-380.

Fernandez, J.E. 1995. Ergonomics in the workplace. *Facilities*. 13(4):20-27.

Filus, R., and Okimorto, M.L. 2012. The effect of job rotation intervals on muscle fatigue – lactic acid. *Work*. 41:1572-1581.

Filus, R., and Partel, L. 2012. Managing ergonomics in the development of rotation between workstations in the automotive industry. A balance between health and traceability of tasks. *Work*. 41:4402-4408.

Fitzgerald, A.J. 2010. A Social History of the Slaughterhouse: From inception to contemporary implications. *Human Ecology Review*. 17(1):58-69.

Franasiak, J., Craven, R., Mosaly, P., and Gehrig, P.A. 2014. Feasibility and Acceptance of a Robotic Surgery Ergonomic Training Program. *Journal of the Society of Laparoendoscopic Surgeons Society of Laparoendoscopic Surgeos*. 18(4):1-7.

Fransson-Hall, C., and Kilbom, A. 1993. Sensitivity of the hand to surface pressure. *Applied Ergonomics*. 24(3):181-189.

Frazer, M.B., Norman, R.W., Wells, R.P., and Neumann, W.P. 2003. The effects of job rotation on the risk of reporting low back pain. *Ergonomics*. 46(9):904-919.

Fuentes, J.M., Lopez-Sanches, M., Garcia, A.I., and Ayuga, F. 2015. Public abattoirs in Spain: History, construction characteristics and the possibility of their reuse. *Journal of Cultural Heritage*. 16(5):632-639.

Fusion Tech. 2014. Ergonomic workstation design – in Ergo & Safety Tips. https://ftiinc.org/ergonomic-work-station-design/. [06 April 2021].

Garg, A., and Kapellusch, J. M. 2009. Applications of biomechanics for prevention of work-related musculoskeletal disorders. *Ergonomics*. 52(1):36-59.

Gil, I.J., and Durao, C.J. 1990. A colour atlas of Meat Inspection. Lisbon: Wolfe Publishing.

Gillespie, K. 2017. Industrial Slaughter – Postdoctoral fellow in animal studies. Wesleyan University. Middletown. CT.

Grant, K.A., Habes, D.J., and Steward, L.L. 1992. An analysis of handle designs for reducing manual effort: The influence of grip diameter. *International Journal of Industrial Ergonomics*. 10(3):199-206.

Grant, A., and Habes, D.J. 1997. An electromyographic study of strength and upper extremity muscle activity in simulated meat cutting tasks. *Applied Ergonomics*. 28(2):129-137.

Guild, R., Ehrlich, R.I., Johnston, J.R., and Ross, M.H. 2001. *A handbook on occupational health practice in the South African mining industry*. Johannesburg, South Africa: Safety in Mines Research Advisory Committee.

Habibi, E., Kazemi, M., Dehghan, H., Mahaki, B., and Hassanzadeh, A. 2013. Hand grip and pinch strength: Effects of workload, hand dominance, age, and Body Mass Index. *Pakistan Journal of Medical Science*. 29(1):363-367.

Hägg, G.M., and Milerad, E. 1997. Forearm extensor and flexor muscle exertion during simulated gripping work - an electromyographic study. *Clinical Biomechanics*. 12(1):39-43.

Hägg, G. M., Vogel, K., Karltun, J., and McGorry, R. 2012. Knife force differences when cutting meat at different temperatures. NES2012 : Ergonomics for Sustainability and Growth. Presented at the NES2012 Ergonomics for Sustainability and Growth. KTH Royal Institute of Technology. https://urn.kb.se/resolve?urn=urn:nbn:se:hj:diva-26831. [27 January 2016].

Harmse, J.L., Engelbrecht, J.C., and Bekker, J.L. 2016. The impact of physical and ergonomic hazards on Poultry abattoir processing workers – A review. *The International Journal of Environmental Health and Public Health*. 13:197.

Harvard Health Publishing (HHP). 2021. What to do about rotator cuff tendinitis. *The best way to treat rotator cuff tendinitis, the most common cause of shoulder pain, is with simple home therapies. Harvard Medical School*. https://www.health.harvard.edu/pain/what-to-do-about-rotator-cuff-tendinitis. [05 September 2023].

Health and Safety Executive. 2023. Work-related Musculoskeletal Disorder statistics in Great Britain. https://www.hse.gov.uk/statistics/assets/docs/msd.pdf. [06 April 2024].

Hellig, T., Mertens, A., and Brandl, C. 2018. The interaction effect of working postures on muscle activity and subjective discomfort during static working postures and its correlation with OWAS. *International Journal of Industrial Ergonomics*. 68(2):25-33.

Hendrix, J.A., and Dollar, C.B. 2017. American Slaughterhouses and the Need for Speed: An Examination of the Meatpacking-Methamphetamine Hypothesis. *Organization and Environment*. 31(2):133-151.

Hill, A., Brouwer, A., Donaldson, N., Lambton, S., Buncic, S., and Griffiths, I. 2013. A Risk and Benefit Assessment for Visual-Only Meat Inspection of UK Indoor and Outdoor Pigs. *Food Control*. 30(1):255-264.

Hlasa, M.A. 2006. The characterisation of noise levels in various throughput abattoirs during the slaughter of different species. Magister Technologiae. Central University of Technology, South Africa.

Hoogendoorn, W.E., Van Poppel, M.N., Bongers, P.M., Koes, B.W., and Bouter, L.M. 1999. Physical load during work and leisure time as risk factors for back pain. *Scandinavian Journal of Work, Environment and Health*. 387-403.

Huang, H.J. 1999. Job Rotation from the Employees' Point of View. *Research and Practice in Human Resource Management*. 7(1):75-85.

Human Rights Watch (HRW). 2019. "When We're Dead and Buried, Our Bones Will Keep Hurting". Workers' Rights Under Threat in US Meat and Poultry Plants. USA.

Igwenagu, C. 2016. Fundamentals of research methodology and data collection. State University of Science and Technology. Enugu.

Imrhan, N. 1991. The influence of wrist position on different types of pinch strength. Applied *Ergonomics*. 22(6):379-384.

Inkson K., and Cammock P. 1984. Labour process theory and the chain system in New Zealand meatworks. *New Zealand Journal on Industrial relations.* 9:149-160.

International Ergonomics Association (IEA). (no date). What is ergonomics? https://iea.cc/what-is-ergonomics/. [29 April 2021].

International Labour Office. 2001. Guidelines on occupational safety and health management systems, ILO-OSH 2001. Geneva.

International Labour Organization. 2013. Prevention of Occupational Diseases. International Labour Organization. Geneva.

Jerie, S., and Matunhira, K. 2022. Occupational safety and health hazards associated with the slaughtering and meat processing industry in urban areas of Zimbabwe: A case study of the Gweru City Municipal Abattoir. Ghana Journal of Geography. 14(1):22-40.

Johnson, S.L. 1990. Ergonomic Design of Handheld Tools to Prevent Trauma to the Hand and Upper Extremity. *Journal of Hand Therapy*. 3(2):86-93.

Johnson, O.E., and Etokidem, A.J. 2019. Occupational hazards and health problems among butchers in Uyo, Nigeria. *Nigeria Medical Journal*. 60(3):106-112.

Jorgensen, M., Davis, K., Kotowski, S., Aedla, P., and Dunnig, K. 2005. Characteristics of job rotation in the Midwest US manufacturing sector. *Ergonomics*. 48(15):1721-1733.

Kadefors, R., Areskoug, A., Dahlman, S., Kiibom, A., Sperling, L., Wikström, L., and Oster, J. 1993. An approach to ergonomics evaluation of hand tools. *Applied Ergonomics*. 24(3):203-211.

Karltun, J., Vogel, K., Bergstrand, M., and Eklund, J. 2016. Maintaining knife sharpness in industrial meat cutting: A matter of knife or meat cutter ability. *Applied Ergonomics.* 56:92-100.

Karwowski, W., and Marras, W.S. eds. 1998. *The occupational ergonomics handbook*. Place of publication. CRC Press.

Kelloway, C. 2019. Meat processing is a dangerous job. It's about to get a lot worse. https://talkpoverty.org/2019/04/24/meat-dangerous-job-get-worse/index.html. [06 April 2021].

Knauth, P., and Hornberger, S. 1998. Changes from weekly backward to quicker forward rotating shift systems in the steel industry. *International Journal of Industrial Ergonomics*. 21(3-4):267-273.

Knauth, P., and Hornberger, S. 2003. Preventive and compensatory measures for shift workers. *Occupational Medicine*. 53(2):109-116.

Kothari, C.R. 1990. *Research Methodology – Methods and Techniques*. 2nd edition. New Delhi. New Age International (P) Limited Publishers.

Kroemer, K.H.E. 1989. Cumulative trauma disorders: Their recognition and ergonomics measures to avoid them. *Applied Ergonomics*. 20(4):274-280.

Kurpa, K., Waris, P., and Rokkanen, P. 1979. Tennis elbow. Lateral elbow pain syndrome. *Scandinavian Journal of Work, Environment & Health*. 5(3):15-18.

La Novara, P. 1991. Factors affecting occupational injury rates: An analysis of Canadian data. Unpublished Thesis for Master of Art. McGill University, Montreal. Canada.

Lean Strategies International LLC. 2022. Cycle Time. https://www.leanstrategiesinternational.com/glossary/cycle-time#. [14 September 2023].

Leclerc, A., Chastang, J.F., Niedhammer, I., Landre, M.F., and Roquelaure, Y. 2004. Incidence of shoulder pain in repetitive work. *Occupational and Environmental Medicine*. 61(1):39-44.

Lewis, W.G., and Narayan, C.V. 1993. Design and sizing of ergonomic handles for hand tools. *Applied Ergonomics*. 24(5):351-356.

Lubbe, W.F., and Groenewald, J.A. 1992. Market Reform in the Red Meat Industry. *Agrekon*. 31(4):294-301.

Luppnow, A. 2007. An investigation into the impact of imported pork on the demand for pork in Queenstown. Master of Business Administration. University of Kwazulu-Natal.

Laerd dissertation, Lund Research Ltd. 2012. Research strategy – Types of purposive sampling. https://dissertation.laerd.com/purposive-sampling.php#types. [13 September 2023].

Macleod, D. 1996. Ergonomic Success in Meatpacking – What you can learn from this experience. *National Ergonomics Exposition*. https://www.danmacleod.com/Articles/Ergonomics_Success_Meatpacking.htm. [05 September 2023].

Mafuwane, B.M. 2011. The contribution of instructional leadership to learner performance. Unpublished thesis for Philosophiae Doctor. University of Pretoria. South Africa.

Makori, C.M., Warutere, P.N. and Nguhiu, P.N. 2018. Factors Associated with the Injuries Inflicted to workers in slaughterhouses and meat processing plants in Nairobi, Kenya. International *Journal of Current Research in Life Sciences*. 7(5):2020-2023.

Manchikanti, L. 2000. Epidemiology of Low Back Pain. *Pain Physician*. 3(2):167-192.

Manchikanti, L., Singh, V., Falco, F.J., Benyamin, R.M., and Hirsch, J.A. 2014. Epidemiology of low back pain in adults. *Neuromodulation: Technology at the Neural Interface.* 17:3-10.

Marras, W.S. 2000. Occupational low back disorder causation and control. *Ergonomics*. 43(7):880-902.

Marras, W.S. 2012. Basic Biomechanics and Workstation Design. In: Handbook of Human Factors and Ergonomics, (ed.) G. Salvendy. pp 347-381. 4th edition. New Jersey. John Wiley & Sons.

Marsot, J., Claudon, L., and Jacqmin, M. 2007. Assessment of knife sharpness by means of a cutting force measuring system. *Applied Ergonomics*. 38(1):83-89.

Maseko, M.M. 2016. Effects of non-compliance with the Occupational Health and Safety Act (No. 85 of 1993) among the Food and Beverage Industries in selected Provinces of South Africa. Unpublished thesis for Doctor of Literature and Philosophy. University of South Africa. South Africa.

Maseko, M., Zungu, L., and Gabe, S. 2017. Occupational slips, trips and falls amongst workers in the meat sector in Gauteng Province of South Africa. *PULA: Botswana Journal of African Studies.* 31(2):119-133.

McCarthy, C.T., Hussey, M., and Gilchrist, M.D. 2007. On the sharpness of straight edge blades in cutting soft solids: Part I–indentation experiments. *Engineering Fracture Mechanics.* 74(14):2205-2224.

McCarthy, C.T., Annaidh, A.N., and Gilchrist, M.D. 2010. On the sharpness of straight edge blades in cutting soft solids: Part II–Analysis of blade geometry. *Engineering Fracture Mechanics.* 77(3):437-451.

McDowell, T.W., Wimer, B.M., Welcome, D.E., Warren, C., and Dong, R.G. 2012. Effects of handle size and shape on measured grip strength. *International Journal of Industrial Ergonomics*. 42(2):199-205.

McGorry, R.W., Dowd, P.C., and Dempsey, P.G. 2003. Cutting moments and grip forces in meat cutting operations and the effect of knife sharpness. *Applied Ergonomics*. 34(4):375-382.

McGorry, R.W., Dowd, P.C., and Dempsey, P.G. 2005. The effect of blade finish and blade edge angle on forces used in meat cutting operations. *Applied Ergonomics*. 36(1):71-77.

Middlesworth, M. 2023a. A step-by-step guide – Rapid Entire Body Assessment (REBA). http://ergo-plus.com/wp-content/uploads/REBA-A-Step-by-Step-Guide.pdf. [13 September 2023].

Middlesworth, M. 2023b. Ergonomics Awareness Training for Employees. ErgoPlus. https://ergo-plus.com/ergonomics-awareness-training-for-employees-pdf/. [05 September 2023].

Middlesworth, M. 2023c. The most important benefit of maintaining a neutral posture. ErgoPlus. https://ergo-plus.com/the-most-important-benefit-of-maintaining-a-neutral-posture/. [05 September 2023].

Miele, M. 2016. Killing animals for food: How science, religion and technology affect the public debate about religious slaughter. *Food ethics*. 1(1):47-60.

Mientjes, M.I.V. 2000. On a 55/5 second minute of light assembly work by women: effects of work/recovery ratios on discomfort and loading of the low back. Unpublished thesis for Doctor of Philosophy in Kinesiology. University of Waterloo. Ontario.

Mishra, D.K., Friden, J., Schmitz, M.C., and Lieber, R.L. 1995. Anti-Inflammatory medication after muscle injury - A treatment resulting in short-term improvement but subsequent loss of muscle function. *The Journal of Bone and Joint Surgery*. 77(10):1510-1519.

Mital, A., and Kilbom, A. 1992. Design, selection and use of hand tools to alleviate trauma of the upper extremities: Part II - The scientific basis (knowledge base) for the guide. *International Journal of Industrial Ergonomics*. 10(1-2):7-21.

Mukhopadhyay, P., and Khan, A. 2015. The evaluation of ergonomic risk factors among meat cutters working in Jabalpur, India. *International Journal of Occupational and Environmental Health*. 21(3):192-198.

Mustard, C.A., Chambers, A., Ibrahim, S., and Etches, J. 2014. Time trends in musculoskeletal disorders attributed to work exposures in Ontario using three independent data sources, 2004-2011. *Occupational and Environmental Medicine (London, England)*. 72(4):252-257.

Mweshi, G.K., and Sakyi, K. 2020. Application of sampling methods for the research design. *Archives of Business Research*. 8(11):180-193.

Nath, N.D., Akhavian, R., and Behzadan, A.H. 2017. Ergonomic analysis of construction worker's body postures using wearable mobile sensors. *Applied Ergonomics*. 62:107-117.

National Agricultural Marketing Council (NAMC). 2001. *Report on the Investigation into the Effect of Deregulation on the Red Meat Industry.* www.namc.co.za. [29 August 2019].

Nayak, J.K., and Singh, P. 2015. *Fundamentals of Research Methodology Problems and Prospects*. SSDN Publishers and Distributors. New Delhi.

Nicholas, J.W., Corvese, R.J., Woolley, C., and Armstrong, T.J. 2012. Quantification of hand grasp force using a pressure mapping system. *Work.* 41(Supplement 1):605-612.

Nilsson, F. 2017. Upper body ergonomics in virtual reality: An ergonomic assessment of the arms and neck in virtual environments. Unpublished Master degree thesis. Linköping University. Sweden.

Norman, R., and Wells, R. 1998. Ergonomic Interventions for Reducing Musculoskeletal Disorders: An Overview, Related Issues and Future Directions. Institute for Work & Health. Royal Commission on Workers Compensation in British Columbia.

Olivier, G.C. 2004. An analysis of the South African Beef supply chain: From farm to fork. Magister Commercii, Rand Afrikaans University, Johannesburg.

Oluchi, E.T., and Elochukwu, E.J. 2023. Occupational Health Hazards and Safety Practises on Abattoir Workers in Owerri Metropolis, Imo State. *Global Academic Journal of Medical Science*. 5(1):51-59.

O'Sullivan, L.W., and Gallwey, T.J. 2002. Upper-limb surface electro-myography at maximum supination and pronation torques: the effect of elbow and forearm angle. *Journal of Electromyography and Kinesiology*. 12(4):275-285.

Pandey, P., and Pandey, M.M. 2015. Research Methodology: Tools and Techniques. Bridge Center. Romania.

Park, J., and Kim, Y. 2020. Association of Exposure to a Combination of Ergonomic Risk Factors with Musculoskeletal Symptoms in Korean Workers. *International Journal Environmental Research and Public Health*. 17(24):9456.

Patkin, M. 2001. A checklist for handle design. Ergonomics Australia On-Line. http://ergonomics.uq.edu.au/eaol/handle.pdf. [12 April 2021].

Pouliakas, K., and Theodossiou, I. 2010. An Inquiry into the Theory, Causes and Consequences of Monitoring Indicators of Health and Safety at Work. IZA Discussion Papers, No. 4734, *Institute for the Study of Labor (IZA), Bonn*.

Price, K. 2023. Reviewnery – Boning knife vs butcher's knife. Is there a difference? https://reviewnery.com/boning-knife-vs-butcher-knife/#. [14 September 2023).

ProHealth Clinic. 2022. Painful Arc. https://prohealthclinic.co.uk/blog/painful-arc. [13 September 2023].

Punnett, L., Prüss-Üstün, A., Nelson, D.I., Fingerhut, M.A., Leigh, J., Tak, S., and Phillips, S. 2005. Estimating the Global Burden of Low Back Pain Attributable to Combined Occupational Exposures. *American Journal of Industrial Medicine*. 48(6):459-469.

Punnett, L., and Wegman, D.H. 2004. Work-related musculoskeletal disorders: the epidemiologic evidence and the debate. *Journal of electromyography and kinesiology*. 14(1):13-23.

Quansah, R. 2005. Harmful postures and musculoskeletal symptoms among fish trimmers of a fish processing factory in Ghana: A Preliminary Investigation. *International Journal of Occupational Safety and Ergonomics (JOSE)*. 11(2):181-190.

Rochester Hand Centre. 2007. Education – Hand anatomy. *Motion Terminology your surgeon may use.* https://rochesterhandcenter.com/education/trauma/anatomy.html. [04 September 2023].

Ross, P. 1994. Ergonomic Hazards in the Workplace: Assessment and prevention. *AAOHN Journal*. 42(4):171-176.

Salvendy, G. ed. 2012. *Handbook of human factors and ergonomics*. Place of publication. John Wiley & Sons.

Sancho-Bru, J.L., Pe´rez-Gonza´lez, A., Vergara, M., and Giurintano, D.J. 2003. A 3D Biomechanical Model of the Hand for Power Grip. *Journal of Biomechanical Engineering*. 125(1):78-83.

Savescu, A., Cuny-Guerrier, A., Wild, P., Reno, G., Aublet-Cuvelier, A., and Claudona, L. 2018. Objective assessment of knife sharpness over a working day cutting meat. *Applied Ergonomics*. 68:109-116.

Schall Jr, M.C., Fethke, N.B., and Chen, H. 2016. Working postures and physical activity among registered nurses. *Applied Ergonomics.* 54:243-250.

Schneider, S., Davis, K., and Jorgensen, M. 2005. Pros and Cons of Job Rotation as a Means of Reducing Injury Costs. *Journal of occupational and environmental hygiene*. [Online] 2(1):D1-D3.

Seethamma, K.M., Raj, J.O., Prakash, N., and Shetty, K. 2019. Correlation of forearm circumference and hand length with grip strength in healthy young adults. *Acta Scientific Orthopaedics*. 2(10):10-15.

Shaikh, A.S., and Shelke, R.D. 2016. Studies assessing the effects of prolonged standing at work: A review. *International Journal of Advanced Engineering Research and Science.* 3(10):236873.

Sharma, G. 2017. Pros and cons of different sampling techniques. *International Journal of Applied Research*. 3(7):749-752.

Shorten, A., and Smith, J. 2017. Mixed methods research: expanding the evidence base. *Evidence-Based Nursing*. 20(3):74-75.

Silverstein, B.A., Fine, L.J., and Armstrong, T.J. 1986. Hand wrist cumulative trauma disorders in industry. *British Journal of Industrial Medicine (BJIM)*. 43(11):779-784.

South Africa. Constitution of the Republic of South Africa, Act No. 108 of 1996. https://www.gov.za/documents/constitution/constitution-republic-south-africa-04-feb-1997. [21 April 2024].

South Africa. 1972. Abattoirs throughout the country to be improved. *Farming in South Africa.* 47(11):2-3.

South Africa. Department of Agriculture. 2000. *Meat Safety Act (Act No. 40 of 2000)*. http://www.old.dalrrd.gov.za/vetweb/Legislation/Meat%20safety/Act-Meat%20Safetyx.pdf. [25 August 2016].

South Africa. Department of Agriculture. 2004. Red Meat Regulations (G.N. R1072 of 17 September 2004). http://www.old.dalrrd.gov.za/vetweb/Legislation/Meat%20safety/RED%20MEAT%20REGS%202004.pdf. [06 October 2018].

South Africa. Department of Agriculture. 2015. Meat Inspection Scheme. https://www.gov.za/sites/default/files/gcis_document/201512/39519gon1238.pdf. [27 February 2020].

South Africa. Department of Labour. 1986. General Safety Regulations (G.N. R1031 of 30 May 1986). https://lawlibrary.org.za/akn/za/act/gn/1986/r1031/eng@1986-06-20/source.pdf. [21 April 2024].

South Africa. Department of Labour. 1987. Environmental Regulations for Workplaces (G.N. R2281 of 16 October 1987). https://www.labour.gov.za/DocumentCenter/Regulations%20and%20Notices/Regulations/Occupational%20Health%20and%20Safety/Environmental%20Rgulations%20for%20Workplaces%201987%20as%20amended.pdf. [21 April 2024].

South Africa. Department of Labour. 1993. Occupational Health and Safety Act (Act No. 85 of 1993). https://www.gov.za/sites/default/files/gcis_document/201409/act85of1993.pdf. [29 October 2023].

South Africa, Department of Labour. 1993. Compensation for Occupational Injuries and Diseases Act (Act No. 130 of 1993). https://www.gov.za/sites/default/files/gcis_document/201409/act130of1993.pdf. [22 April 2024].

South Africa, Department of Labour. Year?? Circular Instruction 180 regarding the compensation of Work-related Upper Limb Disorders (WRULDs). (G.N. 498 of 23 April 2004). https://www.gov.za/sites/default/files/gcis_document/201409/26270a0.pdf. [22 April 2024].

South Africa. 1997. Department of Labour. Basic conditions of employment Act (Act No. 75 of 1997). Government Printer, Pretoria. https://www.gov.za/documents/basic-conditions-employment-act. [20 August 2023].

South Africa. Department of Labour. 2001. Regulations for Hazardous Biological Agents (G.N. R1390 of 27 December 2001). https://www.gov.za/sites/default/files/gcis_document/201409/229560.pdf. [21 April 2024].

South Africa. Department of Labour. 2003. Noise-Induced Hearing Loss Regulations (G.N. R307 of 07 March 2003). https://science.uct.ac.za/sites/default/files/media/documents/noise-induced_hearing_loss_regs_2003.pdf. [21 April 2024].

South Africa. Department of Labour. 2019. Ergonomics Regulations (G.N. R1589 of 06 December 2019). https://www.gov.za/sites/default/files/gcis_document/201912/42894rg10177gon1589.pdf. [30 March 2024].

Spies, D.C. 2011. Analysis and Quantification of the South African Red Meat Value Chain. Doctoral thesis. University of Free State. Bloemfontein.

Sporrong, H., Palmerud, G., and Herberts, P. 1996. Hand grip increases shoulder muscle activity: An EMG analysis with static hand contractions in 9 subjects. *Acta Orthopaedica Scandinavica*. 67(5):485-490.

Stoy, D.W., and Aspen, J. 1999. Force and Repetition Measurement of Ham Boning – Relationship to Musculoskeletal Symptoms. *AAOHN Journal*. 47(6):254-260.

Stroud, K.A., and Booth, D.J. 2013. Advanced Engineering Mathematics. Palgrave Macmillan. 7th ed.

Strydom, H., and Venter, L. 2002. Sampling and Sampling Methods. In: Research at Grass Roots – For the social sciences and human service professions, (eds.) A.S. De Vos, A.S., Strydom, H., Fouché, C.B., and Delport, C.S.L. pp 197-209. 2nd edition. Pretoria. Van Schaik Publishers.

Sumpor, D., Taboršak, D., and Jurum-Kipke, J. 2015. Antrhopometric measures important for control panel design in locomotive or railcar. *Technical Gazette*. 22(1):1-10.

Sundelin, G., and Hagberg, M. 1992. Electromyographic signs of shoulder muscle fatigue in repetitive arm work paced by the Methods Time Measurement system. *Scandinavian Journal of Work, Environment and Health*. 18(4):262-268.

Szabo, R.L., Radwin, R.G., and Henderson, C.J. 2001. The Influence of Knife Dullness on Poultry Processing Operator Exertions and the Effectiveness of Periodic Knife Steeling. *AIHAJ*. 62(4):428-433.

Taderera, H. 2012. Occupational Health and Safety Management Systems: Institutional and Regulatory Frameworks in Zimbabwe. *International Journal of Human Resources Studies*. 2(4):99-117.

Taifa, I.W.R., and Vhora, T.N. 2019. Cycle time reduction for productivity improvement in the manufacturing industry. *Journal of Industrial Engineering and Mechanical studies (JIEMS)*. 6(2):147-164.

Takala, J., Hamalainen, P., Saarela, K.L., Yun, L.Y., Manickam, K., Jin, T.W., Heng, P., Tjong, C., Kheng, L.G., Lim, S., and Lin, G.S. 2014. Global Estimates of the Burden of Injury and Illness at Work in 2012. *Journal of Occupational and Environmental Hygiene*. 11(5):326-337.

Tappin, D.C., Bentley, T.A., and Vitalis, A. 2008. The role of contextual factors for musculoskeletal disorders in the New Zealand meat processing industry. *Ergonomics*. 51(10):1576-1593.

Tappin, D., Vitalis, A., and Bentlry, T. 2016. The application of an Industry level participatory ergonomics approach in developing MSD interventions. *Applied Ergonomics*. 52:151-159.

Tavakol, M., and Dennick, R. 2011. Making sense of Cronbach’s alpha. *International Journal of Medical Education*. 2:53-55.

Terrell, R., and Purswell, J.L. 1976. The influence of forearm and wrist orientation on static grip strength as a design criterion for hand tools. In *Proceedings of the Human Factors Society Annual Meeting*. 20(1):28-32. Sage CA: Los Angeles, CA: SAGE Publications.

Thun, J., Lehr, C.B., and Bierwirth, M. 2011. Feel free to feel comfortable - An empirical analysis of ergonomics in the German automotive industry. *International Journal Production Economics*. 133(2):551-561.

Tichauer, E.R. 1966. Some Aspects of Stress on Forearm and Hand in Industry. Journal of Occupational Medicine. 8(2):63-71.

Tirloni, A.S., Cunha dos Reis, D.C., Tirloni, S.F., and Moro, A.R.P. 2020. Exertion perception when performing cutting tasks in Poultry Slaughterhouses: Risk assessment of developing Musculoskeletal Disorders. *International Journal of Environmental Research and Public Health*. 17:9534.

Tomlinson, S., Lewis, R., and Carré, M.J. 2007. Review of the frictional properties of finger-object contact when gripping. *Proceedings of the Institution of Mechanical Engineers. Part J, Journal of Engineering Tribology*. 221(8), 841-850.

Tomoda, S. 1997. *Safety and health of meat, poultry and fish processing workers* (Vol. 104). International Labour Office, Sectoral Activities Programme, Industrial Activities Branch.

Van Dieèn, J.H., and Oude Vrielink, H.H.E. 1998. Evaluation of work-rest schedules with respect to the effects of postural workload in standing work. *Ergonomics*. 41(12):1832-1844.

Van Nieuwenhuyse, A., Somville, P.R., Crombez, G., Burdorf, A., Verbeke, G., Johannik, K., Van den Bergh, O., Masschelein, R., Mairiaux, P., and Moens, G.F. 2006. The role of physical workload and pain related fear in the development of low back pain in young workers: evidence from the BelCoBack Study; results after one year of follow up. *Occupational and Environmental Medicine.* 63(1):45-52.

Van Zyl, A.P. 1995. Handleiding vir die Abattoirbedryf. 1st ed. Place of publications. Sentraaldruk.

Vaske, J., Beaman, J., and Sponarski, C.C. 2017. Rethinking Internal Consistency in Cronbach's Alpha. *Leisure Sciences*. 39(2):163-173.

Vyas, H., Nag, A., and Nag, P. 2016. Ergonomics evaluation of user-hand tool interaction. *Work.* 53(4):745-753.

Vergara, L. G. L. and Pansera, T. R. (2012) Ergonomics analysis of the activity of boning shoulder in a pig slaughter-house in the city of Ipiranga-SC. *Work (Reading, Mass.)*. [Online]. 41(Suppl 1):703-709.

Vieira, E.R., and Kumar, S. 2004. Working Postures: A Literature Review. *Journal of Occupational Rehabilitation*. 14(2):143-159.

Walker, P., Rhubart-Berg, P., Mckenzie, S., Kelling, K., and Lawrence, R.S. 2005. Public health implications of meat production and consumption. *Public Health Nutrition*. 8(4):348–356.

Wartenberg, C., Dukic, T., Ann-Christine Falck, A., and Hallbeck, S. 2004. The effect of assembly tolerance on performance of a tape application task: A pilot study. *International Journal of Industrial Ergonomics*. 33(4):369-379.

Waters, T.R., and Dick, R.B. 2015. Evidence of health risks associated with prolonged standing at work and intervention effectiveness. *Rehabilitation Nursing.* 40(3):148-165.

Wasley, A., and Heal, A. 2018. Revealed: Shocking safety records of UK meat plants. The Bureau of Investigative Journalism. https://www.thebureauinvestigates.com/stories/2018-07-29/uk-meat-plant-injuries. [29 July 2018].

Westgaard, R.H., and Winkel, J. 1997. Ergonomic intervention research for improved musculoskeletal health: A critical review. *International Journal of Industrial Ergonomics.* 20(6):463-500.

White, C.M. 1999. Ergonomics: What is it? Clearing away the confusion. Michigan Gamma. https://www.tbp.org/pubs/Features/Su08White.pdf. [31 March 2021].

World Health Organistion (WHO). 2020. Zoonosis. https://www.who.int/news-room/fact-sheets/detail/zoonoses#. [29 October 2023].

Zadry, H.R., Dawal, S.Z., and Taha, Z. 2011. The Relation Between Upper Limb Muscle and Brain Activity in Two Precision Levels of Repetitive Light Tasks. *International Journal of Occupational Safety and Ergonomics*. 17(4):373-384.

APPENDIX A: CONSENT LETTER

Cape Peninsula University of Technology

24 February 2020

Cape Peninsula University of Technology
Faculty of Applied Sciences
PO Box 652
Cape Town 8000

Supervisor: 021 460 3199 odendaalj@cput.ac.za
Researcher: 082 905 3297 williamj@elsenburg.com

INFORMED CONSENT FOR RESEARCH: ***ERGONOMIC HAZARDS TO MEAT INSPECTORS AT SELECTED HIGH THROUGHPUT RED MEAT ABATTOIRS IN THE WESTERN CAPE***

To whom it may concern:

Introduction

This project will contribute towards a Master of Environmental Health degree at the Cape Peninsula University of Technology. The objective of this research is to conduct an analysis of the significance, the prevalence and the impact of ergonomic hazards on meat inspectors at selected high throughput red meat abattoirs in the Western Cape.

Purpose of the study

The focus of the study is to detect the presence and the prevalence of ergonomic hazards at selected high throughput abattoirs. The study aims to identify the different types of hazards present in an abattoir and to determine the impact that it may have on meat inspectors. In addition, it aims to highlight the relevance and the importance of ergonomics to a growing red meat industry and to provide regulating authorities with an opportunity to assess and improve the traditional approaches applicable to the design and development of abattoirs.

Description of the research

The research data will be collected from meat inspectors and designated abattoir representatives. Data will be collected through the use of questionnaires and interviews. The overall success of this research fundamentally depends on the honest and accurate completion of the questionnaires. The participation in this project is entirely voluntary and all the data collected will be treated with the highest degree of confidentiality.

Potential harm, injuries, discomfort and inconvenience

The research is structured in such a way that the greatest of care will be taken to protect the anonymity of participants. It is therefore expected that there should be no negative consequences to respondents. Prior to the commencement of any data collection, respondents will be notified of the fact that the research is conducted as part of an academic research initiative done solely for academic purposes. In the event where participants disclose any sensitive information, they will not face any form of reprisal, nor will their identities be made known. All the questionnaires, interviews, records of observation, notes and pictures will be treated as strictly confidential. The information and data collected will not be used for inspection purposes. In the event where non-conformances may be observed during the course of this study, it will not be used against the facility and will not result in any penalties. The projected time to complete the interviews and questionnaires will be a maximum of 30 minutes.

Potential benefits

Participants may not experience any immediate or direct benefits from taking part in this study, neither may there be any payments for their participation in the study. This thesis will be provided to the Department of Agriculture with the aim of improving the occupational health and safety environment within which abattoirs operate. This study will benefit participants in the medium to long term as the recommendations of this study is expected to effect change and be implemented over time. The researcher undertake to provide feedback to participants of this study through information sessions after the completion of this investigation.

Confidentiality

The confidentiality of participants will be respected, and the researcher undertake not to disclose any information that may reveal the identities of participants. No such information will be released or published and the records of questionnaires and interview will be coded with a number only and not a person's name. No unauthorised person will have access to the data collected.

Participation

Participation in this research is voluntary. Participants have the right not to participate without any consequences. If a participant chooses to participate in this study, he or she have the right to withdraw at any time. There may be an interpreter for the briefing session, where and if necessary, for the employees taking part in the data collection process. Participants are also informed that there are no clear cut right or wrong answers to any question or its responses. Participants will be treated anonymously. The study is anticipating the development of a platform where occupational health and safety challenges may be discussed and where feedback may be provided.

Consent

By signing this form, I agree that:

1. The study was explained to me and all my questions answered.
2. I have the right to participate and the right to stop at any time without any consequences.
3. I have been told that my personal information will be kept confidential.
4. There will be no likely harm or direct benefits to me by participating in this study.

I hereby consent to participate in this study:

Name of the participant: …………………………..……………………………

…………………………………. ……………………………….

Signature Date

Name of investigator:..……………………..…..……………………………….

………………………………… ……………………………….. Signature

Date

2

APPENDIX B: ERGON RESEARCH SCHEDULE

Cape Peninsula University of Technology

01 September 2020

Cape Peninsula University of Technology
Faculty of Applied Sciences
PO Box 652
Cape Town 8000

Supervisor: 021 460 3199 odendaalj@cput.ac.za
Researcher: 082 905 3297 williamj@elsenburg.com

RESEARCH SCHEDULE: ***ERGONOMIC HAZARDS TO MEAT INSPECTORS AT SELECTED HIGH THROUGHPUT RED MEAT ABATTOIRS IN THE WESTERN CAPE***

Abattoir	**September 2020**						
	02	**07**	**08**	**09**	**10**	**11**	**14**
H_3							
J_2							
I_3							
A_2							
E_1							
G_2							
F_2							
D_2							
B_1							
P_3	Pilot						
C_1							

APPENDIX C: QUESTIONNAIRE FOR MEAT INSPECTORS

Cape Peninsula University of Technology

Faculty of Applied Sciences

Department for Environmental Health and Occupational Studies

Tel. 021 808 7751

Fax: 021 808 5274

Researcher's e-mail: williamj@elsenburg.com

Researcher's contact no: 082 905 3297

Supervisor's e-mail: odendaalj@cput.ac.za

Supervisor's contact no.: 021 460 3199

Ergonomic hazards to meat inspectors at selected high throughput red meat abattoirs in the Western Cape.

QUESTIONNAIRE

Meat inspection personnel

INTRODUCTION

Thank you for your willingness to participate in this research project.

The aim of the study is to conduct an analysis of the significance, the prevalence and the impact of ergonomic hazards on meat inspectors at selected high throughput abattoirs in the Western Cape.

All information will be treated as confidential, and the researcher undertakes not to link any information to the respondent. The respondents will not be required to identify themselves anywhere on this questionnaire. The questionnaire will take approximately 30 minutes to complete.

Respondents may answer open ended questions in any South African language.

Researcher: Mr WN Jephtas

Supervisors: Prof. JP Odendaal

Prof. IS Human

A. Demographic and General Information

1. Please indicate your gender?

Male	1	
Female	2	1

2. Please indicate your age?

Below 25	1	
26 – 35	2	
36 – 45	3	
46 – 55	4	
56 and above	5	2

3. What is the highest level of education you obtained?

Meat Examiner Certificate (Grade 12 (matric)	1	
National Diploma	2	
B Tech Degree or Degree	3	
Postgraduate Degree	4	
other please specify: ………………………	5	3

4. What is your average physical height?

< 1,5 m	1	
1,5 – < 1,6 m	2	
1,6 – < 1,7 m	3	
1,7 – < 1,8 mm	4	
other please specify: …………………..…..	5	4

5. What is your average physical weight?

< 60 kg	1	
61 – 70 kg	2	
71 – 80 kg	3	
81 – 90 kg	4	
other please specify: ………………………	5	5

6. How many years' experience do you have in meat inspection?

< 1 years	1	
1 – 5	2	
6 – 10	3	
11 – 15	4	
16 - 20	5	
21 +	6	6

7. How many years have you been working at this abattoir?

< 1 years	1	
1 – 5	2	
6 – 10	3	
11 – 15	4	
16 +	5	7

8. What is the nature of your job?

internship (meat inspector in training)	1	
relief meat inspector	2	
permanent meat inspector	3	
supervisory meat inspector	4	
other please specify: ………………………	5	8

B. Occupational Health and Safety (OH&S) Management System

9. In your opinion, do the abattoir have an OH&S management system?

	Yes	No	Do not Know	
management system	1	2	3	9

Note: If your answer to question 9 is "No", please go to question 13!

10. In your view, do the abattoir have a designated OH&S representative?

	Yes	No	Do not Know	
health and safety representatives	1	2	3	10

11. Do you believe that the abattoir have control measures in place to prevent the occurrence of health and safety hazards?

	Yes	No	Do not Know	
control measures to prevent hazards	1	2	3	11

12. Do the abattoir have a system in place to report and address health and safety hazards?

	Yes	No	Do not Know	
reporting system	1	2	3	12

C. Occupational Health and Safety Training and Awareness

13. Subject to your opinion, do the abattoir conduct health and safety training and awareness programmes?

	Yes	No	Do not Know	
awareness and training conducted	1	2	3	13

Note: If your answer to question 13 is "No", please go to question 19!

14. If yes, how often are training and awareness conducted?

Daily	1	
Weekly	2	
Monthly	3	
Annually	4	
Never	5	14

15. Do you participate in training and awareness programmes at the abattoir?

	Yes	No
participate in awareness and training	1	2

15

Note: If your answer to question 15 is "No", please go to question 19!

16. If so, do training and awareness programmes cover the following components?

Components	Yes	No	
awkward postures	1	2	16
grip force	1	2	17
repetitive work	1	2	18
variable line speed	1	2	19
lifting	1	2	20
bending	1	2	21
vibration	1	2	22

17. Do you feel training programmes improve the overall health and safety awareness at abattoirs?

	Yes	No	Do not Know
training improve health and safety awareness	1	2	3

23

18. To what extent do you agree or disagree with the following statements?

Statements	Strongly agree	Agree	Unsure	Disagree	Strongly disagree	
Health and safety training and awareness						
... contribute to better health and safety management	1	2	3	4	5	24
... reduces health and safety risks	1	2	3	4	5	25
... enhances the reporting of health and safety hazards	1	2	3	4	5	26

D. Significance of Ergonomic Hazards

i. Meat Inspection Areas

19. Do the abattoir have dedicated areas available for the performance of meat inspection?

	Yes	No
dedicated areas for meat inspection	1	2

27

20. Do the abattoir layout make provision for the effective use of these dedicated areas?

always	1
Seldom	2
never	3

28

21. Do these areas provide sufficient floor space necessary to perform meat inspection?

always	1
Seldom	2
never	3

29

22. Do you perform your tasks at a comfortable height?

always	1
seldom	2
never	3

30

23. Are you able to keep up with the line speed or the pace of work?

always	1
seldom	2
never	3

31

24. Can you perform all the necessary tasks within the required time frames?

always	1
seldom	2
never	3

32

25. In your opinion, do you consider the number of inspectors to be sufficient for this abattoir?

always	1
seldom	2
never	3

33

26. Do you rotate between the different inspection points or different tasks?

	Yes	No
tasks rotation system	1	2

34

27. If yes, how often do you rotate between tasks or inspection points?

every 30 minutes	1
every 45 minutes	2
every 60 minutes	3
never	4

35

ii. Meat Inspection Platforms

28. Do you require working platforms to perform certain tasks?

	Yes	No
platforms necessary	1	2

36

29. Do platforms provide sufficient walk-length available to inspectors?

	Yes	No
sufficient walk-length	1	2

37

30. Do platforms make provision for height differences of individual inspectors?

	Yes	No
provision for individual height differences	1	2

38

31. Are platforms adequately distanced from the slaughter line?

	Yes	No	
adequately distanced from slaughter line	1	2	39

32. Are these platforms fitted with side rails?

	Yes	No	
fitted with side rails	1	2	40

33. Please indicate, if in your opinion these platforms are safe and comfortable to work on?

	Yes	No	
are platforms safe to work on	1	2	41

iii. Hand Tools for meat inspectors

34. Do you have an adequate set of hand tools to perform your duties?

	Yes	No	
adequate set of hand tools	1	2	42

35. If no, please give a description of the type of tools that are inadequate:

....

....

43

36. How often do you make use of hand tools in the day to day performance of your duties?

all day	1	
most of the day	2	
seldom	3	44

37. In your opinion, are hand tools well designed to provide a comfortable grip?

	Yes	No	
well designed for a comfortable grip	1	2	45

38. Do you reckon that "handle design" could impact on the type of grip that are being used?

	Yes	No	
handle design impact on type of grip used	1	2	46

39. In your view, do you believe that "handle design" could impact on the strength of the grip used?

	Yes	No	
handle design impact on grip strength	1	2	47

40. Do you feel that "knife sharpness" may affect the extent to which you perform your tasks?

	Yes	No	
knife sharpness affect task performance	1	2	48

41. Please indicate type and size of knife you use in performing meat inspection?

Knife type & size	Straight boning knife (12.7 cm)	Curved boning knife (12.7 cm)	Beef skinning knife (15.24 cm)	Butchers knife(25.4 cm)
	 **1**	 **2**	 **3**	 **4**

49

iv. Body Posture while doing meat inspection

42. Do you have to stretch or reach to perform certain tasks?

always	1
Seldom	2
never	3

50

43. Do you perform certain tasks with arms in an elevated position (above the shoulders)?

	1
Seldom	2
never	3

51

44. Are you required to perform certain tasks bending forward?

always	1
Seldom	2
never	3

52

v. Repetitive Work while doing meat inspection

45. Do you have to repeat a series of tasks when doing meat inspection?

always	1
Seldom	2
never	3

53

46. If yes, are these standard tasks?

	Yes	**No**
tasks prescribed	1	2

54

vi. Working Conditions of meat inspectors

47. Please specify which of the following actions may be closely associated with your daily working activities?(NB!!! You can select more than one)

Repetitive work	1
Hand grip (gripping of hand tools)	2
Working with arms in elevated positions	3
Overreaching or stretching	4
Variable line speeds	5
Bending actions (neck and spine activity)	6
Vibration (working platforms or surfaces)	7
Lifting of products	8
other please specify: …………………………………………………………………	9

55

48. Please indicate if any of the following may apply to the nature of your work (NB!!! You can select more than one):

Physically demanding tasks	1	
Long hours	2	
No rest or recovery breaks	3	
No rotation between tasks	4	
Awkward stance or working positions	5	
Highly paced activities	6	
other please specify: ………………………………………………………………	7	56

49. Did you ever, for a prolonged period of time, experience any of the following discomfort during the course of your work as a meat inspector (NB!!! You can select more than one):

	Yes	No	
neck	1	2	57
Back	1	2	58
Shoulders	1	2	59
Wrist	1	2	60
hand	1	2	61
other please specify: ……….	1	2	62

E. Common Approaches to Ergonomics and OH&S

50. Please respond to the following statement:

Statement	Yes	No	
I know whom to report health and safety hazards to.	1	2	63

51. Please indicate to whom you report health and safety hazards to? (NB!!! You may select more than one)

supervisory meat inspector	1	
abattoir line manager	2	
employer	3	
Departmental officials (Agriculture)	4	
other please specify: ………………………	5	64

52. Please answer the following question:

	Yes	No	
Did you ever identify and reported occupational health and safety hazards at the abattoir?	1	2	65

53. Please specify which of the following statements are True or False.

Statement	True	False	
I have an understanding of the field of ergonomics	1	2	66
Reducing ergonomics hazards at the abattoir is important	1	2	67
Ergonomic hazards outside my scope of work is my concern.	1	2	68
Ergonomic principles applies to tool and equipment design	1	2	69

54. To what extent do you agree or disagree with the following statement?

Statement	Strongly agree	Agree	Unsure	Disagree	Strongly disagree	
Training conducted is relevant to the field of ergonomics	1	2	3	4	5	70

F. Attitudes towards Ergonomics

55. Please answer the following questions.

Questions	Yes	No	Do not Know	
Do you think the field of ergonomics is concerned with people and their work?	1	2	3	71
Do you think that workspace and equipment design are key elements in terms of ergonomics?	1	2	3	72
Do you think that the principles of ergonomics could be incorporated into the initial planning and design of abattoirs?	1	2	3	73

Remember No, Names [should appear on this form; everyone should remain anonymous]

Thank You

APPENDIX D: QUESTIONNAIRE FOR SUPERVISORS OR MANAGERS

Cape Peninsula University of Technology
Faculty of Applied Sciences
Department for Environmental Health and Occupational Studies
Tel. 021 808 7751

Fax: 021 808 5274

Researcher's e-mail: williamj@elsenburg.com

Researcher's contact no: 082 905 3297

Supervisor's e-mail: odendaalj@cput.ac.za

Supervisor's contact no.: 021 460 3199

Ergonomic hazards to meat inspectors at selected high throughput red meat abattoirs in the Western Cape

QUESTIONNAIRE

Abattoir Managerial Employees (Supervisors, Managers, Technical Advisors)

INTRODUCTION

Thank you for your willingness to participate in this research project.

The aim of the study is to conduct an analysis of the significance, the prevalence and the impact of ergonomic hazards to meat inspectors at selected high throughput abattoirs in the Western Cape.

All information will be treated as confidential, and the researcher undertakes not to link any information to the respondent. The respondents will not be required to identify themselves anywhere on this questionnaire. The questionnaire will take approximately 30 minutes to complete.

Respondents may answer open ended questions in any South African language.

Researcher: Mr WN Jephtas

Supervisors: Prof. JP Odendaal

Prof. IS Human

A. Demographic and General Information

1. Please indicate your gender?

Male	1	
Female	2	1

2. Please indicate your age?

Below 25	1	
26 – 35	2	
36 – 45	3	
46 – 55	4	
56 and above	5	2

3. What is the highest level of education you obtained?

Grade 12 (matric)	1	
National Diploma	2	
Degree or B Tech Degree	3	
Postgrad Degree	4	
other please specify: ……………………….	5	3

4. Please specify in which section you are working (at the abattoir)

Production (slaughter floor)	1	
Maintenance	2	
marketing and sales	3	
Management	4	
other please specify: ……………………….	5	4

5. How many years' experience do you have in your field of work?

< 1 years	1	
1 – 5	2	
6 – 10	3	
11 – 15	4	
16 - 20	5	
21 +	6	5

6. How many years have you been working at this abattoir?

< 1 years	1	
1 – 5	2	
6 – 10	3	
11 – 15	4	
16 +	5	6

7. What is the nature of your job?

supervisor	1	
manager	2	
consultant	3	
owner	4	
other please specify: ……………………….	5	7

B. Occupational Health and Safety (OH&S) Management System

8. Do the abattoir have an OH&S management system?

	Yes	No	Do not Know	
management system	1	2	3	8

Note: If your answer to question 08 is "No", please go to question 12!

9. If yes, is the system supported by an appropriate health and safety policy?

	Yes	No	Do not Know	
system supported by policy	1	2	3	9

10. Would you say that the health and safety policy is clearly defined?

	Yes	No	Do not Know	
policy defined	1	2	3	10

11. Is the health and safety policy clearly displayed in the workplace?

	Yes	No	Do not Know	
policy displayed	1	2	3	11

12. Do the abattoir have a designated health and safety representative?

	Yes	No	Do not Know	
health and safety representative	1	2	3	12

13. Is OH&S an essential part of the abattoir and are health and safety inspections conducted?

	Yes	No	Do not Know	
inspections conducted	1	2	3	13

14. If yes, how often are these inspections done?

daily	1	
weekly	2	
monthly	3	
annually	4	
never	5	14

15. Do control measures exist to prevent the occurrence of health and safety hazards?

	Yes	No	Do not Know	
control measures in place	1	2	3	15

16. Do the abattoir have a system in place to report and address health and safety hazards?

	Yes	No	Do not Know	
reporting system in place	1	2	3	16

C. Occupational Health and Safety Training and Awareness

17. Do the abattoir have a health and safety training and awareness programme?

	Yes	No	Do not Know	
health and safety programme in place	1	2	3	17

18. Are regular health and safety training and awareness sessions conducted?

	Yes	No	Do not Know	
awareness and training conducted	1	2	3	18

19. If yes, please indicate how often training and awareness sessions are conducted?

Daily	1	
Weekly	2	
Monthly	3	
Annually	4	
Never	5	19

20. Do the training and awareness programme cover the following:

Components	Yes	No	
awkward postures	1	2	20
grip force	1	2	21
repetitive work	1	2	22
variable line speed	1	2	23
lifting	1	2	24
bending	1	2	25
vibration	1	2	26

21. Do you think the training programmes improve health and safety awareness at the abattoir

	Yes	No	Do not Know	
improve health and safety awareness	1	2	3	27

22. To what extent do you agree or disagree with the following statements?

Statements	Strongly agree	Agree	Unsure	Disagree	Strongly disagree	
Health and safety training and awareness ……						
… contribute to better health and safety management	1	2	3	4	5	28
… reduces health and safety risks	1	2	3	4	5	29
… enhances the reporting of hazards	1	2	3	4	5	30

D. Significance of Ergonomic Hazards

i. Meat Inspection Areas

23. Do the abattoir layout make provision for designated meat inspection areas?

	Yes	No	
designated areas for meat inspection	1	2	31

24. If so, are these areas clearly identified on the slaughter floor?

	Yes	No	
inspection areas clearly identifiable	1	2	32

25. Do the meat inspection areas provide sufficient floor space to meat inspectors?

	Yes	No	
sufficient floor space for meat inspection	1	2	33

26. Can these areas (mentioned in 23) accommodate more than one inspector at a time?

	Yes	No	
accommodate more than 1 inspector at a time	1	2	34

ii. Meat Inspection Platforms

27. In your view, do you think inspectors may require working platforms to perform certain tasks?

	Yes	No	
platforms necessary	1	2	35

Note: If your answer to question 27 is "No", please go to question 31!

28. Do platforms make provision for height differences of individual inspectors?

	Yes	No	
provide for height difference of inspectors	1	2	36

29. Are platforms fitted with side rails?

	Yes	No	
platforms fitted with side rails	1	2	37

30. Do platforms allow for sufficient workspace for inspectors?

	Yes	No	
sufficient working space for inspectors	1	2	38

iii. Hand Tools for meat inspectors

31. In your view, inspectors require a specific and adequate set of hand tools to perform certain tasks?

	Yes	No	Do not Know	
specific and adequate set of hand tools	1	2	3	39

Note: If your answer to question 31 is "No", please go to question 34!

32. In your opinion, do you think that these hand tools are well designed?

	Yes	No	Do not Know	
hand tools well designed & comfortable to use	1	2	3	40

33. Do you believe that these hand tools allows for a comfortable grip?

	Yes	No	Do not Know	
hand tool allow for comfortable grip	1	2	3	41

iv. Body Postures while doing meat inspection

34. In your view, do you suppose that inspectors have to stretch or reach to perform certain tasks?

always	1	
Seldom	2	
never	3	42

35. Based on your judgement, do you think that inspectors perform certain tasks with their arms in an elevated position (above the shoulders)?

always	1	
Seldom	2	
never	3	43

36. Do you think that inspectors may perform tasks that require them to bend forward?

always	1	
Seldom	2	
never	3	44

v. Repetitive Work while doing meat inspection

37. Do meat inspectors have to repeat a series of tasks when doing meat inspection?

	Yes	No	Do not Know	
meat inspector repeat series of tasks	1	2	3	45

38. If yes, are these standard tasks?

	Yes	No	Do not Know	
repeat series of standard tasks	1	2	3	46

vi. Working Conditions of meat inspectors

39. Please specify which of the following actions may be part of the daily working activities of meat inspectors (may select more than one)?

Repetitive work	1	
Hand grip (gripping of hand tools)	2	
Working with arms in elevated positions	3	
Overreaching or stretching	4	
Variable line speeds	5	
Bending actions (neck and spine activity)	6	
Vibration (working platforms or surfaces)	7	
Lifting of products	8	
other please specify: …………………………………………………………	9	47

40. Please indicate if any of the following may apply to the work of meat inspectors:

Physically demanding tasks	1	
Long hours	2	
No rest or recovery breaks	3	
No rotation between tasks	4	
Awkward stance	5	
Highly paced activities	6	
other please specify: …………………………………………………………	7	48

41. Did you ever receive complaints from inspectors who experienced any form of discomfort in the following areas? (NB!!! You may select more than one)

	Yes	No	
neck	1	2	49
Back	1	2	50
Shoulders	1	2	51
Wrist	1	2	52
hand	1	2	53
other please specify: …….	1	2	54

42. Do the abattoir have a procedure to for the handling of complaints?

	Yes	No	Do not Know	
do procedure exist for handling complaints	1	2	3	55

43. If yes, please describe the procedure

………………………………………………………………………………………………	
………………………………………………………………………………………………	56

E. Common Approaches to Ergonomics and OH&S

44. Please answer the following questions:

	Yes	No	
Did meat inspectors ever identify and report occupational health and safety hazards at the abattoir?	1	2	57

45. To what extent do you agree or disagree with the following statement?

Statement	Strongly agree	Agree	Unsure	Disagree	Strongly disagree	
OH&S at the abattoir includes ergonomic hazards.	1	2	3	4	5	58

46. Please specify which of the following statements are True or False.

Statement	True	False	
I have an understanding of the field of ergonomics	1	2	59
Reducing ergonomics hazards, at the abattoir, is important	1	2	60
Ergonomic principles applies to tool and equipment design	1	2	61

47. To what extent do you agree or disagree with the following statement?

Statement	Strongly agree	Agree	Unsure	Disagree	Strongly disagree	
Training conducted is relevant to the field of ergonomics	1	2	3	4	5	62

F. Attitudes towards Ergonomics

48. Please answer the following questions.

Questions	Yes	No	Do not Know	
Do you think the field of ergonomics is concerned with people and their work?	1	2	3	63
Do you think that workspace and equipment design are key elements in terms of ergonomics?	1	2	3	64
Do you think that the principles of ergonomics could be incorporated into the initial planning and design of abattoirs?	1	2	3	65

Remember No, Names [should appear on this form; everyone should remain anonymous]

Thank You

APPENDIX E: SEMI-STRUCTURED INTERVIEW SCHEDULE

Cape Peninsula University of Technology

Faculty of Applied Sciences

Department for Environmental Health and Occupational Studies

Tel. 021 808 7751

Fax: 021 808 5274

Researcher's e-mail: williamj@elsenburg.com

Researcher's contact no: 082 905 3297

Supervisor's e-mail: odendaalj@cput.ac.za

Supervisor's contact no.: 021 460 3199

Ergonomic hazards to meat inspectors at selected high throughput red meat abattoirs in the Western Cape.

INTERVIEW QUESTIONS

Government and Meat Inspection Service Providers

INTRODUCTION

Thank you for your willingness to participate in this research project. The aim of the study is to undertake an analysis of the significance, the prevalence and the impact of ergonomic hazards on meat inspection personnel at selected high throughput abattoirs in the Western Cape. All information will be treated as confidential, and the researcher undertakes not to link any information to the respondent. The respondents will not be required to identify themselves anywhere on this questionnaire. The questionnaire will take approximately 30 minutes to complete. Respondents may answer open ended questions in any South African language.

Researcher: Mr WN Jephtas

Supervisors: Prof. JP Odendaal

Prof. IS Human

OH&S and Ergonomics – its role, importance, context *(points B)*

1. Do you think there is a clear understanding of what constitutes occupational health and safety at abattoirs in the Western Cape?

	Yes	No	Don't Know
Is there a clear understanding of OH&S	1	2	3

1

2. Do abattoirs make adequate provision for incorporating the principles of ergonomics into the work environment of meat inspectors?

	Yes	No	Don't Know
Ergonomics incorporated into work environment	1	2	3

2

Work Environment – physical elements, factors affecting design and layout *(point D)*

3. In your opinion, do you believe that the design and layout of high throughput red meat abattoirs make provision for different meat inspection areas?

	Yes	No	Don't Know
Provision for different meat inspection areas	1	2	3

3

4. In your view, do you think that meat inspectors have sufficient floor space available to perform meat inspection duties?

	Yes	No	Don't Know
Meat inspectors have sufficient floor space	1	2	3

4

Workload and Patterns – operations, breaks, long hours *(points E, F)*

5. Do you think that meat inspectors operate within a highly paced work environment?

	Yes	No	Don't Know
Meat inspectors work in highly paced environment	1	2	3

5

6. Do meat inspectors perform physically demanding work that is associated with long hours?

	Yes	No	Don't Know
Physically demanding work with long hours	1	2	3

6

Monitoring and Reporting – awareness, occurrence, and prevention *(point B, C)*

7. Do abattoirs have a system in place to accommodate for the reporting of ergonomic hazards by meat inspectors?

	Yes	No	Don't Know
System in place for reporting of hazards	1	2	3

7

8. In your view, are ergonomic hazards to meat inspectors adequately monitored at abattoirs?

	Yes	No	Don't Know
Are ergonomic hazards adequately monitored	1	2	3

8

9. Do you think abattoirs take sufficient steps to prevent the occurrence or re-occurrence of ergonomic hazards to meat inspectors?

	Yes	No	Don't Know
Steps taken to prevent occurrence of hazards	1	2	3

9

Liability

10. In your opinion, do you think that abattoirs have taken sufficient steps to reduce their potential liability to the impact of ergonomic hazards?

	Yes	No	Don't Know
Steps to reduce liability to impact of hazards	1	2	3

10

Remember No, Names [should appear on this form; everyone should remain anonymous]

Thank You

APPENDIX F: DEPARTMENTAL APPROVAL LETTER

Western Cape Government
Agriculture

Dr G Msiza
Veterinary Services
Email: [illegible]@elsenburg.com
tel: +27 21 808 5001 fax +27 21 808 7612

REFERENCE: 3/2/1/2/4

ENQUIRIES: Dr G Msiza

HEAD OF DEPARTMENT:

MS JS ISAACS

DEPARTMENT OF AGRICULTURE: WESTERN CAPE: PROGRAMME: VETERINARY SERVICES: SUB DIRECTORATE: FOOD SAFETY: RESEARCH PROJECT OF MR. WN. JEPHTAS - ERGONOMIC HAZARDS TO MEAT INSPECTORS AT SELECTED HIGH THROUGHPUT RED MEAT ABATTOIRS IN THE WESTERN CAPE; PERSAL NUMBER: 53882393

1. PURPOSE

To obtain permission to conduct an investigation into the significance, the prevalence and the impact of ergonomic hazards on meat inspectors at selected high throughput red meat abattoirs.

2. MOTIVATION

Mr Jephtas, a Departmental bursary holder is currently registered to complete his Master of Environmental Health at the Cape Peninsula University of Technology. The purpose of the study is to determine and assess the type of ergonomic hazards that may be present in the working environment of meat inspectors. Facilities included in this research will present the project with the best possible outline of the current state of occupational health and safety at red meat abattoirs. In essence the aim of the study is to create an enabling environment to guide and inform the formation of a suitable policy framework for addressing ergonomic hazards in the red meat industry.

3. PERSONNEL IMPLICATIONS

It is envisaged that this study will not have any negative personnel implications.

DEPARTMENT OF AGRICULTURE: WESTERN CAPE: PROGRAMME: VETERINARY SERVICES: SUB DIRECTORATE: FOOD SAFETY: RESEARCH PROJECT OF MR. WN. JEPHTAS – ERGONOMIC HAZARDS TO MEAT INSPECTORS AT SELECTED HIGH THROUGHPUT RED MEAT ABATTOIRS IN THE WESTERN CAPE; PERSAL NUMBER: 53882393

3. FINANCIAL IMPLICATIONS

The estimated amounts are as follows:

Item	**Amount**
Printing of questionnaires:	R1 235
Transport/Travelling Costs	R6 000
Network connectivity	R300
Accommodation	R1 400
Compiling of information	R2 000
TOTAL ESTIMATE	R10 935

Funds are available under the following item:

Segment Details	
Fund	**Voted fund -047**
Objective	**30121 : Veterinary Public Health**
Responsibility	**30155: Stellenbosch 4.3**
Project	**No project related** **18-047**
Item	**Bursaries (Employees): 1453**
Amount	**R10 935**

4. RECOMMENDATION

In view of the above, it is therefore recommended that an in principle approval for this request be granted.

.... 17·01·2020

DR G MSIZA **DATE**
CHIEF DIRECTOR: VETERINARY SERVICES

DEPARTMENT OF AGRICULTURE: WESTERN CAPE: PROGRAMME: VETERINARY SERVICES: SUB DIRECTORATE: FOOD SAFETY: RESEARCH PROJECT OF MR. WN. JEPHTAS – ERGONOMIC HAZARDS TO MEAT INSPECTORS AT SELECTED HIGH THROUGHPUT RED MEAT ABATTOIRS IN THE WESTERN CAPE; PERSAL NUMBER: 53882393

The funds are budgeted.

D. C. Zana 20/01/2020

MS D ZANA **DATE**

MANAGER: MANAGEMENT ACCOUNTING

~~Recommended / Not Recommended~~ Supported with comments: A request should be submitted rather to increase the current bursary to include this costs.

.... 2020/01/28

MRS R WENTZEL **DATE**

DIRECTOR: OPERATIONAL SUPPORT SERVICES

"I, the undersigned, do hereby certify that I have evaluated the submission and that I can advise the accounting officer that the application/request satisfies the following requirements:

I. it complies with the relevant prescriptions;
II. it can be accommodated within the approved budget framework;
III. it supports the attainment of the department's tabled strategic objectives and budget programmes; and
IV. the submission is therefore in order."

Additional comments: agree with the above suggestion

.... 28/01/2020

MR FJJ HUYSAMER **DATE**

CHIEF FINANCIAL OFFICER

DEPARTMENT OF AGRICULTURE: WESTERN CAPE: PROGRAMME: VETERINARY SERVICES: SUB DIRECTORATE: FOOD SAFETY: RESEARCH PROJECT OF MR. WN. JEPHTAS – ERGONOMIC HAZARDS TO MEAT INSPECTORS AT SELECTED HIGH THROUGHPUT RED MEAT ABATTOIRS IN THE WESTERN CAPE; PERSAL NUMBER: 53882393

Approved/ ~~not approved~~ with comments

.... 29/1/2020

MS JS ISAACS **DATE**

HEAD OF DEPARTMENT AGRICULTURE

APPENDIX G: CPUT ETHICS APPROVAL LETTER

Cape Peninsula University of Technology

Statement of Permission

Data/Sample collection permission is required for this study.

Reference no.	189040890/04/2020
Surname & name	Jephtas, W.N.
Student Number	189040890
Degree	Master of Environmental Health
Title	Ergonomic hazards to meat inspectors at selected high throughput red meat abattoirs in the Western Cape, South Africa
Supervisor(s)	PROF JAMES PHILANDER ODENDAAL
FRC Signature	
Date	2020 April 27

Cape Peninsula University of Technology

P.O. Box 1906 · Bellville 7535 South Africa ·Tel: +27 21 953 8677 (Bellville), +27 21 460 4213 (Cape Town)

Ethics Approval Letter **Reference no:** 189040890/04/2020

Office of the Chairperson **Research Ethics Committee**	**Faculty of Applied Sciences**

On 27 April 2020, the Faculty Research Ethics Committee of the Faculty of Applied Sciences granted ethics approval to Jephtas, W.N. for research activities related to a project to be undertaken for a degree (Master of Environmental Health) at the Cape Peninsula University of Technology.

Title of project:	Ergonomic hazards to meat inspectors at selected high throughput red meat abattoirs in the Western Cape, South Africa

Comments (Add any further comments deemed necessary, e.g., permission required)

1. Human subjects are included in the proposed study.
2. This permission is granted for the duration of the study.
3. Research activities are restricted to those detailed in the research proposal.
4. The research team must comply with conditions outlined in AppSci/ASFREC/2015/1.1 v1, CODE OF ETHICS, ETHICAL VALUES AND GUIDELINES FOR RESEARCHERS.

Signed: Chairperson: Research Ethics Committee	**27/04/2020** **Date**

APPENDIX H: ASSESSMENT OF WORK ENVIRONMENT FOR MEAT INSPECTORS DURING SHEEP SLAUGHTER

Assessment of the work environment of meat inspectors during sheep slaughter	
Abattoir	**Dimensions and comments**
D_2	**Sheep| automated line:** dressing line height of 2.420 m, estimated ground clearance (distance measured from lowest part of carcass, .i.e., fore-legs, to the floor level) of approximately 1.100 m measured, varied depending on carcass length, might be less if bigger carcasses processed (presented for slaughter), area available for inspection measured 3.300 m (l) x 1.200 m (w) = 3.960 m^2. **Red offal:** hung on hooks and presented for inspection, hooks measured 1.500 m above ground level (from the bottom of the hook to ground level), height measured from bottom of red offal to floor level 1.250 m, total floor space available for inspection measured 2.000 m (l) x 0.600 m (w) = 1.200 m^2. **Rough offal:** placed chute and subjected to meat inspection, chute 2.700 m in length and 0.470 m wide, two measurements taken at different points, to determine height of chute, measurements 1.100 m at highest point and 1.050 m at a lower point. **NB!!! Work cycle times measured at different inspection points was approximately 15 seconds per inspection activity.**
I_3	**Sheep| carcass and red offal:** dressing line height of 2.300 m, approximate carcass length measured 1,220 m, no ground clearance including gambrel measurements recorded, dimensions of gambrels estimated 0.750 m ground clearance of approximately 0.330 m calculated (carcass length of 1.220 m + hook length of 0.750 m (gambrel hooks vary in dimensions) = 1.970 m), inspectors required to conduct red offal inspection at same point where final carcass inspections conducted, area available for inspection measured 1.400 m (l) x 1.100 m (w) = 1.540 m^2. **Red offal:** no dedicated inspection area, carcass and red offal inspection carried out at same point. **Rough offal:** conveyor table, 1.100 m highest point, 1.080 m at lowest point. **NB!!! Work cycle times measured at different inspection points was between 15 to 20 seconds per inspection activity.**
J_2	**Sheep| carcass:** dressing line height of 2.200 m, approximate carcass length of 1.150 m, ground clearance of approximately 0.670 m calculated (carcass length of 1.150 m + hook length of 0.380 m used at abattoir = 1.530 m, to be subtracted from line height of 2.200 m), area measured 2.600 m (l) x 1.450 m (w) = 3.770 m^2, length measured in the direction of carcass flow and width measured perpendicular to direction of carcass flow from wall to dressing line. **Red offal:** hung on hooks and presented for inspection, unit had two layers for hanging red offal, top row of hooks measured 1.550 m in height, bottom row measured 0.650 m in height from ground level, hooks measured 0.400 m in length. **NB!!! Work cycle times measured at different inspection points was approximately 15 seconds per inspection activity.**

APPENDIX I: ASSESSMENT OF WORK ENVIRONMENT FOR MEAT INSPECTORS DURING CATTLE SLAUGHTER

Assessment of the work environment of meat inspectors during cattle slaughter	
Abattoir	**Dimensions and comments**
A_2	**Cattle| carcass inspection:** height of platform measured 1.600 m (from ground level), fitted with rails around the back and across the one side of the platform (diagram to be provided), measured approximately 1.150 m high, platform working surface at top, measured 0.460 m (l) x 0.860 m (w) = 0.396 m^2, supported by three steps, each measuring 0.460 m (l) x 0.860 m (w) and 0.380 m in height apart from each other. **Cattle head inspection:** heads hung on hooks on rail, mounted to wall approximately 1.685 m high, hung on roller measured 0.420 m in length, inspection performed at height of 1.265 m above the ground level, dimensions of area measured 2.100 m (l) x 1.400 m (w) = 2.940 m^2, length of area measured from wall on one side, parallel to direction of carcass flow and to edge of rail at other end, width of area measured perpendicular to direction of carcass flow from wall to edge of drainage channel. **Rough offal inspection:** presented for inspection on t-shaped conveyor table, dimensions of conveyor table measured at three different points: (a) start - 1.780 m (l) x 0.580 m (w) at a height of 0.780 m; (b) middle – 1.810 m (l) x 0.580 m (w) at a height of 0.770 m; (c) end – 1.860 m (l) x 0.580 m (w) at a height of 0.780 m, rough offal placed in plastic containers, moved on conveyor table to relevant room for further processing, dimensions of containers not measured. **Red offal inspection area** measured at 6.000 m (l) x 1.400 m (w) = 8.400 m^2, hung on hooks on rail, at same height as height of sheep dressing line i.e. 2.350 m (from bottom of rail), hooks measured about 0.270 m in length, offal hung at an approximate height of 2.030 m above ground level, length of red offal not measured, no measurements of estimated ground clearances recorded. **NB!!! Work cycle times measured at different inspection points was between 15 to 30 seconds per inspection activity.**
F_2	**Cattle| red offal** hung on sheep cradles, measured 1.700 m from horizontal bar to ground level, length of hooks on cradle not measured, distance from lowest part of red offal to ground level measured 0.200 m. **Rough offal:** placed on chute slightly sloped towards rough offal room, length of chute not measured, width of chute measured 0.800 m, height of chute measured at two points: (a) front of chute at 1.022 m high, (b) entrance to rough offal room height measured 1.000 m. **Cattle head inspection:** placed on a fixed platform, tongues removed, hung on hooks on rail, hooks used for hanging tongues measured 0.200 m in length, tongue measured 0.700 m in length, examination of heads conducted on platform, dimension of platform not measured, area in front of platform measured 2.900 m (l) x 1.500 m (w) = 4.350 m^2, length measured parallel to direction of carcass flow, width measured perpendicular to direction of carcass flow. **Carcasses:** platform equipped with working surface measured 1.300 m (l) x 0.810 m (w) = 1.053 m^2, height of platform measured 0.790 in front, 0.810 at the back, fitted with two steps, first step measured 0.300 m above ground level, the second step measured 0.250 m above the first, platform 0.250 m above second step. **NB!!! Work cycle times measured at different inspection points was between 15 to 65 seconds per inspection activity.**

G_2	**Cattle| head inspection:** hung on sheep gambrels (used in sheep dressing) on sheep dressing line, sheep gambrel measured 0.430 m in length, area measured 2.000 m (l) x 0.900 m (w) = 1.800 m^2, inspection of tongues not observed, sheep rail 2.300 m. **Red offal:** hung on sheep cradle, no measurements of height or ground clearances recorded. **Rough offal:** placed on chute sloped rough offal room, length of chute not measured, width of chute measured 0.900 m, height of chute measured 1.100 m. **Carcass inspection:** used platform equipped with two working surfaces, each fitted at different levels, first surface measured 0.720 m above ground level, consisted of two steps, each measured 0.200 m apart, dimensions of first surface measured 0.830 m (l) x 0.630 m (w) = 0.523 m^2, second platform fitted two steps, leading from first level and 0.200 m apart, dimensions of second surface measured 0.830 m (l) x 0.630 m (w) = 0.523 m^2, final height of platform measured 1.240 m above ground level. **NB!!! Work cycle times measured at different inspection points was between 15 to 50 seconds per inspection activity.**
I_3	**Cattle| head inspection:** hanged on hooks measuring 1.170 m to 1.200 m in length, hung on sheep dressing line, area measured 2.900 m (l) x 1.450 m (w) = 4.210 m^2, inspection of tongues not observed. **Red offal:** hung on hooks on sheep dressing line, hooks measured 0.350 m in length, area measured 1.400 m (l) x 1.450 m (w) = 2.030 m^2, no further measurements of height or ground clearance recorded. **Rough offal:** placed on chute sloped towards rough offal room, length of chute not measured, width of chute measured at three different points: 1.020 m (w); 0.970 m (w) and 0.830 m (w), height of chute measured two different points: (a) start - 1.100 m (h); (b) middle – 1.080 m (h); **Carcass inspection:** platform equipped with three working surfaces, fitted at different height levels, first surface measured 0.620 m above ground level, second surface 0.220 m above first surface, third surface 0.400 m above second surface, platform fitted with steps with first step 0.340 m above ground level, second step approximately 0.250 m above first step, two steps 0.200 m apart, dimensions of first platform 0.830 m (l) x 0.630 m (w) = 0.523 m^2, second platform fitted with two steps leading up from first platform surface also 0.200 m apart, dimensions of second platform measured 0.830 m (l) x 0.630 m (w) = 0.523 m^2, final height of platform measured 1.240 m above ground level. **NB!!! Work cycle times measured at different inspection points was between 15 to 35 seconds per inspection activity.**

APPENDIX J: ASSESSENT OF WORK ENVIRONMENT FOR MEAT INSPECTORS DURING PIG SLAUGHTER

Assessment of the work environment of meat inspectors during pig slaughter	
Abattoir	**Dimensions and comments**
B_1	**Pigs| rail height:** rail to floor 3.000 m. **Carcass inspection:** height of the platform measured 1.030 m (from ground level), fitted with rails around the back and across the one side of the platform, platform provided a working surface at the top that measured 2.880 m (l) x 0.800 m (w) = 2.304 m^2, supported by four steps, first step was 0.230 m above ground level, second step was 0.170 m above the first, the third step was 0.350 m above the second and the fourth step was 0.350 m above the third. **Head inspection:** provided with two portable stands each with following dimensions – 1.560 m (l) x 0.760 m (w) = 1.186 m^2 with a height of 0.230 m above ground level, not all inspectors used platforms, approximate height at which meat inspection of the head was performed calculated as 0.780 m high (3.000 m rail height – 1.800 m average carcass length – 0.420 m roller = 0.780 m), heights varied subject to size of carcass, approximate height affected by height of inspector, available floor space at head inspection area measured 0.800 m between the wall and the carcass. **Red and rough offal:** conveyor pan system – 12.340 m (l) x 0.850 m (w) x 0.945 m (h), portable stand 12.340 m (l) x 0.500 m (w)0.350 m (h), area measured 12.340 m x 0.900 m = 11.106 m^2. **NB!!! Work cycle times measured at different inspection points was between 13 to 15 seconds per inspection activity.**
C_1	**Final carcass inspection:** no measurements recorded of distances between lowest part of carcass and ground level, final inspection of carcasses conducted (platform provided not used), dimensions of platform not measured. **Head inspection**: area provided, no measurements taken or recorded. **Red and rough offal:** facilities provided, no measurements taken. **NB!!! Work cycle times measured at different inspection points was between 13 to 15 seconds per inspection activity.**
E_1	**Pigs| head inspection:** area provided, measured 3.500 m (l) x 1.800 m (w) = 6.300 m^2, length of area measured in direction of carcass flow and width measured from wall perpendicular to carcass flow to edge of drainage channel. **Carcass inspection:** no measurements recorded of distances between lowest part of carcass and ground level, final inspection of carcasses conducted using platform, platform comprised of two working surfaces, height of highest working surface measured 1.200 m (from ground level – 1.310 m – 0.110 m = 1.200 m), height of lowest surface measured 0.610 m (0.720 m – 0.110 m = 0.610 m), platform fitted with rails (1.065 m high) around the back and across one side of platform, supported with two steps leading to each surface, first step 0.240 m above ground level, second step 0.200 m above first, first working surface 0.200 m above second step, first step (leading to the second surface) 0.220 m above first surface, second step 0.200 m above first step, second surface 0.200 above second step. **Red offal:** hanged onto triangular frame for inspection, frame measured 1.800 m high, length 2.000 m, bottom width 1.150 m, offal hung on hooks measuring 0.220 m in length, frame supported by two-step portable stand measured 0.340 m (l) x 0.540 m (w) = 0.184 m^2, height dimensions not recorded. **Rough offal:** intestines removed, placed into chute, no length measurements recorded, height measurements taken at three different points: start – 1.120 m; middle – 1.080 m and at the end - 1.110 m, reaching distance of inspector measured halfway across chute to distance 0.500 m. **NB!!! Work cycle times measured at different inspection points was between 10 to 15 seconds per inspection activity.**

H_3	**Pigs| carcass inspection:** rail clearance - 3.400 m, no measurements recorded of distances between lowest part of carcass and ground level, carcasses hung on chain measuring 1.150 m in length, final inspection conducted without use of platform, subtracting chain length from rail height provide estimated height of height tasks may be performed (3.400 m – 1.150 m = 2.250 m – 1.800 m = 0.450 m (ground clearance for a carcass of 1.800 m in length), ground clearance could be reduced if size of carcasses increased. **Head inspection**: conducted along slaughter line, no dedicated areas observed, no area measurement recorded. **Red offal:** removed from carcass, inspection procedures not observed, no measurements recorded. **Rough offal:** placed into a chute measured 1.750 m in length, chute 0.890 m wide and 0.940 m high. **NB!!! Work cycle times measured at different inspection points was between 10 to 15 seconds per inspection activity.**
I_3	**Pig| Carcass inspection area:** 2.300 m (l) x 0.800 m (w) = 1.840 m^2, carcasses hung on chains 0.840 m and 0.900 m in length, no measurements recorded of distances between lowest part of carcass and ground level, carcasses hung on chain measuring 0.840 m and 0.900 m in length, final inspection of carcasses conducted without use of platform, subtracting chain length from rail height provide estimated height of height at which tasks be performed (3.400 m – 0.840 m = 2.560 m – 1.800 m = 0.760 m ground clearance for a carcass of 1.800 m in length, second chain of 0.900, then 3.400 m – 0.900 m = 2.500 m – 1.800 m = 0.700 m ground clearance for carcass of 1.800 m), ground clearance reduced if size of carcasses increased. **Head inspection:** area measuring 0.900 m (l) x 0.500 m (w) = 0.450 m^2. **NB!!! Work cycle times measured at different inspection points was between 10 to 15 seconds per inspection activity.**

APPENDIX K: CONTROL LIST FOR PRIMARY MEAT INSPECTION

Section A

Abattoir:……………………………

Date:………………………

Method of inspection:

O = Observation

P = Palpation

I = Incision

Inspector:……………………………………………

Controlling Officer:…………………………………

	CATTLE			SHEEP			PIGS			HORSES			COMMENTS:
HIND-QUARTER:													
Parietal peritonium	O			O			O			O			
Diaphragm			I			O			I				
Lnn. Iliaci			I	O					I			I	
Lnn. subiliacus			I		P							I	
Lnn inguinales superficiales			I		P		O		I				
Lnn. analis					P								
Kidneys			I*	O	P				I*			I*	* By exposure and if necessary, incise
Lnn. renalis			I*		P				I*			I*	* If necessary
Lnn. popliteus					P								
Feet	O			O			O						
Vertebrae & spinal cord if split	O						O			O			
FORE-QUARTER:													
Parietal Pleura	O			O			O			O			
Lnn. cervicales superficiales		P			P						P		
M triceps brachii			I						I*				*Except baconers 54 – 92 kg
Feet	O			O			O			O			
Sternum, ribs, vertebrae if split	O						O			O			
HEAD:													
Tongue	O	P		O*			O				P		*Only if necessary
Hard / soft palate	O			O*			O			O			*Only if necessary
Skin / lips / gums	O			O			O			O			
Eyes / nostrils	O			O			O			O			
Lnn. Mandibulares			I	O*					I				*Only if necessary; can also be incised
Lnn. Parotidei			I	O*					I				*Only if necessary; can also be incised
Lnn. Retropharyngialis			I	O*									*Only if necessary; can also be incised
M. masseter muscle X 2			I						I				
M pterygoideus muscle X1			I						I				
Tonsils removed after inspection	O												
RED OFFAL:													
Visceral pleura	O			O			O			O			
Liver		P	I		P	I		P	I		P	I	
Lnn. Hepaticus			I			I			I			I	
Trachea			I	O	P	I			I	O	P	I	
Oesophagus	O			O	P		O			O	P		
Lungs		P	I	O	P			P	I	O	P		
Lnn. Mediastinales			I		P				I				
Lnn. Bronchiales			I		P				I				
Pericardium			I			I			I			I	
Heart			I			I			I			I	
Spleen	O		I*	O			O		I*	O	P*		* Only if necessary
Tail	O						O			O			
Thyroid gland	O												
Diaphragm (visceral)	O			O			O			O			
Testes	O			O			O			O			
ROUGH OFFAL:													
Visceral peritoneum	O			O			O			O			
Outer surface of stomach, int	O			O			O			O			
Inner surface of stomach, int intestines			I*			I*			I*				*If necessary, only in offal room or DFI
Lnn. Gastrici	O			O			O						
Lnn.mesenterici (cran & caud)	O			O			O		I*				*Only if necessary
Omentum	O			O			O			O			
	(49)			(45)			(45)			(35)			*(Mark negatively and subtract from totals)*

Section B With above inspection the following must be considered:

	C	P	S	H
State of nutrition				
Colour				
Odour				
Symmetry				
Efficiency of bleeding				
Contamination				
Pathological conditions				
Parasitic infestation				

	C	P	S	H
Injection marks				
Bruising & Injuries				
Any abnormalities				
Age & sex of animal				
(12)				

SCORE	
CATTLE (A+B) ÷ 1.173	
SHEEP (A+B) ÷ 1.096	
PIGS (A+B) ÷ 1.096	
HORSES (A+B) **x** 1.106	
Sub-total	
One species: ÷ by 1 Two species: ÷ by 2 Three species: ÷ by 3 Four species: ÷ by 4	
TOTAL (52 ÷ 2) **=**	

APPENDIX L: ERGONOMICS WORKING ACTIVITY ASSESSMENT CHECKLIST

Abattoir:

Ergonomics work activity checklist								
Head	straight	☐	tilted back	☐	bent sideways	☐	rotated sideways	☐
Neck	bent forward	☐	tilted back	☐	bent sideways	☐	rotated sideways	☐
Body	bent forward	☐	bent backward	☐	tuned sideways	☐	rotated	☐
Shoulders	faced forward	☐	tilted sideways	☐	left side higher & right side lower	☐	right side higher & left side lower	☐
Arms	bent at elbow	☐	lower than shoulder	☐	higher than shoulder	☐	reaching or stretching	☐
Hands	grip type	☐	repetitive movement	☐	radial deviation	☐	ulnar deviation	☐
Wrist	pronated position (palm down)	☐	supinated position (palm up)	☐	extended or flexed (bent from midline - sideways or up and down)	☐	radial or ulnar deviation (twisted or turned wrist)	☐
Legs	apart (balanced stance)	☐	weight shifted to one leg	☐	one leg bent	☐	both legs bent	☐
Feet	flat	☐	heels lifted	☐	standing on toes	☐	standing for long periods	☐

APPENDIX M: RAPID ENTIRE BODY ASSESSMENT

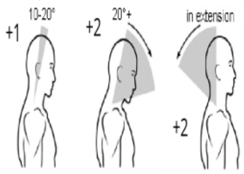
ERGONOMICS PLUS

REBA Employee Assessment Worksheet

Task Name: Date:

A. Neck, Trunk and Leg Analysis

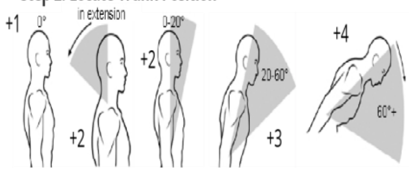
Step 1: Locate Neck Position



Neck Score

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

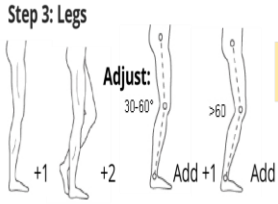
Step 2: Locate Trunk Position



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

Trunk Score

Step 3: Legs



Leg Score

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

Posture Score A

+

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

Force / Load Score

=

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

Score A

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

Scores

Table A		Neck											
		1				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
	2	2	3	4	5	3	4	5	6	4	5	6	7
	3	2	4	5	6	4	5	6	7	5	6	7	8
	4	3	5	6	7	5	6	7	8	6	7	8	9
	5	4	6	7	8	6	7	8	9	7	8	9	9

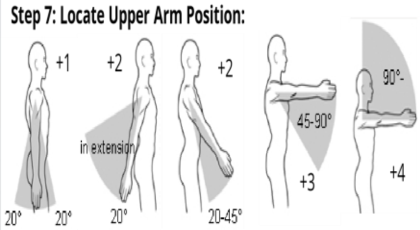
Table B		Lower Arm					
		1			2		
	Wrist	1	2	3	1	2	3
Upper Arm Score	1	1	2	2	1	2	3
	2	1	2	3	2	3	4
	3	3	4	5	4	5	5
	4	4	5	5	5	6	7
	5	6	7	8	7	8	8
	6	7	8	8	8	9	9

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

Table C Score + Activity Score = REBA Score

B. Arm and Wrist Analysis

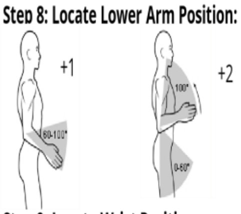
Step 7: Locate Upper Arm Position:



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

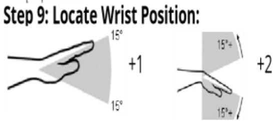
Upper Arm Score

Step 8: Locate Lower Arm Position:



Lower Arm Score

Step 9: Locate Wrist Position:



Wrist Score

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

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

Posture Score B

+

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

Coupling Score

=

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

Score B

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

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

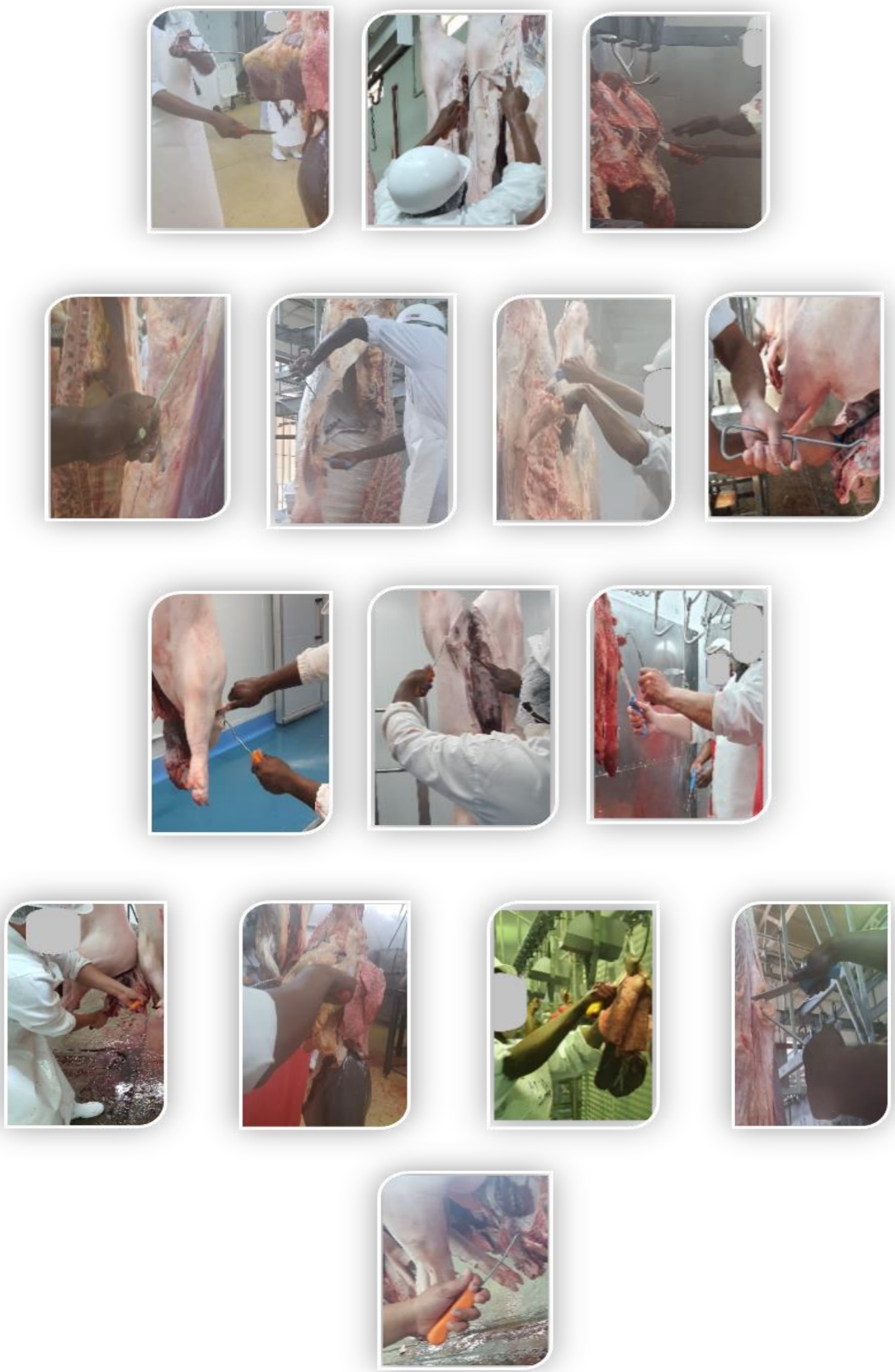
APPENDIX N: BACK BENDING ACTIVITIES

APPENDIX O: NECK BENDING ACTIVITIES

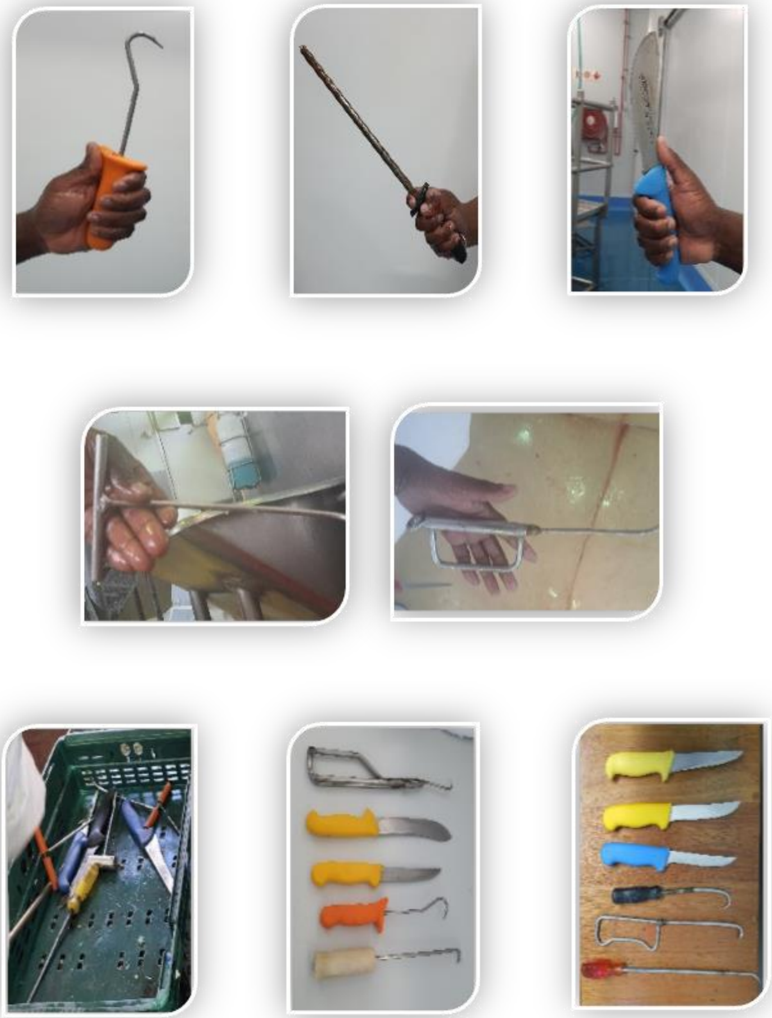
APPENDIX P: ARMS IN ELEVATED POSITIONS

APPENDIX Q: ABDUCTION OR ADDUCTION OF ARMS

APPENDIX R: HAND AND WRIST POSITIONS



APPENDIX S: TYPE OF HAND TOOLS USED



APPENDIX T: TYPE OF WORKING PLATFORMS USED