The physical characteristics and functional manual handling ability of males and females ammunition handlers

Lorraine Mac Duff
(dip. O.T., Hons. B.Sc)

Dissertation submitted in partial fulfilment of the requirements for the degree of Masters of Science in the School of Biokinetics, Recreation and Sport Science at the NORTH-WEST UNIVERSITY (POTCHEFSTROOM CAMPUS)

Supervisor : Professor JH de Ridder
Co-supervisor : Professor DDJ Malan
Assistant Supervisor: Mr JR Smith

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One of the real privileges of being an ergonomist is the opportunity to be part of what others do within their daily occupations. This opportunity has left me with a greater respect for many of the men and women who go about their work with dedication and passion. It is hoped that in some way the ergonomics research and recommendations will be used to further protect and promote the abilities of these men and women.

Rarely is the research of this magnitude the accomplishment of one person, and in this case this is definitely true. I wish to acknowledge firstly the support of the South African National Defence Force: Ergonomics Research Institute Management and the Artillery Formation for their support in completing this work and providing the necessary funding and making members available for testing. To the men and women who participated in the study with interest and enthusiasm. A special note of thanks to Col 'Dif' de Villiers, SA Artillery.

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The Author

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SUMMARY

Mismatch of human capabilities and the physical requirements of the job they are employed to do, are often the focus of attention for ergonomists. Efforts to address these mismatches require that the determination of both the characteristics of the job demands, as well as the capabilities of the individual or population are objectively quantified.

A heavy manual handling task that was inherent in the performance of a specific job within a military environment became the focus of this study. Concern was raised regarding the safety and efficiency of the current employee population to carry out this task, with the equipment and procedures that was originally designed for use by a younger and all male population. Despite the change in user profile, there were no selection criteria in place for employee selection that was based on objective quantified measurements of the physical demands of the job.

Thus, the objectives of the study were as follows:

1. To determine if the lifting and carrying capabilities of the current population of ammunition handlers can safely match the requirements of the manual handling tasks inherent in their job.

2. To determine the correlation between aerobic, strength exertion or anthropometric characteristics of the ammunition handler and their manual handling capability.

3. To compare the functional strength capabilities between the female and male ammunition handlers.

A one-time cross sectional study design was used. One hundred and eighty seven subjects participated in the study, thirty eight of whom were women. The participants were drawn from a sample of convenience from the worker population and who voluntarily agreed to participate in the study.

A multi-faceted approach was taken to address the characteristics and capability of the participants regarding manual material handling. The measured parameters included: basic anthropometry, an aerobic capacity prediction test, isokinetic arm and leg strength tests and an isometric back strength test. The participants also underwent a functional lift and carry test that was designed specifically for this study and made use of the key ergonomics components for the manual handling task being addressed. Dummy objects were constructed to replicate the object that is handled, in three different mass configurations; 47 kg, 35 kg and 20 kg.

The results of the functional lift and carry test of the total population were compared to that of the job requirements in terms of the mass of the object (47 kg), the time duration, the number of repetitions and the levels to which the object had to be lifted (300 mm, 900 mm and 1500 mm) . The results indicated that only 43% of the total sample group could safely and effectively match the manual handling requirements of the job. Of that group, 0% of the women were able to fully meet the requirements.

Correlation tests were applied to the results of the anthropometric variables, the results of the predicted aerobic capacity test, the arm, leg and back muscle strength tests, with that of the functional lift and carry capability test results. There were no correlations found between the functional test and that of the other variables. There was a moderate correlation found between aerobic capacity and functional lift ability, as well as between right knee concentric extensors endurance results and that of functional lift ability. Thus, there were no strong predictive tests that could be used for employment screening purposes; the functional test remains the closest representation to the job requirements.

The results of the functional test of the men and women subgroups were analysed for effect size. There was a large effect size calculated ($d>0.80$) between the functional lift ability of the men and the women of all levels for all masses. The implication is that a task must first be designed to be non gender biased before a policy of open employment for heavy manual handling tasks can be successfully implemented.

The findings of the study confirm that the entire current worker population would probably not be able to safely and effectively perform the manual handling task they were required to do within their post profile. The implications are that the risks for musculoskeletal injuries, fatigue, uneven workload distribution and poor performance are high. The capabilities of the workers do not match that of the job demands. However, should the mass of the object that is handled be replaced with an object of similar capability and characteristics, but having a mass of not more than 20 kg, more than 98% of the sample population would then be able to safely and effectively perform the task.

The ergonomics interventions required to improve the mismatch of the job requirements to capabilities would include 1) redesign of the manual handling task or 2) implementing a functionally based selection criterion for employees to be posted in the specific job profile.

OPSOMMING

As deel van sy werk moet die wetenskaplike op die vakterrein ergonomie dikwels kyk na die wanaanpassing wat bestaan tussen die werker se menslike vermoëns en die fisiese vereistes van die werk wat hy of sy aangestel is om te doen. Ten eerste moet daar vasgestel word wat die kenmerke van die vereistes van die werk is, en ook wat die vermoëns is waaroor die individu of individue moet beskik om daardie werk veilig en doeltreffend te kan verrig.

Die narvorsing waaroor dit in hierdie studie gaan, behels die fisiese hantering van swaar goedere in 'n militêre omgewing. Kommer is geopper oor die veiligheid en doeltreffendheid waarmee die huidige werknemersgroep hierdie taak verrig met toerusting en volgens prosedures wat oorspronklik vir 'n groep jonger en slegs manlike werknemers ontwerp is. Daar is geen seleksiekriteria in plek wat gebaseer is op die fisiese vermoëns wat vir die taak vereis word en waarvolgens die werknemers gekies kan word nie.

Die doelwitte van die studie was dus:

1. Om vas te stel of die optel- en dravermoëns van die huidige groep werknemers geskik is vir die vereistes van die fisiese hanteringstake wat deel van hul werk uitmaak.

2. Om vas te stel wat die korrelasie is tussen die werkers se aërobiese, kraginspannings- of antropometriese kenmerke en hul vermoë om die fisiese hanteringstake te verrig.

3. Om die funksionele kragvermoëns van die manlike en vroulike werkers met mekaar te vergelyk.

'n Enkele dwarssnitstudie narorsings ontwerp is gebruik. Eenhonderd-en-sewe-en-tagtig werkers het aan die studie deelgeneem, waaronder agt-en-dertig vroue. Die deelnemers is volgens 'n gerieflikheidssteekproefneming uit die werknemersgroep gekies en het vrywilliglik aan die studie deelgeneem.

'n Veelvuldige benadering is geneem om die deelnemers se eienskappe en vermoëns wat fisiese hantering betref, te ondersoek. Die metingsparameters was soos volg: basiese antropometrie, 'n toets om die aërobiese vermoëns te voorspel, isokinetiese arm- en beenkragtoetse en 'n isometriese rugskragtoets. Die deelnemers het ook 'n funksionele optel- en dratoets deurloop wat spesifiek vir hierdie studie ontwerp is en wat gebruik gemaak het van die sleutel ergonomiese komponente van die betrokke fisiese hanteringstaak. Modelle is gemaak wat as replikas van die items wat hanteer word, gedien het, in drie massakonfigurasies, naamlik 47 kg, 35 kg en 20 kg.

Die uitslae van die funksionele optel- en dratoets van die totale populasie is met die vereistes van die werk vergelyk ten opsigte van die item se massa (47 kg), die tyd, die getal herhalings en die vlakke tot waar die item opgetel moes word (300 mm, 900 mm en 1 500 mm). Die uitslae het getoon dat slegs 43% van die totale steekproefgroep geskik was om veilig en doeltreffend aan die fisiese handteringsvereistes van die werk te voldoen. In die groep was 0% van die vroue geskik om aan die vereistes te voldoen.

Toetse is toegepas om die korrelasie vas te stel tussen die uitslae van die antropometriese veranderlikes, die uitslae van die toets om die aërobiese vermoë te voorspel en die arm-, been- en rugkragtoets, en die uitslae van die funksionele optel- en dravermoëtoetse. Geen korrelasie is gevind tussen die uitslae van die funksionele toetse en dié van die ander veranderlikes nie. 'n Matige korrelasie is gevind tussen aërobiese vermoë en funksionele optelvermoë, asook tussen die uitslae van regterknie konsentriese ekstensor-uithouvermoë en dié van funksionele uithouvermoë. Daar kon dus geen sterk voorspellingstoetse vir personeelaanstellingsdoeleindes gebruik word nie en die funksionele toets kom die naaste daaraan om die vereistes van die werk te weerspieël.

Die uitslae van die funksionele toets van die mans- en vrouesubgroepe is ontleed om die uitwerking van grootte te bepaal. 'n Groot effekgrootte is bereken (d>0.80) tussen die funksionele optelvermoë van die mans en die vrouens op al die vlakke en vir al die massas. Die implikasie is dat 'n taak eers ontwerp moet word om nie-geslagpartydig te wees voordat 'n beleid van oop indiensneming vir swaar fisiese hanteringstake suksesvol geïmplementeer kan word.

Die bevindings van die studie bevestig dat die huidige werkersgroep waarskynlik nie die fisiese hanteringstaak volgens hul posbeskrywing veilig en doeltreffend kan verrig nie. Die implikasies is dat 'n hoë risiko bestaan vir spierbeserings, uitputting, ongelyke werklasverspreiding en swak prestasie. Indien die massa van die item wat hanteer moet word egter met 'n item vervang sou word wat soortgelyke kenmerke het maar met 'n massa van nie meer as 20 kg nie, sou meer as 98% van die steekproefgroep wel die taak veilig en doeltreffend kon verrig.

Die ergonomiese intervensies wat nodig is om die wanaanpassing tussen die vereistes van die werk en die werker se vermoëns te verbeter, sou twee aspekte behels: 1) herontwerp van die fisiese hanteringstaak of 2) die implementering van 'n funksiegebaseerde seleksiekriteria vir werknemers vir die spesifieke taakbeskrywing.

DECLARATION

The co-authors of the articles which form part of this dissertation, Prof. J Hans de Ridder (supervisor), Prof Dawie Malan (co-supervisor) and Ms Bredenkamp (co-author of chapter three), hereby give permission to the candidate, Ms Lorraine Mac Duff to include the two articles as part of a Masters dissertation. The contribution (advisory and supportive) of these co-authors was kept within reasonable limits, thereby enabling the candidate to submit this dissertation for examination purposes. This dissertation is therefore submitted in partial fulfilment of the requirements for the degree of Masters of Science in the School of Biokinetics, Recreation and Sports Science at the North-West University (Potchefstroom campus).

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Prof JH de Ridder
Supervisor and co-author

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Prof DDJ Malan
Co-supervisor and co-author

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Ms Karen Bredenkamp
Co-author of Chapter 3

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LIST OF ABBREVIATIONS

DTI:	Department of Trade and Industry
FCE:	Functional capacity evaluation
ILT:	Incremental lift test
JPE:	Job physical demands
MMH:	Manual material handling
MSD:	Musculoskeletal disorder
MWL:	Maximal weight limit
NIOSH:	National Institute for Occupational Safety and Health.
NOC:	Number of objects carried
PSS:	Perceived strain scale
RPE:	Rate of perceived exertion
SAT:	Strength aptitude test
SIMRAC:	Safety in Mine Research Advisory Committee
VO_2:	Volume of oxygen per period of time

CHAPTER ONE

Problem statement and aims of the study

Problem statement and aims of the study

1.1 PROBLEM STATEMENT

The Research and Development officer of the Artillery Formation in the South African National Defence Force (SANDF) has with great insight, recognised that manual handling tasks are inherent within the post profile of an ammunition handler. These tasks inevitably require both strength and endurance capabilities. According to Fleischmann (1979) these can be described respectively as the qualitative and quantitative capabilities of the worker. As part of the transformation process, the SANDF have implement the Employment Equity Act No. 55 of 1998, which brought about a change in the human resource profile of the work force. Women were also introduced as ammunition handlers at this time. Unfortunately, this was done without taking cognisance of the inherent physical demands and requirements of the tasks associated with ammunition handling and the fact that the weapons, projectiles and task procedures remain unchanged from the time of being implemented many years ago.

With these changes in the human resources profiles, certain problems became apparent in the ability to perform the manual handling tasks that are inherent in certain post profiles. However, there was no objective and quantifiable data available from which the task demands requirements for manual material handling (MMH) tasks such as ammunition handling could be determined, nor the manual handling capability of the current work force. These data are not presently available. The approach must include a detailed task analysis to quantify the physical demands required to complete the task and then the determination of the functional strength capability of the workers for MMH tasks. According to researchers Constable and Palmer (2000), Deakin *et al.* (2000), Gledhill *et al.* (2000), Kumar (1995) and Matheson *et al.* (2002), the job specific approach for the evaluation and determination of the strength capabilities of workers who perform such tasks is increasingly preferred due to its functional representativeness of the actual task demands. As far as the handling of heavy objects and masses are concerned, Mital *et al.* (1997) expressed that the biomechanical method of evaluation (e.g. determination of forces acting upon the skeletal spine) to be regarded as more suitable for determining the physical impact of the task. Mital *et al.* (1997) also indicated that physiological (e.g. aerobic capacity) and psychophysical (e.g self-limiting determination) methodologies have greater accuracy and application in repetitive tasks.

Campion (1983) indicated that if the functional capability of a person during lifting, carrying or other work related physical demands are exceeded, it can result in musculoskeletal problems or injuries. The costs incurred by a single musculoskeletal injury would include the medical expenses, sick leave, replacement staff and training, and perhaps of greatest concern to the military community is the loss of productivity, temporary or otherwise, of trained personnel. It has been demonstrated by researchers (Keyserling *et al.*, 1980; Lechner, 1994) that the proper evaluation, selection and training of workers resulted in lower incidence or work-related injuries and the associated costs involved. However, they may still experience fatigue that would affect their ability to perform their duties effectively (Chaffin & Page, 1992; Saunders, 1997). This last scenario still has a serious impact upon the organization, particularly in a life and death situation as experienced under emergency conditions.

A database of South African functional body strength was published in the RSA-MIL-STD-127: VOL 5 (2001). RSA-MIL-STD-127: VOL 5 is a South African military standard that was published for the express use by professionals who are involved in the acquisition or development process of products such as vehicles, weapons, ammunition and systems for the SANDF. Data on twelve strength variables are presented for the test protocols that were designed to simulate typical strength exertions during work tasks. The variables are mostly arm strength exertions, one whole body and one leg strength exertion. In the above mentioned study, the data was the first of its kind for the South African military, but did not include lifting and carrying capabilities, RSA-MIL-STD-127: VOL 5 (2001).

A similar approach on collecting of functional body strength data was taken by a British study. Sponsored by Department of Trade and Industry (DTI), the results of a recent study were published in a document, Strength Data for design safety – Phase 1 (DTI, 2003). The document presents 6 strength variables; five finger and hand strength exertions and one push and pull strength. The research was done on 150 British subjects from both genders, aged between 2 and 86 years old. The application of data was intended for consumer items such as medicine bottles and cleaning agent containers. Again there was no data on lifting and carrying capabilities.

Previously, when strength data needed to be referenced for the SANDF, use was made of the American standard (MIL-STD-1472-F, 1999) by the Department of Defence and the British standards (DEF-STD-0025 (Part 3)/ Issue 2, 1997) by the Ministry of Defence and their preceding issues. Both, the British and the American standards make use of the research done by Waters *et al.* (1996) for the National Institute of Occupational Health and Safety (NIOSH) on determining lifting limitations. The NIOSH equation is at this stage the most widely used tool for guidelines on lifting limitations. However, as was discussed by Evans (1990) these data are not always applicable for other nations.

It is within this framework that the proposed research will be undertaken. The research questions that will be answered by this study are as follows:

1. Do the physical capabilities of the current ammunition handlers match the physical demands of the tasks/job?

2. Is there a correlation between the functional lifting capabilities (simulating the task demands) and the aerobic capacity, strength exertion, perceived exertion or anthropometric characteristics of the ammunition handlers?

3. Are there differences between the capability of the female and male ammunition handlers?

Answering these questions will allow decisions to be made regarding the staffing of such posts by male or female soldiers, the mass limits that must be cited in future specifications of weapons and their components, decisions regarding the requirement for automated loading systems and the development of pre-screening tests that can predict manual handling capability of the potential soldiers. It is anticipated that this will significantly impact on the safety, effectiveness, productivity and well being of these soldiers in their line of active duty, albeit currently un-quantified.

1.2 OBJECTIVES

The objectives of the study are:

1. To determine if the lifting and carrying capabilities of the current population of ammunition handlers can safely match the requirements of the manual handling tasks inherent in their job.

2. To determine the correlation between aerobic capacity, physical strength exertion, perceived exertion or anthropometric characteristics of the ammunition handler and their manual handling capability.

3. To compare the functional strength capabilities between the female and male ammunition handlers.

1.3 HYPOTHESIS

The hypothesis statements are that:

1. The manual handling capabilities of the current ammunition handlers does not match the requirements of the job.

2. The aerobic capacity, physical strength exertion, perceived exertion and anthropometric characteristics show strong statistical correlations with the manual handling capability of the ammunition handler.

3. There are significant differences in the functional strength capabilities between the male and female soldiers.

1.4 STRUCTURE OF THE DISSERTATION

The structure of the dissertation is presented in accordance with the guidelines provided by the North-West University. Chapter one outlines the problem statement and background on the situation that lead to this research project being conducted. The research hypothesis and objectives will also be included in this chapter.

Chapter two will present the results of a literature survey that was conducted related to the ergonomics issues that are considered to have an influence on the capacity and capability of an individual to be able to perform manual handling tasks. The chapter has been prepared for submission of a review article in accordance to the guidelines of the Ergonomics SA, Journal of the Ergonomics Society of South Africa. The title of the article is, "***Anthropometric, biomechanical strength and aerobic characteristics of humans and other influences that affect manual handling performance***". The guidelines for journal submission have been included in Appendix A.

Chapter Three will be in the form of a research article. The methodology and results of this study are presented in the article which has been prepared for submission to Ergonomics, an international journal of research and practice in human factors and ergonomics. The title of the article is "***Determining the manual handling capability of a South African worker population in relation to the critical job demands.***" The format guidelines have been presented in Appendix A.

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[1] The SANDF has agreed to allow the data from this study to be used for purposes of a post graduate dissertation on the premise that any published data will not reflect the actual population used. In addition, this confidentiality agreement must be upheld by the University examiners, the primary researcher and the Artillery Formation.

Chapter Four concludes the research project, discussing the results of the study with regards to the hypothesis and whether the objectives were met. It further discusses the implications that the results have for the user population, the ammunition handlers as well as to indicate possible future research related to this matter.

Appendix A presents the guidelines for submitting a paper for publication to both journals.

Appendix B presents the informed consent form that was used in the study.

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CHAPTER TWO

Anthropometric, biomechanical strength and aerobic characteristics of humans and other influences that affect manual handling performance (review article)

L Mac Duff*†, JH de Ridder‡ and DDJ Malan‡.

Prepared for submission for publication to the **"Ergonomics SA journal"**

Anthropometric, biomechanical strength and aerobic characteristics of humans and other influences that affect manual handling performance

(Review article)

L Mac Duff*†, JH de Ridder‡ and DDJ Malan‡

† Ergonomics Technologies
P.O. Box 6264, Pretoria, South Africa, 0001
‡School of Biokinetics, Recreation and Sport Science
North-West University (Potchefstroom Campus),
Private Bag X6001, Potchefstroom, South Africa, 2520
Corresponding author: lorraine@ergotech.co.za

ABSTRACT

Functional strength is understood as the exertion of muscle strength by an individual in order to carry out functional tasks such as driving a delivery truck that requires the pushing of the gear lever and foot pedals or in the lifting and stacking of boxes. Manual handling of heavy objects requires just such functional strength. It is not an isolated muscle action but a synergistic action that is the result of both characteristics of the individual and the environment in which they are working. A review of the literature relating to the influences on human functional strength exertion was conducted with the focus on aspects of functional strength for manual handling which could be applied within an ergonomics context. The aim was to understand the challenge in collecting and presenting human strength data that can be best applied by ergonomists and engineers alike to improve the human interface of products, vehicles or machines. The characteristics of the individual such as anthropometric dimensions, aerobic capacity and fitness levels are known to contribute to the ability to exert strength and carry out manual handling tasks that are required in many jobs. The influences such as the environmental stressors, hand coupling and working in restricted spaces have also been discussed. The determination of manual handling capability of an individual or population by a functional test that relates specifically to the ergonomic components of the job remains the most applicable form of data collection.

Key words: Manual handling, functional strength, ergonomics

INTRODUCTION

The measurement and collection of human strength data are of interest to those working in areas such as ergonomics, physical education, sports science and medical rehabilitation (Kumar, 2001). From the ergonomics perspective, human strength data is used in the design process and for the specification of jobs, workplaces, equipment and systems. According to RSA-MIL-STD-VOL 1 (2001) the aim of the design process in ergonomics is to create a product, be it a jam jar or a mine vehicle, which can safely and effectively be handled by the majority of a pre-determined user population. The general guideline for ergonomists, is to design for the weakest, typically the 5th percentile in a normal distribution of data. This guideline also implies that, where required, the data from females and the elderly must be considered, (DEF-STD-0025, 1997; Department of Trade and Industry, 2003; Karwowski and Jang, 2001; Kroemer *et al.*, 2001; MIL-STD-1472F, 1999).

The challenge continues for scientists and ergonomists to collect valid and appropriate strength data for application in the design of work tasks, equipment or processes. That is to say for a person to be able to lift in a safe manner and remain productive. Despite the increase in automation and available mechanical assistive devices, there still is a significant mismatch between the manual material handling (MMH) tasks persons are required to do and their safe capability to do so (the emphasis being on the word safe). It is apparent, that people often carry out their tasks without the correct ergonomics factors being in place. The result is fatigue, an acute injury, or the development of a repetitive strain injury (RSI), (Kumar, 2001; Saunders, 1999; Westgaard and Aaras, 1984).

Strength data of a given population can also be used for the scientific development of selection criteria for personnel to match job specific demands. It has been reported by Deakin *et al.* (2000), Garg and Beller (1994) and Keyserling *et al.* (1980) that this approach has been used successfully to promote safe and productive work situations.

According to Harmon and Frykman (1992) the ability of a person to carry out the manual handling tasks that are required in everyday life and in the line of duty for many occupations, is intrinsically linked to both the physical and the psychological characteristics of that individual. In order to design a task or selection process to be within the capabilities of a person or population, those relevant characteristics must be properly determined. Research investigations by Chaffin *et al.* (1999), Kroemer *et al.* (2001), and Mital *et al.* (1997) amongst others, have taken several approaches to determine what critical characteristics are required in manual handling performance and how they relate to one's ability to perform occupational manual handling tasks. These approaches are biomechanical, physiological and psychophysical, and will be discussed separately and in relation to the task of manual handling in this article.

Musculoskeletal disorders that typically arise from overexertion during manual handling tasks are also discussed in order to indicate the potential severity of injuries sustained from the mismatch of manual task demands and the ability of the person carrying out that task. Ergonomics research has identified and investigated (Chaffin *et al.,* 1999; Kroemer *et al.*, 2001; Mital *et al.,* 1997, Shoaf *et al.,* 1997) factors both inherent to humans and to their response to external factors that contribute to the exertion of functional strength. These human characteristics include, but are not limited to:

- anthropometric characteristics
- biomechanical advantage
- aerobic capacity
- fitness
- perceived level of effort

The external factors include, but are not limited to:

- environmental stressors
- hand coupling
- restricted space

The ergonomist must consider these factors in order to effectively design or evaluate a manual-handling task. The starting point in ergonomics design is to look at the anthropometric characteristics of the population involved and ensure that the interface is suitable with regard to the hand coupling and workstation dimensions, as well as creating biomechanical advantage where possible (Kroemer and Grandjean, 1997; Kroemer *et al.*, 2001).

ANTHROPOMETRIC CHARACTERISTICS

Anthropometry is the science of human body dimensions taken from identified and defined body landmarks either with traditional hand measurements or with scanner technology. Pheasant (1996) discusses the application of these data for the purposes of ergonomics typically for workstation design to optimise human performance, safety and efficiency within the work environment.

According to Roebuck (1995), anthropometric data should also be used in the design process, to ensure that the workers have a suitable interface with the object or piece of equipment with which they have to work, specifically with regard to contact surfaces, reach and access limits. There are ranges within which the body can more effectively and safely perform lift and carry tasks. Thus, this information should be considered in order to allow the workers to take advantage of their body size. (Refer to the paragraph titled '*Lifting ranges*').

Anthropometric dimensions such as stature, arm length and leg length can create either a biomechanical advantage or disadvantage. Kumar (1995) reported a variance of 70% to predict strength capability that could be explained by anthropometric characteristics. Examples of this would be a man who is 1800 mm tall, lifting a 20 kg mass to a height of 1200 mm, where he would have a distinct advantage over the person having a stature of 1450 mm. On the other hand the shorter person would have the advantage if they were lifting the object within the confined space of a vehicle with a ceiling height of 1200 mm. Charteris and Van Schalkwyk (2002) confirmed that strength exertion in a restricted space could be reduced by up to 50%. This study was in relation specifically to South African industrial workers and the use of controls.

The influence of anthropometric characteristics has a significant impact on the applicability of one nations' strength data being used for another. The National Institute of Occupational Safety and Health (NIOSH) tool (Waters *et al.,* 1993a,b) is used extensively for the purpose of ergonomics lifting analysis, (Birch *et al.,* 1994; Potvin, 1997; Wheeler *et al.*, 1994; Yeung *et al.,* 2003). However, this equation which is now available on software as an analysis tool is based on a compilation of research conducted using samples drawn from the North American industrial population.

Studies have recently been conducted particularly in the Asian countries that have confirmed that the NIOSH tool has limitations when applied to their population (Chuang *et al.*, 1997; Evans, 1990; Hattori *et al.*, 2000; Lee *et al.*, 1995). The situation is yet to be confirmed within the South African and indeed, the African context. Other studies that provide data on strength capabilities of the American population which are used frequently in work design and evaluation are the push and pull tables developed by Snook and Cirello (1991) and Chaffin *et al.* (1999). More recent data is available on the British population for use in the commercial design of consumer goods. However, these data do not include lifting and carrying ability. In fact, the British military standards for ergonomics design (DEF-STD-0025, 1997) and USA military standards (MIL-STD-1472F, 1999) also make reference to the NIOSH tool for evaluation and guidelines on manual handling. The point to be made here is that the research and literature that are readily used internationally must be used with caution owing to the differences in national anthropometric characteristics that may well influence the validity of the data for South Africans (Charteris, 1999).

BIOMECHANICAL STRENGTH EXERTION

The biomechanical approach to determine characteristics of human strength has been to focus primarily on the measurement of strength exertion and in so doing on the measurement of the different muscle action types, and to determine the external influences that affect the biomechanical strength exertion of a person to perform the task (Chaffin *et al.*, 1999; Kroemer *et al.*, 2001; Mital *et al.*, 1997). Traditionally, the professionals concerned with human strength abilities and capabilities, have been clinicians such as doctors and therapists. From a manual test, such as the Oxford scale (Trombly and Scott, 1977) to the use of computerized assessment equipment, such as the Kincom or Cybex (Chaffin *et al.*, 1999) the focus was to obtain an individual's strength baseline for evaluation purposes and re-evaluations are against that one individual for clinical purposes. These forms of testing were and are still useful in the clinical setting. Ergonomists and design engineers, however require a strength database of the user population to apply in design, while specification and evaluation applications continue to pursue the most accurate and appropriate method with which to collect strength data.

Types of Muscle Action

In order to fully understand the discussions regarding human strength capabilities, one must first review the different types of muscular strength and the type of muscle action that is required to illicit that type of strength. Table I presents a summary adapted from Chaffin *et al.* (1999) that indicates the flow from human performance through to the type of muscle action that specifically can contribute to that action.

Table I : Types of muscle strength and action

Human Performance Task description	Type of muscular strength	Conditions
Static exertions: (e.g., hold, carry, initiate motions) →	Isometric strength	Fixed postures, no joint movement
Dynamic exertions (eg., lifting, pushing, pulling) ↗ ↘	Isokinetic strength	Body movement with constant velocity at specific joint
	Isoinertial strength	Body movement with constant external load

Adapted from Chaffin *et al.* (1999).

Isometric Strength

Strength testing protocols are now largely related to the technology available by which to objectively quantify the results. Needless to say, the variables that are involved in the dynamic action of lifting are numerous, and include speed, posture, muscle bulk, and object-person interface to name but a few, and therefore it is difficult to control or quantify all of them (Marras *et al.,* 2000). It was therefore in the past often easier for researchers to measure isometric strength rather than any of the actions that were dynamic. According to Perrin (1993) isometric strength is "the exertion of muscle force against a fixed object, the length of the muscle remains unchanged". While isometric (static) strength is a more controlled measurement, it is considered to underestimate the dynamic strength capability of an individual with variation of up to 73% (Kumar, 1994; Kumar, 1995). A study by Garg and Beller (1994), reports that at slow lifting speeds, mean static strength was equal to mean isokinetic strength, but not at high lifting speeds. For high lifting speeds, mean isokinetic strength was equal to the mean maximal weight limit (MWL) achieved by the psychophysical ratings. Garg and Beller (1994) also found that there was only moderate correlation between the strength results obtained by isometric, isokinetic and psychophysical methods, and then questioned whether one type of strength measurement alone, could provide for accurately predicting another strength type; a question that was also put by Birch *et al.* (1994).

However, Kumar (1995) reports in his review of the literature, that when work design limitations (albeit based on static strength data) are not exceeded by a given population, the effect was still to significantly reduce the incidence of back injuries. Despite the limitation in the prediction of dynamic strength loading capability; the finding of Kumar (1995) indicates that isokinetic strength is lower than isometric strength, and that as manual handling is a dynamic task, isokinetic or isoinertial measurements are more relevant measures for collecting strength data remains a given. It is recommended to ergonomists using static strength data to specify a (MWL) for a job that these values may in fact give higher than actual safe allowable limits (Mital *et al.,* 1997). Thus, isometric strength has value for design purposes in those tasks for which a worker would have to exert strength against a fixed control or static hold, but has slightly less value for manual handling which is inherently a dynamic process, (Kumar, 2001; Wu and Chen, 2001). Indeed, some of the strength variables reported in RSA-MIL-STD-127:VOL 5 (2001) and Department of Trade and Industry (2003) were measured and reported as isometric strength values such as arm strength exertion against a lever in various positions as well as hand grip, refer to Table II for a summation of similar test arm and hand grip strength results for South African, British and

USA subjects (RSA-MIL-STD-127:VOL 5, 2001; Department of Trade and Industry, 2003; MIL-STD-1472F, 1999).

Table II : Values of isometric strength variables for different nations expressed in newton [N]

Strength variable	Sample population	Mean value [N]
Right hand grip strength	SA male	378
	USA male	208
	UK male	248
Arm push 90° elbow flexion on vertical bar	SA male	140
	USA male	128
	UK male	130

(UK data=Department of Trade and Industry, 2003; USA data= MIL- STD- 1472-F, 1999; SA data=RSA-MIL-STD-VOL 5, 2001)

"The term isokinetics may be reserved to denote the type of muscular contraction which accompanies a constant angular rate of limb movement, rather than a constant linear rate of muscular shortening" (Hinson *et al.,* 1979). So the challenge remains to find a method to collect strength data that is more closely aligned to the biomechanical efforts of manual handling as a dynamic process. While the technology has developed to produce such commercially available isokinetic units such as the KinCom® (Chattanooga Group, Tennessee), Baltimore Therapeutic Equipment® (bte Technologies Inc., Maryland) and the Cybex® machine (Lumex Inc., New York) there remain limitations in the set up postures that can be tested and their simulation of actual movement patterns in the workplace, and that lifting protocols can significantly impact the performance results (Cabri, 1991; Stevenson *et al.,* 1990). These test equipment are also extremely expensive both to purchase and test on, which is often a factor in the decision regarding their use. The remainder of the South African arm and leg strength data reported in RSA-MIL-STD-127 VOL 5 (2001) was collected making use of a Cybex® unit measuring isokinetic strength. Similar testing protocols were used and reported by Charteris (1999) and Charteris and Van Schalkwyk (2002). Again these protocols addressed strength exertion of pushing and pulling actions and not specifically for lifting actions for manual handling.

Isoinertial Strength

Isoinertial and functional strength tests such as the Strength Aptitude Test (SAT), as the Liftest or Incremental Lift Test (ILT), have been used in the pre-selection of employees for the USA Army and Air Force as well as by the Canadian Forces (Stevenson *et al.,* 1990). This form of testing was later replaced for more functionally based job demands tests in the Canadian military population because of its poor predictability for female personnel (Deakin *et al.,* 2000).

The international trend has been to take a more practical approach as supported by the popular implementation of Functional Capacity Evaluations (FCE) and Job Physical Demands (JPA) (Deakin *et al.,* 2000; Gross and Battie, 2002; Matheson *et al.,* 2002; Saunders, 1999). These practical approaches first determines the critical essential tasks of the job demands, which are then simulated and the subject is tested against the requirements of the job. Throughout the USA and Canada, function evaluations have been devised to determine the level of functionality of an injured worker and the limitations and abilities to return to work (Deakin *et al.,* 2000; Matheson *et al.,* 2002). This more practical approach has also influenced the data collection test set up for use on isokinetic strength to make use of a functional or 'free posture' posture (RSA-MIL-STD-127:VOL 5, 2001; Marras *et al.,* 2000). According to Gross and Battie (2002) there are primarily two forms of Functional Capacity Evaluations (FCE). The first one is based on the principle of the psychophysical where the subject tests self-limits and determines the MWL. The second form is based on the kinesiophysical approach where the administrating therapist determines the MWL based upon biomechanical signs of maximal effort such as muscle substitution patterns or counterbalancing accommodations.

While the numerous variables in lifting and manual handling cannot be totally controlled within the isoinertial protocols, they are considered a better representation of the strength requirements used under actual work conditions (Matheson *et al.*, 2002; Straker *et al.*, 1997a). It has been suggested that at this time, the most valuable tool to ascertain strength abilities of workers must be collected using the components of the actual manual handling job (Chaffin *et al.,* 1999; Dempsey *et al.,* 1998). It has been reported by Keyserling *et al.* (1980), Kumar (1995) and www.osh.net/articles/archive (2002) that to match the strength capabilities of the worker selected to match the demands of the job can significantly decrease the incidence of injuries on the job.

Future of Biomechanical Strength Evaluations

Efforts to address manual lifting from a more accurate biomechanical perspective within a software modelling capacity are being made now by Marras *et al.* (2000), Kumar (1995) and Chaffin *et al.* (1999) amongst others. Once biomechanical strength data, aerobic capacity and anthropometric data for a specific population can be imported into such modelling capacity, ergonomics evaluations and predictions of safe working capability can be more effectively and quickly undertaken.

AEROBIC CAPACITY AND MANUAL MATERIAL HANDLING CAPABILITY

It is generally accepted that aerobic capacity is a limiting factor for the ability of an individual to perform manual handling tasks, particularly during repetitive work or carrying of materials over any distance. Astrand and Rodahl (1986) discussed a threshold of 30% of an individual's maximum aerobic capacity for regular work over an eight hour period. This work has been further supported by work done at NATICK on load carriage by Harmon *et al.* (1999). It was suggested by Scott (2001) that this threshold value could well be as high as 50% of maximum capacity for certain well-conditioned, fit South African individuals for load carrying work. However as it is reported that there is only an 11% percent range of possible increase in aerobic capacity by the improvement of fitness (Astrand & Rodahl, 1986) it is unlikely that this would hold true for a general industrial population to conduct manual handling tasks.

FACTORS AFFECTING MANUAL HANDLING CAPABILITY

Age

The young adult continues to gain or maintain strength through early adulthood. Generally strength with endurance capability peaks is evident when people are in their thirties. This capability is obviously dependent on the person's state of fitness of the person. A noticeable decline in peak strength capability from the thirties, and a decline in endurance strength can be expected for persons working into their fifties. However, work experience does have somewhat of a counter-affect on this occurrence which maintains performance levels for a longer period, (Astrand and Rodahl, 1986; Mital *et al.,* 1997; Parker, 2002; Parkhouse and Gall, 2004; Shephard, 1995).

There is understanding that the biomechanics of the spine will typically be weakening with the ageing process, and thus, one can expect that a younger man can safely handle a heavier mass than a man in his later years. For example work done by NIOSH (Waters *et al.*, 1993a) reference 3400N as the biomechanical threshold for the spine to protect 99% of the population. Thus, following the line of logic, this threshold of 3400N must be reduced for males in their latter working years.

Gender

Kumar (2001) demonstrated a significant difference between strength capabilities of men and women. Female arm strength is used (as a general rule of thumb) as two thirds that of men, while leg strength is generally up to 80% of that of men (Kroemer *et al.,* 2001; Kumar, 2001; Kumar, 1995). Very similar results were found for the SANDF male and female strength results (RSA-MIL-STD:VOL 5, 2001).

Chaffin and Page (1994) reported that the lift guidelines outlined by the NIOSH tool state that the biomechanical spinal stress threshold for females is lower than that of males and may well be as low as 2600N. The problem with this recommendation is that this load of the spine may amount to as little as a lifting an envelope from the ground, depending on body size. These recommendations are problematic to implement in the work place as it would practically bring to a halt most manual material handling tasks.

Fitness

Fitness training programs that are task specific can result in MMH improvements of 26-99% in comparison with general fitness training which indicates improvements of performance of 16-19% for women and 19-23% for men (Knapkik, 1997). The state of aerobic fitness of a person would directly influence the person's stamina required to do a task. Muscle strength training can also positively impact on lifting ability, as a larger cross section of muscle can generally exert more force, as well as provide better protection against musculoskeletal injuries. Kroemer *et al.* (2001) reported that a physically fit person generally has a positive perspective for carrying out physical work than an unfit person.

Lifting Regions

Biomechanically, the safest region of lifting objects is between the hips and chest height (Chaffin *et al.,* 1999; Kumar, 2001). Interestingly, Lee *et al.* (1995) found the MWL to be highest when lifting from the floor to knuckle height, the second highest was from the floor to the shoulder height, and lastly knuckle to shoulder height. It is recommended that the object is kept close to the body, as lifting with extended arms reduces strength capability and increases the risk of injury (Chaffin *et al.,* 1999; Kumar, 2001). Hattori *et al.* (2000) had reported in their study that females had the most difficulty lifting in the region from shoulder height and above. Nag (1991) investigated strength endurance on different loading levels, and found it to be the best from waist to shoulder level and the worst, below the knee when in a stooped posture.

A biomechanical advantage is further created within certain joint ranges of the arms, legs and trunk where the muscles, being the primary activator can exert greater strength capability. This is well illustrated in MIL-STD-1472-F (1999) which presents leg strength in a seated position with the foot against a pedal, and the knee joint in varying positions. The variance that was produced by the difference in the knee position was up to 90% (Kroemer *et al.*, 2001). Thus, the relation of the optimal joint range to exert functional strength must be considered with the interface of the person to the lifting regions.

Personal Perceptions

The psychophysical approach to determining lifting capacity is based upon subjective reports by which the person will estimate their MWL lifting capacity over an eight hour shift. The work by Mital *et al.* (1997) and Snook and Cirello (1991) have been used extensively in manual handling evaluation as threshold guidelines. The psychophysical methodology used for these works have also been used as an accepted protocol for manual-handling capacity determination (Mital *et al.*, 1997). Chaffin and Page (1994) also reported that women were better in using a psychophysical approach to determine a MWL that is still within biomechanical threshold limits than were men that participated in the same study. It is reported by Fernandez *et al.* (1991) that the psychophysical protocol tends to have better validity for lifting at lower frequency lifts, than for high frequency lifts. Davis *et al.* (2000) reported that MWL determined by psychophysical measures were more sensitive to local muscle strain and whole body strain rather than spinal loading. Similarly, it is not sensitive for MWL that comply with biomechanical spinal threshold loading (Waiker *et al,* 1991).

The subjective approach typically makes use of such validated psychophysical tools as the Borg Scale of perceived rate of exertion (RPE) (Borg, 1970), the body discomfort map (Wilson and Corlett, 1992) and the Perceived Strain Scale (PSS) by Scott (1995) which was developed for use with populations of low literacy or language barrier problems such as is often encountered in South Africa.

Straker *et al.* (1997b) found that there was a strong correlation between the perceived exertion of the person and the heart rate measures, while Hazard *et al.* (1991) did not find a similar correlation. There certainly has been a strong correlation found between RPE ratings and the ability of that person to successfully complete the lifting and carrying tasks (Mital *et al.,* 1997). The implication is that conditioning to do the task will not only improve fitness levels, but also the confidence levels in handling the mass (Knapkik, 1997; Parker, 2002).

EXTERNAL INFLUENCES AND MANUAL HANDLING

Temperature

Hot and humid ambient environmental conditions will reduce the physical performance capabilities of the worker (McArdle *et al.,* 1996). Cold weather can reduce hand dexterity and joint movement and thus negatively impact on lifting and carrying capability of personnel (Hancock and Vasmatzidix, 1998; Wilson and Corlett, 1992).

Restricted Workspace

It was reported by Kumar (1994), Kuorinka *et al.* (1994) and Marras and Davis (1998) that values of up to 60% of strength variation are dependent on posture and that posture is dependent on the workspace. It was likewise reported by Drury (1980) and Charteris and Van Schalkwyk (2002) that restricted postures in confined workspace can reduce strength capability by up to 50%. Optimal strength exertion is typically with the joint in mid-range and not at full flexion or extension. Bending, stooping or overextended postures for material manual handling, such as is typical in underground mining scenarios, place the individual at a disadvantage of having their strength capability reduced in such instances (Haslegrave, 1994, Gallagher *et al.,* 1994).

Handholds, Type and Orientation

The existence of handgrips alone on an object can reduce the force required for lifting tasks by up to 20%, and positively affect the efficiency with which a lift can be safely performed (Drury, 1980; Potvin and Bent, 1997; Waters *et al.,* 1993b; Wu and Chen, 2001). Pinder *et al.* (1999) looked at the effect of hand position on manual handling capacity. They found that there was no significant difference in manual handling capability for the load under investigation, when the hands were held at the person's sides or in front of the body. Davis *et al.* (1998) discussed that spinal loading could be decreased by nearly 7% through the use of handles. Marras and Davis (1998) discussed the increased spinal loading that takes place when conducting a one-handed lift as opposed to a two-handed lift.

MUSCULOSKELETAL DISORDERS RESULTING FROM MANUAL MATERIAL HANDLING

There are studies that have reported causal links of manual material handling components such as heavy mass, high repetition and awkward postures that push the body beyond its threshold for working without resulting in fatigue or incidence of injury (Mital *et al.,* 1997; Chaffin *et al.,* 1999; Kroemer, 1999; Marras *et al.,* 2000). The dosage for such causative factors has yet to be determined, but the existence of this relationship has been ascertained beyond doubt.

Musculoskeletal disorders (MSD) can be due to injury sustained, either acutely or through the affect of cumulative strain on the body that affects the muscles, tendons, ligamentous structures, nerves or blood vessels and is typically characterised by pain and discomfort that may or may not cause impairment of functional ability of the worker (Guild *et al.,* 2001; Saunders, 1999). The most predominately reported injuries both locally in South Africa and in the USA (www.cdc.gov, 2004) relating to MMH are low back injuries. In the USA this was followed by the shoulder region for injuries related to material manual handling tasks as reported by Kumar (2001). This finding was in keeping with the results of an epidemiological study conducted by Schierhout *et al.* (1992) in the manufacturing industry in the Cape. According to the 1998 statistics report by the South African Compensation Board (www.statssa.gov.za, 2004), on the total compensable work injuries, 8.68% were back injuries, 7.24% arm injuries and 6.46% leg injuries. These are reported according to the category of body injury site. It can be surmised that these occupational work injuries may indeed not be representative of the actual MSD's that are experienced in the industrial sector of SA workers, as cumulative trauma is either typically reported or compensable in South Africa. The findings in a preliminary report on reportable musculoskeletal problems within the mining sector by the Safety in Mine Research Advisory Committee (SIMRAC) (Schutte *et al.*, 2003) indicate that musculoskeletal incidence in total represent less than 7 % prevalence of reported sick examinations. The most common site of complaint was the low back followed by knee injuries and lastly foot pain.

The cost of a worker sustaining a musculoskeletal injury will include not only the medical costs, and lost time, but also the cost of replacing or retraining the worker, in addition to any compensation paid. The loss and discomfort to the injured worker must also be considered, and lastly that the worker in a state of fatigue or discomfort that impairs his or her performance will be at increased risk to injury in the workplace (Saunders, 1999; www.osh.net, 2002).

Overexertion is discussed by Kumar (2001) as the extending of the physical and physiological capacity beyond the capability of the individual in relation to the demands of the job. To reduce the risk factors inherent in material manual handling tasks, the components thereof must be analysed, and the weight of the risk factors prioritized and reduced, typically by redesigning one or more of the task components. However, by determining the capability of a population with regard to their job demands, the redesign can be adjusted within the safe parameters of the majority of the workers (Kroemer, 1999). Charteris (1999) discusses the requirement for representative strength data on South African workers for benchmark purposes of rehabilitation or retraining of injured workers. In this paper he does presents work output strength on a sample of thirty healthy young South African males. The format of the data as total power output, would however be more applicable in a rehabilitation setting for individuals, but would be expected to be of limited value for the design specification of limits for a work environment.

CONCLUSIONS

Despite the increase in automation and technology available in many sectors of the workplace, the task of manual handling remains a physical demand that is inherent in many job profiles. The repetitive loading of heavy objects may well be a task that with the introduction of automated systems will reduce the repetition and levels of handling, but will not be completely eradicated in the supply chain. The ability of the personnel to effectively and safely handle such loads remains critical to the success of a task execution, be it training or operational. Thus, as discussed in this chapter, the characteristics of the personnel inclusive of anthropometry, the biomechanical strength capability and the aerobic capacity will contribute in determining the design and threshold limits of manual handling tasks in future.

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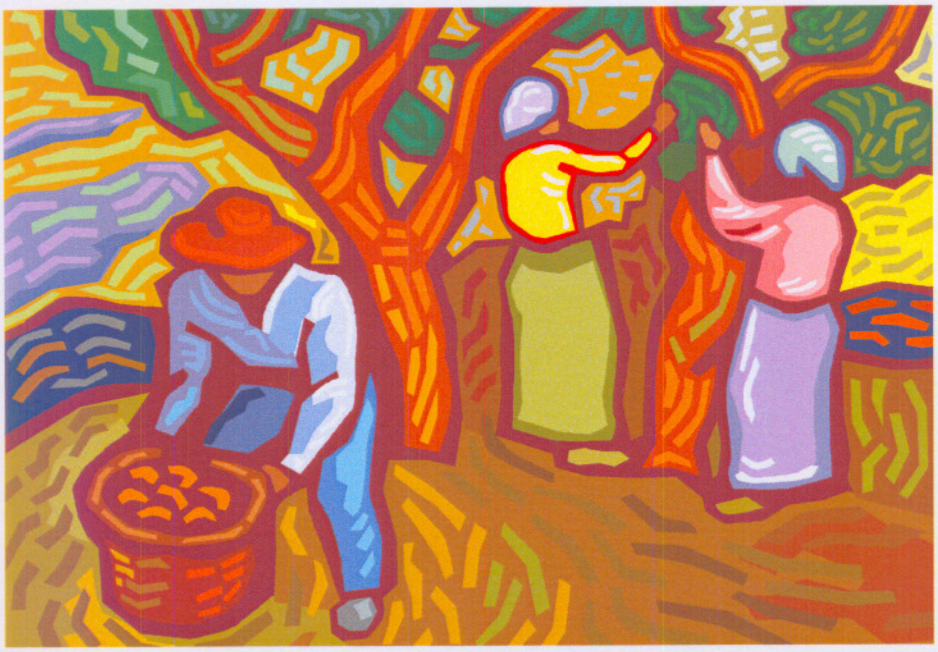
CHAPTER THREE

Determining the manual handling capability of a South African worker population in relation to the critical job demands

L. MAC DUFF*†, J.H. DE RIDDER‡, D.D.J. MALAN‡, K. BREDENKAMP†.



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Determining the manual handling capability of a South African worker population in relation to the critical job demands

L. MAC DUFF*†, J.H. DE RIDDER‡, D.D.J. MALAN‡, K. BREDENKAMP†.

† Ergonomics Technologies
P.O. Box 6264, Pretoria, South Africa, 0001
‡School of Biokinetics, Recreation and Sport Science
North-West University (Potchefstroom Campus),
Private Bag X6001, Potchefstroom, South Africa, 2520

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Problems that were related to ergonomics issues of a heavy manual-handling task within a military environment, required that both the physical task demands and the manual handling capability of the current workers be determined. A total of 187 subjects from the active worker population voluntarily agreed to participate in the study; thirty-eight of whom were females. A functional test was designed to replicate the critical key components of the actual manual-handling task. The shape and the hand contact surface of the objects handled were replicated in experimental dummies of three masses, 20 kg, 35 kg and 47 kg. Anthropometric characteristics, predicted aerobic capacity and strength tests of the muscles in the arms, legs and back were collected in order to determine any relationships between functional task ability that may be used for selection screening purposes. The results indicate that the functional test using the 35 kg mass appears to be the most suitable for a predictive selection test, following by VO_2, and then right leg endurance capacity. It was also found that 43% of the current population could meet the current manual handling requirements of the job. This representation could be increased to 80% of the worker population with a reduction only to the mass of the object being handled. There were large effect size differences in the functional lifting and carrying capability and strength variables between the genders. The implication is that tasks must be designed to be gender independent or a specific selection process based on physical demands of the job be implemented.

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*Corresponding author: lorraine@ergotech.co.za

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1. Introduction

The application of the equal opportunity employment laws in South African such as the Promotion of equality and prevention of unfair discrimination Act of 2000 and Employment Equity Act, No. 55 of 1998, resulted in more physically demanding jobs being filled by women. Unfortunately, this practice takes place without taking the effects of overexertion and risk of injury into account. The tasks have often not yet been redesigned for use by a larger variance in the population nor the introduction of selection of employees based on the physical task demands required for the job. Questions regarding the current capability of the workers in relation to the physical demands of the task were raised and were required to be scientifically quantified. The understanding within the military environment of the potentially serious implications that a heavy manual handling task can have on the productivity and health and safety of their personnel, has necessitated this study. Should the physical task demands exceed the capability of the worker, the outcome may result in fatigue (McArdle *et al.* 1999) and/ or occupational injuries (Schierhout *et al.* 1992, Saunders 1997, Marras *et al.* 2000, Kumar 2001).

There are ergonomics tools available for the analysis and risk prediction of manual handling tasks. These tools include the National Industrial Occupational Safety and Health (NIOSH) equation (Waters *et al.* 1993), the Michigan 3D movement analysis tool – OWAS (Chaffin *et al.* 1999) and human modeling software such as LifeMod (www.lifemodeler.com 2004). With the exception of the NIOSH equation, which is a compilation of biomechanical, physiological and psychophysical studies, the other tools are primarily based on biomechanical principles for evaluation of the task against the recommended thresholds for the manual handling task. Kumar (2001) stated that each of these tools have therefore both value and limitations of use and application.

It has not always proved appropriate, or accurate to use an analysis tool such as the NIOSH, which is based on data from an American industrial population and apply it to a different population (Evans 1990, Lee *et al.* 1995, Chuang *et al.* 1997, Wu and Chen 2001). Differences in anthropometric and aerobic characteristics of the populations would in part explain the limited results in using such tools directly on a South African (SA) population. While databases on strength capabilities of the South African population are limited

(Charteris 1999, Charteris and James 2000, RSA-MIL-STD-127: VOL 5, 2001) data on manual handling capabilities, representative of the population, are apparently non-existent. Thus studies on the actual population were warranted.

The aims of this study were therefore to determine:

1. If the lifting and carrying capabilities of the current population of workers can safely match the demands inherent in their job,
2. The correlations between aerobic capacity, strength exertion, perceived exertion, anthropometric characteristics and the functional lifting ability of the workers,
3. The differences in the lifting capability of males and females within a representative population employed to do a specific manual handling task.

2. Methodology

2.1 Study design

A one- time, cross sectional design was used for the purpose of this study. The research ethics committees of the North-West University, Potchefstroom Campus and the South African Military Health Service approved the study. All subjects were briefed and voluntarily signed an informed consent form. No incentives were provided for the subjects' participation in the study. The testing protocol was conducted over a 3 week period, each participant being tested on two days, with a minimum of 3 days rest between the testing days. Day one, the subjects were measured for anthropometric characterization taken according to ISO 7250 (1996) and the RSA-MIL-STD-127: Vol 1 (2001). The subjects then completed the tests for back, arm and leg strength and after the required rest period, everyone participated in the Multistage Shuttle Test. On Day two of testing the subjects underwent a functional manual handling test that simulated the actual task performed in their job.

2.2 Subjects

A total of one hundred and eighty seven subjects voluntarily participated in the study. The ethnic distribution was determined to be representative of the worker population that was employed to perform the manual handling task under investigation. The thirty eight female subjects that participated in the study were the entire group of women employed at the time of the study for this job profile and thus the sample was not randomised, but from a sample of convenience. The remaining one hundred and forty nine subjects were men.

All subjects had to have a medical clearance to participate in the study. Anyone who suffered from a recent musculoskeletal injury, being pregnant or had a seated blood pressure higher than 140/90 mmHg at the time of commencing with the study, were excluded.

2.3 Apparatus

A segmometer (lengths) and stadiometer (stature) as well as a calibrated electronic weighing scale (body mass) were used to take the anthropometric measurements.

The Cybex® Norm 7000 was used to measure functional arm and leg strength and the calibration was verified on a daily basis. The back strength was measured isometrically by using a stand alone Takei dynamometer load cell anchored to a standing platform. Bilateral handgrip strength was measured using a Takei hand dynamometer. The dynamometers were calibrated prior to the commencement of the measurements.

A dummy object was constructed specifically for this study to replicate the object which was used by the workers in the actual loading task of the job. The objects were made of plumbing pipe, cut to a length of 900 mm, diameter of 160 mm and packed to a mass of 20 kg, 35 kg and 47 kg. One end of the object had an insert for a hand hold and was lined with hose pipe to protect the hands. Two sets of industrial metal shelving were used to replicate the lifting surfaces. The shelf heights were set at 300 mm, 900 mm and 1500 mm. The shelves surfaces were 600 mm deep by 1000 mm wide.

Hand held stop-watches were used for timing purposes and Accurex Polar Heart Rate monitors were used on the subjects for heart rate monitoring. The environmental conditions were captured using a Wet Bulb Globe Temperature (WBGT) apparatus for the duration of the outdoor functional testing, which took place from 8am up to 3pm. The functional lift and carry tests were conducted outdoors. The weather conditions for the duration of the study did not supersede the limitations for intermittent exercise according to the military training handbook. The weather conditions ranged from moderate to hot, with no rain, the WBGT was mean 22°C +/- 2 °C throughout the testing.

2.4 Test procedures

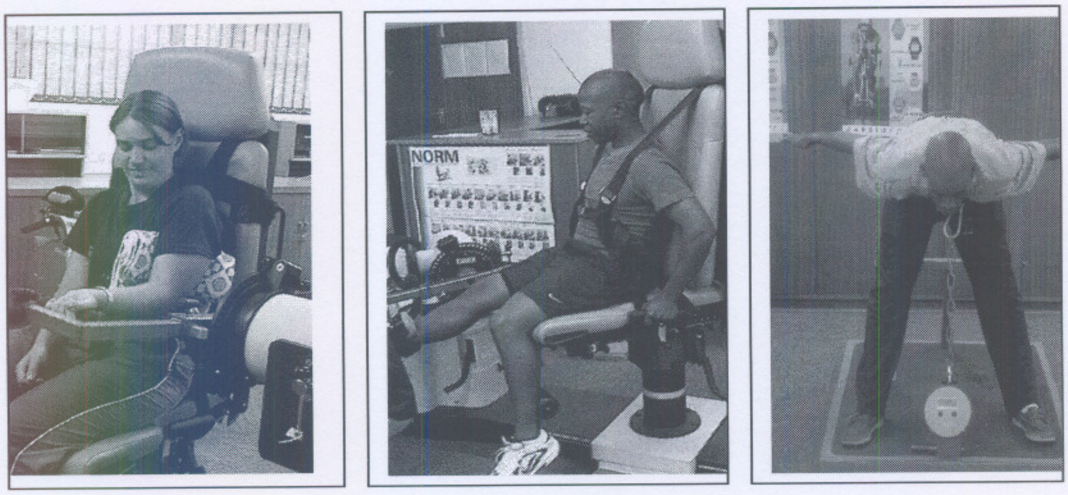
Basic anthropometric measurements were taken on each subject to include stature, arm length, leg length and body mass. Measurements were taken by internationally accredited ISAC level 2 anthropometrists according to "Basic human body measurements for technological design" ISO 7250 (1996) and the definitions used in RSA-MIL-STD-127: Vol 1 (2001). To estimate aerobic capacity of each individual, the Multistage Shuttle Test was conducted according to Leger and Lambert (1982).

The strength exertions for the arm were measured using an adapted protocol from the Cybex® manual to replicate the primary muscle movers when lifting and lowering an object using the arms as seen in Figure 1. The test determined the force exerted by the concentric and eccentric flexors of the elbow. The leg test is illustrated in Figure 2. This test was a standard Cybex® test protocol and determined the concentric muscle strength for knee flexion and extension. Tests for peak strength and then a 50% fatigue protocol for endurance were used for both the arms and the legs, bilaterally. The settings used for the tests are presented in Table 1.

Table 1: Cybex settings for arm and leg functional strength tests

Muscle strength test	Setting [degrees/second]	Repetitions [#]
Arm: Isokinetic concentric/eccentric flexors	60 - 60	5
Arm: Isokinetic concentric/concentric flexors/extensors	180-180	25
Leg: Isokinetic concentric/concentric flexors/extensors	60 – 60	6
Leg: Isokinetic concentric/concentric flexors/extensors	240-240	25

The back strength protocol illustrated in Figure 3 was adapted from McArdle *et al*. (1999). A wide webbing strap was placed over the mid-thoracic back region of a subject who was standing flexed from the hips with the knees extended. The webbing was attached to a dynamometer by means of a chain. The subject was instructed to lift his/her torso upwards without making use of upper legs muscles. Each subject was allowed two efforts and the best result was recorded.



Figures 1, 2, 3 : Arm, leg and back muscle strength set up

The functional test protocol was designed to include the critical key components as had been determined from a previously completed task analysis. The two shelving units were set up a distance of 30 m apart. An instruction was given to the subjects when to start the test cycle. A test cycle comprised of lifting the object from the designated level for the shelf and then carrying the object on the shoulder or in the arms to the second set of shelves. There the object was placed onto the same level of shelf and slid into place, as illustrated in Figure 4.

This cycle action was recorded as one NOC (number of object carried), the subject was allowed to continue this cycle for a maximum duration of 4 minutes. Each subject was required to attempt all of the nine carrying conditions. The physiological responses were monitored by use of Polar Heart Rate monitors as a safety precaution by monitoring that the recommended individual maximum heart rate was not exceeded. The functional test apparatus was set up on an outdoor flat dirt terrain under the shade of some large trees.

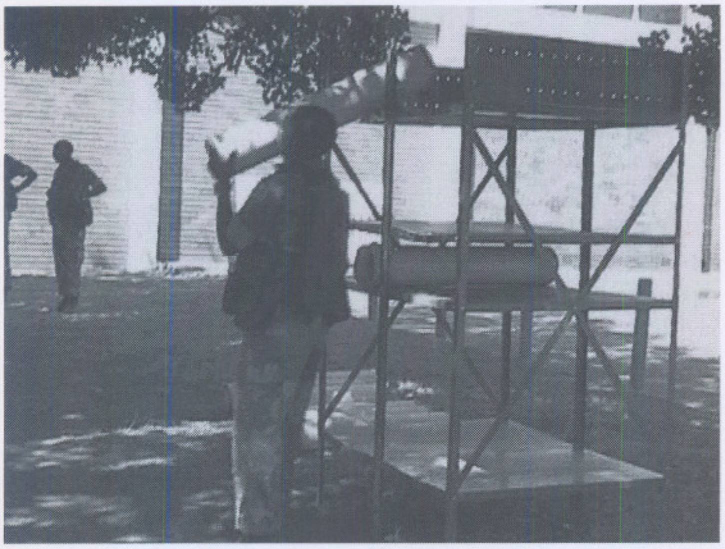


Figure 4 : Functional lift and carry test set up

The nine conditions were tested in the order as presented in Table 2.

Table 2 : Functional test conditions and test order

Condition 1	47kg –High (47H)
Condition 2	47kg –Low (47L)
Condition 3	47kg –Middle (47M)
Condition 4	35kg –High (35H)
Condition 5	35kg –Low (35L)
Condition 6	35kg –Middle (35M)
Condition 7	20kg –High (20H)
Condition 8	20kg –Low(20L)
Condition 9	20kg –Middle (20M)

The subjects were required to give a perceived exertion rating on completion of each condition by using a Modified Borg Rating Scale of Perceived Exertion, the Perceived Strain Scale (PSS) as described by Scott (1995). Subjects were stopped at their maximal level of effort based on either their own self-limiting psychophysical response or by producing a heart rate in excess of 220 minus their age or for making use of unsafe biomechanical lift patterns as determined by the research team members.

2.5 Data analysis

Descriptive statistics were completed on the data using the STATISTICA software package (Statsoft, Inc., 2002). Differences in the n values are as a result of the removal of extreme values from the dataset as determined by a value that is smaller than the 25th percentile value minus three times the quartile range or greater than the 75th percentile value plus three times the quartile range (Statsoft, Inc., 2002). The successful completion of each of the nine lifting and carrying conditions was determined at a target rate of 8 objects handled in 4 minutes. The number of subjects who successfully achieved the required target rate was then expressed as a percentage of the population that had a lifting and manually handling capability that matched those required by the job. Histograms were plotted for the normality distribution of all variables which determined that non parametric tests had to be used for further data analysis. The Spearmans' correlation test was then used, strong correlations are marked at $r>0.60$. As the sample was not drawn randomly and as advised by the Department of Statistics, North-West University, the use of practical effect size was used instead of statistical significance. Large practical effect size was set at $d>0.80$ as suggested by Cohen (1988) for the difference of means between two populations and $w>0.50$ for the effect size for relational contingency tables. Differences between male and female performance was determined with analysis of box and whisker plots and the effect size difference between the two groups was calculated according to Ellis and Steyn (2003). A confidence level of not less than 87% was achieved for the total population for all the parameters that were tested.

3. Results and Discussion

3.1 Anthropometric characteristics

There were 38 females (mean age of 22 years) and 149 (mean age of 27 years) males who successfully completed the two days of the testing schedule. The age and anthropometric characteristics of these subjects are presented in Table 3.

Table 3 : Anthropometric characteristics of subjects

Variables	Females			Males		
	n	$\bar{X}$	±S.D	n	$\bar{X}$	±S.D.
Age [yrs]	37	22	2.3	143	27	5.1
Stature [mm]	38	1624	61.4	149	1719	65.6
Mass [kg]	38	63.3	9.2	149	67.5	10.3
Outer leg length [mm]	38	835	59.6	149	889	47.6
Arm length [mm]	38	543	35.9	147	585	29.7

3.2 Aerobic capacity

The estimated aerobic capacity for the females and males subjects was 33.2 ml/kg/min ±4.3 ml/kg/min and 43.6ml/kg/min ±5.8 ml/kg/min respectively.

3.3 Strength tests

A summary of the descriptive statistics for the strength parameters is presented in Table 4 for the total population. The values are presented in newton [N].

Table 4 : Summary statistics of the strength tests

Strength variable		Strength exertion [N]	
	n	$\bar{X}$	±S.D.
Grip L hand	187	435	85.0
Grip R hand	187	446	85.8
Back strength	186	357	98.4
L elbow concentric flexors	187	124	42.2
R elbow concentric flexors	187	127	45.2
L elbow eccentric flexors	187	194	63.3
R elbow eccentric flexors	187	199	60.9
L elbow concentric flexor peak force at 50% fatigue	187	87	29.7
R elbow concentric flexor peak force at 50% fatigue	187	85	28.8
L elbow concentric extensor peak force at 50% fatigue	187	104	32.1
R elbow concentric extensor peak force at 50% fatigue	187	112	32.8
L knee concentric flexors	186	310	76.8
R knee concentric flexors	186	316	80.1
L knee concentric extensors	186	120	46.9
R knee concentric extensors	185	224	72.0
L knee concentric flexor peak force at 50% fatigue	186	524	121.6
R knee concentric flexor peak force at 50% fatigue	186	544	131.6
L knee concentric extensor peak force at 50% fatigue	186	150	62.7
R knee concentric extensor peak force at 50% fatigue	185	268	77.2

When compared to British data (DTI, 2003) for males, the mean handgrip for this population was lower, but had a slightly higher mean when compared to the RSA-MIL-STD: VOL 5 (2001) data also for males. Likewise, the handgrip strength of the subjects tested in this study was higher than the corresponding USA value MIL-STD-1472-F (1999). There is currently no South African published database to which to compare the back strength data or arm and leg strength with similar test protocols.

3.4 Perceived strain scale

The ratings are given on a scale of 6 to 20. The summary statistics for the perceptual results are presented in Table 5. All the conditions for handling both the 47 kg and the 35 kg objects were rated between 7 (fairly light) to 20 (extremely heavy work). The mean for the total population that could lift the 47 kg object was 16 (heavy). The mean rating for the 35 kg object was 13 and 9 for the 20 kg object. The 47 kg handled to the lowest level was rated as the most difficult and the 20 kg on the lower and middle levels were rated the easiest handling conditions by the total group. There was a slight correlation ($0.30 > r < 0.60$) between the PSS rating and the NOC handled for both the 47 kg and 35 kg conditions.

Mital *et al.* (1997) reported good validity when using a psychophysical methodology for determining manual handling ability. An individuals' perception of the mass and one's strength capability to handle that mass is usually a good indicator of one's performance ability. However in this study, there was no correlation between the PSS and the NOC for the 20 kg load conditions, which indicates that the ability to handle the lighter mass is more likely, linked to other individual characteristics than that of their perceived exertion.

There are other influencing factors such as motivation which were not addressed specifically in this study, but which can impact the actual functional performance. There was however an element of competition observed by the research team of the test groups that comprised primarily of young men. The subjects often responded with an increased physical effort to the cheering of their colleagues. This aspect contributed to motivation as the men tried to look good in front of their friends. This same element was not observed in test groups comprising of women or older men.

Table 5 : Rate of perceived strain scale [PSS] per condition

	Total [PSS]		
Conditions	n	$\bar{X}$	S.D.
NOC 47L	179	7	3.1
NOC 47H	175	7	3.4
NOC 47M	172	6	3.2
NOC 35L	180	8	3.0
NOC 35H	179	9	3.3
NOC 35M	178	8	3.1
NOC 20L	180	12	2.5
NOC 20H	180	12	3.1
NOC 20M	180	12	2.8

3.5 Functional lift and carry test

The first aim of the study was to determine if the worker population could safely match the job requirements with regards to a manual handling task. The actual task demands required the handling of a 47 kg object with a cycle rate of 8 in 4 minutes to any of the three levels. Table 6 presents the percentage of the population that successfully completed each handling condition. Forty three percent of the subjects could successfully handle the 47 kg object for all of the levels for the required duration. None of the women participants were able to successfully complete the necessary number of repetitions and duration of the tasks. The middle level was the most limiting for the total population.

The 35 kg object could successfully be handled by 68 % of the subjects to the low level, whilst 74% and 70% could handle it at the high and middle levels respectively. From the number of objects carried as presented in Table 6, it was apparent that both the 47 kg and 35 kg was extremely challenging for the females. At 0% and 5% respectively for the middle level, they were therefore unable to successfully complete the handling requirement for the job. However, 84% of the women were able to complete the 20M condition and 74% and 89% successfully completed the 20H and 20L conditions respectively. The 47 kg conditions were likewise challenging for many of the men that resulted in 55% that were successful in handling that mass to all levels. Eighty five percent of the males were successfully able to complete all the 35 kg conditions, and a 100% were able to complete the 20 kg conditions in accordance with the actual task requirements.

Table 6 : Percentage of successful completion of the conditions

Object Mass	Low shelf [%]			High shelf [%]			Middle shelf [%]		
	Total	Female	Male	Total	Female	Male	Total	Female	Male
47kg	54	5	67	58	8	71	43	0	55
35kg	68	5	85	74	16	90	70	5	88
20kg	98	89	100	95	74	100	97	84	100

The summary results of the functional handling test for both genders and the total group are presented in Table 7.

Table 7 : Number of objects carried NOC per condition in 4 minutes

Conditions	Total group			Female			Male		
	n	$\bar{X}$	S.D.	n	$\bar{X}$	S.D.	n	$\bar{X}$	S.D.
NOC 47L	179	7	3.1	36	4	2.1	137	8	2.5
NOC 47H	175	7	3.4	33	3	2.3	137	8	2.9
NOC 47M	172	6	3.2	31	2	1.9	136	7	2.7
NOC 35L	180	8	3	38	5	1.6	137	9	2.5
NOC 35H	179	9	3.1	37	5	2.4	137	10	2.5
NOC 35M	178	8	3.1	36	4	1.9	137	10	2.5
NOC 20L	180	12	2.5	38	9	1.3	137	12	2.1
NOC 20H	180	12	3.1	38	8	2.4	137	13	2.4
NOC 20M	180	12	2.8	38	9	2	137	13	2.3

There was an increase in the mean number of 35 kg objects handled, when compared to the mean number of the 47 kg objects handled, but it did not exceed two NOC. However, improvements of up to 5 NOC on the mean performance were recorded between the 20 kg object handled and of the 47 kg object, refer to Table 7. Similar trends were seen for the male and female subgroups. All of the variables showed a large effect size (d>0.8) for the functional lifting results between the males and females.

It was observed by the research team during these trials that those women, who were unable to get the object onto the shoulder to carry over the 30 m, were frequently unable to complete the required number of repetitions. The high shelf level did assist some of the women to position the object on and off their shoulders. The low shelving required that the object be slid out, and lifted from below knee level to their shoulders and was most difficult. The middle shelf although set at a more desirable handling height from a biomechanical view, (Mital *et al.* 1997) proved to be affected by the shelving design.

This resulted in some restriction of manoeuvrability of the object as seen by the lowest NOC mean values for the 47 kg and 35 kg at 2 and 4 respectively, refer to Table 7. The issue that must be noted as a contributing reason to the drop in performance for the middle level was as follows: the middle shelf had a top and bottom surface for reasons of stability in the shelving construction. This configuration was similar to the bins at times used for the actual manual handling task. However, the lower and higher shelves did not have a confining top layer, thus it was easier to manipulate the object on those levels.

3.6 Correlations and practical effect size

In accordance with the second aim of this study, correlations were determined between the measured variables. The results of the Spearman correlation test and practical effect size are presented in Table 8 for those variables only that showed a slight or strong relationship with the functional lift and carry test. There were no strong correlations ($r<0.30$) found between functional lifting capacity as determined by NOC and the other anthropometric and strength variables measured (those that are not included in the Table 8). Only slight correlations ($0.30>r<0.60$) were found for the NOC on all conditions for both VO_2 (aerobic capacity) and right knee concentric extensor endurance.

There were strong correlations ($r>0.60$) between the number of objects carried for the 47 kg object and the lifting of the same mass to the other levels within that condition. Likewise, the same results were found with the 35 kg condition ($r>0.60$) if a subject could lift and carry objects on one level, they could manage on all levels. The NOC 20L had strong correlations ($r>0.60$) to both the NOC 20H and to NOC 20M conditions. However, there was only a slight correlation ($0.30>r<0.60$) between the NOC 20M and NOC 20H. There was a strong correlations ($r>0.60$) recorded for the NOC 47H and NOC 47M with both NOC 35H and NOC 35M. There was only slight correlations ($0.30>r<0.60$) between the NOC 47L and all the 35 kg conditions. This result suggests that those persons who could carry the 35 kg object would probably still manage the 47 kg on the high and middle levels. The 35 kg appears to be the limiting factor within this study design. However, it may well be even a lower mass that was not tested for in this experiment. There was only a slight correlation (0.30>r<0.60) between the number of 20 kg objects handled and the number of objects carried for the 35 kg and 47 kg conditions for all levels with the exception of NOC 20L and NOC 35M. This relationship showed a strong correlation at r=0.65.

Table 8: Correlation values for those variables with results r>0.30 to the NOC

Variables	NOC 47L	NOC 47H	NOC 47M	NOC 35L	NOC 35H	NOC 35M	NOC 20L	NOC 20H	NOC 20M
VO_2	0.23	*0.38*	*0.37*	*0.38*	*0.37*	*0.49*	*0.43*	*0.47*	*0.47*
R knee con ext.endurance	*0.54*	*0.32*	*0.5*	0.27	0.23	*0.43*	*0.36*	*0.3*	0.24
NOC 47L	1	**0.65**	**0.7**	*0.52*	*0.53*	*0.5*	*0.34*	*0.33*	0.28
NOC 47H	**0.65**	**1**	**0.77**	**0.64**	**0.71**	**0.71**	*0.56*	*0.48*	*0.41*
NOC 47M	**0.7**	**0.77**	**1**	**0.65**	**0.66**	**0.74**	*0.53*	*0.54*	*0.43*
PSS 47L	*-0.4*	*-0.52*	*-0.4*	*-0.34*	*-0.43*	*-0.44*	*-0.37*	-0.26	-0.25
PSS 47H	*-0.52*	*-0.55*	-0.27	-0.26	*-0.4*	-0.27	-0.16	-0.15	-0.02
PSS 47M	*-0.48*	*-0.4*	*-0.38*	*-0.3*	*-0.38*	-0.29	*-0.35*	-0.25	-0.25
NOC 35L	*0.52*	**0.64**	**0.65**	**1**	**0.7**	**0.63**	*0.47*	*0.52*	*0.33*
NOC 35H	*0.53*	**0.71**	**0.66**	**0.7**	**1**	**0.69**	*0.55*	*0.54*	*0.51*
NOC 35M	*0.5*	**0.71**	**0.74**	**0.63**	**0.69**	**1**	**0.65**	*0.58*	*0.56*
PSS 35L	*-0.53*	*-0.43*	*-0.5*	*-0.41*	*-0.55*	*-0.43*	-0.28	-0.28	*-0.31*
PSS 35H	*-0.47*	**-0.6**	**-0.6**	*-0.53*	**-0.72**	*-0.48*	*-0.39*	*-0.42*	*-0.37*
PSS 35M	*-0.38*	*-0.33*	*-0.48*	*-0.44*	*-0.53*	*-0.39*	*-0.37*	*-0.34*	*-0.38*
NOC 20L	*0.34*	*0.56*	*0.53*	*0.47*	*0.55*	**0.65**	**1**	**0.78**	**0.77**
NOC 20H	*0.33*	*0.48*	*0.54*	*0.52*	*0.54*	*0.58*	**0.78**	**1**	*0.51*
NOC 20M	0.28	*0.41*	*0.43*	0.33	*0.51*	*0.56*	**0.77**	*0.51*	**1**
PSS 20L	*-0.57*	*-0.51*	*-0.56*	-0.27	*-0.53*	*-0.5*	-0.16	-0.2	0.22
PSS 20H	-0.18	-0.21	-0.24	-0.03	*-0.39*	-0.14	0.09	-0.1	0.03
PSS 20M	*-0.42*	*-0.39*	*-0.41*	-0.19	*-0.46*	-0.3	-0.16	-0.17	-0.25

*Strong correlation = (**r>0.60**), slight *(0.30>r<0.60)*

Large practical effect size = (r>0.50), moderate (0.30>r<0.50)

For this population the practical effect size is considered to be large for all of the functional lift tests with the exception of some of the 20 kg conditions, which are considered to have a moderate effect size. This suggests that the practical effect of these functional lift tests can be used with confidence.

4. Conclusions and Recommendations

The results of this study clearly indicate a mismatch between the manual handling task demands and the capability of the current worker population. The implications are that there is a potentially high risk for the incidence of musculoskeletal injuries or complaints, increased fatigue and reduced productivity all of which are undesirable in a working situation for this job profile. When compared with the task demands for manual handling required in the job under investigation, less than half of the subjects could safely and continuously lift and carry the actual mass of the objects to the required heights. Whereas, there were more than 80 % of the population could safely and continuously handle the 20 kg object to the required heights. A reduction in the configuration of the object to a 20 kg or lower mass would already increase the worker population that would be able to safely handle the object to the required levels, distances and repetitions. Any future redesign of the task or acquisition of the object should be specified to not exceed 20 kg. Should this not be a realistic option within the near future, then a selection criteria based on the functional lift and carry test can be implemented for the personnel.

As expected there was a large effect size difference in the manual handling capability of the female and male personnel. It must be understood that open placement of personnel, regardless of their capability to fulfil the physical demands can only result in either injury or failure to meet performance requirements. The current practise of manning personnel of both mixed gender and capability lends itself to an unfair work load distribution in an attempt to get the job done with the available crew capabilities. This situation is neither fair nor optimal. The one way to rectify this situation is to ensure that future design of manual handling tasks should be within the capability of the greater total population.

This study design made use of three different masses only. The results suggest that the 35 kg object lift and carry could be used as a screening selection criterion for the actual 47 kg object. Future investigations of masses between 35 kg and 20 kg may well reveal another mass that could provide more accurate prediction of the successful performance of personnel selected for the actual job requirements. The selection criterion test must be based on the ability to successfully complete the objective functional physical demands and must not be gender biased.

Levels of fitness and of work experience in handling the object were not analyzed in this study, and both may well have influence on the results and require further investigation, with specific emphasis on improvement of performance with conditioning to the task.

The correlations indicate that functional performance cannot be predicted using anthropometric, age or body mass. Furthermore, that the strength tests used in the protocol cannot be used as predictive of a functional performance level. There were however, the VO_2max, leg force endurance and back strength as indicators that warrant further investigation. While this specific arm strength test parameter did not feature statistically as a predictor, through observation, the ability to lift the object onto one's shoulder for load carriage and not to hold the object in the arms, did indeed have an effect on performance, thus upper body strength remains an issue.

Ergonomics recommendations regarding the reduction of risk inherent in this task would include reducing the number of repetitions of handling of the object with the introduction of automated material handling systems, investigate alternative packaging of the object in order to reduce the mass and the introduction of a gender independent selection screening test.

5. Acknowledgements

Thanks go to the Landward Institute, SANDF for funding of this project, to all the participants in the study and to the North-West University, School of Biokinetics, Recreation and Sports Science for the successful outcome of this project.

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CHAPTER FOUR

Summary, conclusions and recommendations

Summary, conclusions and recommendations

4.1 SUMMARY

Problems regarding a specific job manual handling task within a military environment were raised due to concerns for the health and safety of the workers as well as their actual capacity to perform the required tasks. Answers were required regarding the capacity of the current worker population to safely and successfully perform the actual manual handling task for future management of both the personnel and the task.

Prior to conducting the research study, a task analysis of the manual handling task was conducted and the relevant ergonomics components quantified. It was determined from the task analysis that; the mass, the work heights and the high frequency of handling the objects were challenging and presented as ergonomics potential risk hazards for a general population. The study involved the determination of the muscle strength capabilities and other characteristics such as anthropometry and aerobic capacity of the current worker population that was employed to do this task. A specific functional test was also designed based on the critical task components determined from the task analysis and administered to a sample of convenience of one hundred and eighty seven members of the current workforce which was three hundred strong. The sample group also consisted of thirty eight women which represented the entire group of women employed at that time. Each subject underwent two days of tests which included; anthropometric measurements, aerobic capacity estimate test, isokinetic muscle strength tests of the arms and legs on the Cybex unit, a back strength isometric test using a dynamometer on the first day, and then the functional lift and carry test on the second day. The functional lift test made use of dummy objects of three masses; 20 kg, 35 kg and 47 kg (the mass of actual object).

The findings of the study indicated that for the current physical demands, only 43% of the current population could safely and continuously handle the 47 kg object. However, more than 80% could safely and continuously handle a dummy object of a 20 kg mass, to all levels for the required repetitions and time durations.

The correlation tests indicate a strong correlation between the number of 35 kg and 47 kg objects carried on the lift and carry test. Other correlations were moderate for predicted aerobic capacity and right knee concentric extensor endurance strength and the number of objects carried. There was no correlation between the other test parameters and the functional lift ability tests. Thus, it is suggested that the best predictor for functional performance would be the functional lift and carry test. This test should be used as a basis for a screening criteria tool, which would be required to be implemented should the current manual handling systems remain in place.

There was large effect size differences noted between the genders for the functional lifting capabilities. None of the females were able to successfully complete the lift and carry test which replicated the actual task demands with the 47 kg object.

It must be acknowledged and accepted that the profile of the user of these systems has changed in the past decade, and that to expect a worker to continue to exert him or herself beyond their capabilities would result in the occurrence of fatigue that could affect performance, and exposure to the risk of musculoskeletal injury.

4.2 CONCLUSIONS

The following hypotheses were posed in the research proposal and the results of the hypothesis are then discussed.

HYPOTHESIS 1 : The manual handling capabilities of the current ammunition handlers does not match the requirements of the job.

A functional lift and carry test was designed to represent key ergonomics components of the actual manual handling task under investigation. The components included; mass, shape and form of the object that was handled manually; the maximum distance that the object was carried; the maximum and minimum heights that the object was lifted to; the time and duration of the manual handling task. The results indicate that 43% of the total sample population were able to successfully complete the task requirements. Of the total population, none of the females that participated were able to successfully complete the task requirements. The statistically large effect size indicates that the manual handling capabilities of the current workers does not match the requirements of the job.

Hypothesis 1: is therefore accepted on the findings of this study.

HYPOTHESIS 2: The aerobic capacity, physical strength exertion and anthropometric characteristics show strong statistical correlations with the manual handling capability of the ammunition handler.

The aerobic capacity showed a moderate correlation ($0.30>r<0.60$) with the results of the functional lift and carry test. The isokinetic arm strength tests that were conducted on the Cybex unit did not correlate well with the results of the functional test. The specific arm test that was used to simulate the primary muscle movers of lifting and lowering an object within waist to shoulder levels was dictated by the confines of the instrumentation used. However, observations of those who could or could not complete the functional lift and carry test were often linked with persons who could lift the object onto their shoulder. This action required more emphasis on shoulder muscle strength and not just upper arm muscle strength. Thus, investigations into an alternative arm strength test should be considered in future studies to identify screening selection tests. Of the isokinetic leg strength data that was collected on the Cybex, only the results for the right knee concentric extensor endurance test demonstrated a moderate correlation ($0.30>r<0.60$) with that of the functional lift test. There were no correlations between the other measured parameters including all anthropometric characteristics and the isometric back strength test, and that of the results of the functional lift test. The rationale of the objective in testing this hypothesis was that test parameters with strong correlations may lead to further investigations for use as a cost effective means of employee screening selection criteria. None of the other test parameters used in this protocol show promise as a screening selection criteria. The only strong correlations demonstrated were between the functional lift test conditions on all levels for 47 kg and for the 35 kg on all levels, and between the 20 kg for the high and middle levels. There were likewise strong correlations between the 47 kg and 35 kg for both the high and middle levels. As the functional lift test was based on the critical components of the actual manual handling task, it shows the most promise to be used as an employee selection test. It can further be derived that the 35 kg test on the middle level should be investigated as a base line condition.

Hypothesis 2 is therefore rejected on the findings of this study.

HYPOTHESIS 3 : There are significant differences in the functional strength capabilities between the male and female soldiers.

The sample population was drawn from a sample of convenience and thus the statistician's advice was to make use of a effect size calculation for d value rather than the statically significant p value, which is used on randomly drawn samples. There was a large effect size ($d>0.50$) calculated for the difference between the functional lifting strength capabilities of the male and female participants for the conditions of all three masses, 20 kg, 35 kg and 47 kg. The implication here should not be that this manual handling task be made available to men only. This is not in keeping with current legislation, but rather that all efforts should be made to redesign the task, such that a larger proportion of the population would be capable of performing the task. Should the redesign of the task not be possible within a reasonable timeframe, it is recommended that a selection criterion for personnel be introduced, such that a man or woman who is capable of doing the job safely, may be employed to that post. It must further be noted that it not prudent to put the emphasis on employee representativeness with regard to gender without looking at the capabilities of the person in comparison with the job requirements. The result may well be increased risk to health and safety of the person and decrease in performance ability.

Hypothesis 3 is therefore accepted based on the findings of this study.

4.3 RECOMMENDATIONS

A multi-faceted approach was taken in this study in order to comprehensively address the objectives of this study.

The results and recommendations that were forthcoming from this study have been drafted into one larger article to be submitted to a peer reviewed journal for publication. The findings were also published in a technical report for delivery to the client in a format that was suitable for their purposes and well as in a power point presentation to the stakeholders involved.

The following recommendations are proposed:

4.1.1 The findings of this study indicate that the current population cannot safely perform the manual handling requirements of the task, thus one of two actions should be considered: 1) to redesign the task, 2) to implement an employee selection criteria.

4.1.2 Should the task be redesigned, this study indicates that a change of mass alone, from the current 47 kg to a mass of 20 kg or less would improve the performance of the current population from 43 % to 98 %.

4.1.3 The functional lift and carry test could be repeated with masses other than the 20 kg and the 35 kg that has been tested in this study. These investigations would more accurately define the cut-off mass for the total population.

4.1.4 The task should be redesigned to reduce the number of repetitions that the object is handled as well as the levels above shoulder height. An automated loading system would be the optimal solution.

4.1.5 An alternative arm isokinetic test protocol should be investigated that may result in a higher correlation with the functional test results for use in a screening criterion. The test should focus on shoulder elevator muscle strength.

4.1.6 Other parameters such as the VO_2 max, leg force endurance and back strength warrant further attention as potential predictors for functional performance.

Neither levels of fitness nor levels of experience were investigated within the scope of this study in relation to functional manual handling performance. Further investigations should address these aspects as they would be expected to influence the performance results, and could be incorporated into a conditioning programme to improve performance.

APPENDIX A

Guidelines to Authors for the Ergonomics journal and SA Ergonomics journal.

Guidelines to Authors

1. SEE NOTES FOR CHAPTER 2

INFORMATION FOR CONTRIBUTORS

ERGONOMICS SA is a BI-ANNUAL publication of the Ergonomics Society of South Africa aimed at promoting scholarly and professional interest in the domain of humans at work. Six categories of contribution are recognised: Research papers; Review Articles; Methodological Reports; Case Studies and Observational Records; Research Notes/Updates; News and Views.

Specific Instruction to Authors

1. The title should be concise but sufficiently informative for information retrieval purposes.
2. The language of the Journal, to facilitate its contribution to the sub-continent, is English.
3. Arrange the manuscript as follows:
   i. Title page, including full title of the article (**Arial, BOLD CAPS, 15 font**), name(s) of author(s) and source of work, full address of the first author (**Arial 11 font**).
   ii. Title, repeated, and an abstract (**Arial 10 font**, *italics*) of no more than 200 words summarising the manuscript. No author identification
   iii. Text of manuscript (**Arial 10 font, Headings Arial, BOLD CAPS, 14 font**), followed by references; these pages numbered consecutively from start of text proper to references and acknowledgements (if any).
   iv. Tables, if any, each on a separate unnumbered page. Each table to be numbered (**Roman capitals**) and given a title (**title in bold**).
   v. Figures, if any, each on a separate unnumbered page, Diagrams must be drawn in black ink and the original presented on white card in A4 size, or lazer quality equivalent. Authors should note that illustrations must be accommodated in single (70 mm) or double (160 mm) columns in the journal. On the reverse face of each submitted figures, in soft pencil, the Figure number should be indicated and (originals only) the names of the author(s).

vi. Captions (**title in bold**), each on a separate page, must be provided for each figure. Figure captions to be numbered (**Arabic capitals**).

General Notes

The journal recognises the Systeme International d'Unites (SI Sytem) only and, in conformity with major international journals in the field, accepts the point rather than the comma to designate decimals.

Reference lists must be presented alphabetically by author, according to the following convention:

FOR JOURNAL ARTICLES:

Datta, SR, Chatterjee BB and Roy BN (1975). Maximum permissible weight to be carried on the head by a male worker from Eastern India. **Journal of Applied Physiology**, 38: 132-135.

Lundberg V, Granqvist M, Hansson T, Magnusson M and Wallin L (1989). Psychological and physiological stress responses during repetitive work at an assembly line. **Work and Stress**, 3(2): 143-153.

FOR BOOKS:

Tichauer E R (1978). **The Biomechanical Basis of Ergonomics**. New York: John Wiley and Sons.

FOR CONFERENCE PROCEEDINGS:

Snijders CJ, Seroo JM, Snijder JG and Hoedt HT (1976). Change in form of the spine as a consequence of pregnancy. Digest of the 11th International Conference on Medical and Biological Engineering. 670-671, Ottawa, 4-8th April.

MANUSCRIPT SUBMISSIONS

Original and two copies of the manuscript should be mailed direct to:

Prof P A Scott Editior-in-Chief : Ergonomics SA

Ergonomics Unit, Department of Human Kinetics and Ergonomics, Rhodes University

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2. SEE NOTES FOR CHAPTER 3

Further Notes on Style

General Style

Authors are asked to take account of the diverse audience of the journal. Please avoid the use of terms that might be meaningful only to a local or national audience, or provide a clear explanation where this is unavoidable. However, papers that reflect the particularities of a social and cultural system are acceptable.

Some specific points on style follow:

1. 'US' is preferred to 'American', 'USA' to 'United States', and 'UK' to 'United Kingdom'.
2. Conservative British, not US, spelling is preferred: colour not color; behaviour (behavioural) not behavior (behavioral); [school] programme not program; [he] practises not practices; centre not center; organization not organisation; analyse not analyze; etc.
3. Single quotation marks rather than double are used unless the 'quotation is "within" another'.
4. Punctuation should follow the British style, e.g. 'quotation marks precede punctuation'.
5. Punctuation of common abbreviations should adhere to the following conventions: 'e.g.'; 'i.e.'; 'cf.'. Note that such abbreviations should not generally be followed by a comma or a (double) point/period.
6. Dashes: N-rules (–) and M-rules (—) should be used where needed in applications on disc if possible, or be clearly indicated in manuscripts by way of either a double or a triple hyphen, (--) or (---), respectively.
7. Upper case characters in headings and references should be used sparingly, e.g. only the first word of paper titles, subheadings and any proper nouns begin upper case; similarly for the titles of papers from journals in the references and elsewhere.
8. Apostrophes should be used sparingly. Thus, decades should be referred to as follows: 'The 1980s [not the 1980's] saw...'. Possessives associated with acronyms (e.g. APU), should be written as follows: 'The APU's findings that...' but note that the plural is 'APUs'.
9. All acronyms for national agencies, examinations, etc., should be spelt out the first time they are introduced in text or references. Thereafter the acronym can be used if appropriate, e. g. 'The work of the Assessment of Performance Unit (APU) in the early

1980s...' and subsequently, 'The APU studies of achievement...'; in a reference '(Department of Education and Science [DES] 1989a)'.

10. Brief biographical details of significant national figures should be outlined in the text unless it is quite clear that the person concerned would be known internationally. Some suggested editorial comments in a 'typical' text are indicated in the following with square brackets: 'From the time of H. E. Armstrong [in the 19th century] to the curriculum development work associated with the Nuffield Foundation [in the 1960s], there has been a shift from constructivism to heurism in the design of [British] science courses'.

11. The preferred local (national) usage for ethnic and other minorities should be used in all papers. For the USA, 'African-American', 'Hispanic' and 'Native American' are used, e.g. 'The African-American presidential candidate, Jesse Jackson...'; for the UK, 'West Indian ' (not 'Afro-Caribbean'), etc.

12. Material to be emphasized by italicization in the printed version should preferably be italicized in the typescript rather than underlined. Please use such emphasis sparingly.

13. Numbers in text should take the following forms: 300, 3000, 30 000 (not 30,000). Spell out numbers under 10 unless used with a unit of measure, e.g. nine pupils but 9 mm (do not introduce periods with units). For decimals, use the form 0.05 (not .05, × 05 or 0× 05). '%' (not 'per cent') should be used in typescripts.

14. Appendixes should appear before the references section and after any acknowledgments section. The style of the title is shown by the following example:

'Appendix C: The random network generator'

Figures and tables within appendixes should continue the sequence of numbering from the main body of the text. Sections within appendixes should be numbered, for example, C.1, C.2, ... Equations in appendixes should be numbered, for example, (C 1), (C 2), ... If there is only one appendix, it is called and referred to as 'Appendix A'.

Top of page

Title and authors

Title: the title should be initial capital letter only (except for names), bold and centred on the page; e.g.

This is the title of the paper

For over-long titles, please supply a shortened version, which can be used as a running head for the article.

Authors: Author names should be in block capitals and followed by the link to the relevant affiliation (if there is more than one) and an asterisk to indicate the corresponding author, centred on the page; e.g.

A. N. OTHER*† and J. BLOGGS‡

Affiliation: Centred on the page, preceded by the link to the appropriate authors, each affiliation appearing on its own line; e.g.

†University of Life, UK
‡University of Style, UK

Top of page

Abstracts

Structured abstracts of 100 – 150 words, summarizing the significant coverage and findings of the paper are required for all papers, and should be submitted as detailed below, following the title and authors' names and addresses, preceding the main text.

For papers reporting original research, state the **primary objective** and any hypothesis tested; describe the **research design** and your reasons for adopting that methodology; state the **methods and procedures** employed, including where appropriate tools, hardware, software, the selection and number of study areas/subjects, and the central **experimental interventions**; state the **main outcomes and results**, including relevant data; and state the **conclusions** that might be drawn from these data and results, including their implications for further research or application/practice.

For review essays, state the **primary objective** of the review; the reasoning behind your literature selection; and the way you critically analyse the literature; state the **main outcomes and results** of your review; and state the **conclusions** that might be drawn, including their implications for further research or application/practice.

Format: No 'Abstract' title, text indented both sides.

Keywords: Each paper should have three to six keywords. Format: Keywords indented from the left-hand side (as the Abstract text), in the form:
Keywords: Keyword; Keyword

2000 Mathematics Subject Classification codes: Each paper should have two to six classification codes. Format: Classifications indented from the left-hand side (as the Abstract text), in the form:
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Top of page

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Three levels of headings can be used, as described below.

(A) Flush left, numbered, bold, initial cap only, spaces above and below.
(B) Flush left, numbered, bold, italic, initial cap only, spaces above and below.
(C) Flush left, numbered, bold, initial cap only, space above, text runs on after full point.

The first paragraph of text under each heading should not be indented. All consecutive paragraphs should be indented.

Top of page

Tables and figures

Artwork submitted for publication will not be returned and will be destroyed after publication, unless requested otherwise. Whilst every care is taken of artwork, neither Editors nor Taylor & Francis shall bear any responsibility or liability for its non-return, loss or damage, nor for any associated costs or compensation. Authors are strongly advised to insure appropriately.

1. Tables and figures should be informative, relevant and visually attractive. The style and spelling of lettering in figures must correspond to the main text of the manuscript. Tables and figures must be referred to in the text and numbered with consecutive Arabic numbers in the order of their appearance ('see table/figure 1'; 'see tables/figures 1–4'). Each table and figure should have a stand-alone descriptive caption that explains its purpose without reference to the text; each table column should have an appropriate heading. Avoid the use of vertical rules in tables.

2. The ideal place at which a table or figure should be inserted in the printed text should be indicated clearly in the manuscript:

'[Insert table 2 about here]'

3. Figures and tables must be on separate sheets or in separate files and not embedded in the text. Original artwork for figures should be supplied. The scale of figures should allow for reduction to column width (130 mm) or page width (160 mm) or page length (205 mm) if to be placed landscape, but landscape reproduction (i.e. reading from bottom to top of the page) should be avoided. Photographs may be sent as black and white glossy prints or negatives.

Please number each figure on the reverse lightly in pencil.

Please do not type the caption for a figure on the artwork for that figure. A separate list of figure captions should appear at the end of the manuscript.

Top of page

Mathematics

Special care should be taken with mathematical scripts, especially subscripts and superscripts and differentiation between the letter 'ell' and the figure one, and the letter 'oh' and the figure zero. If your keyboard or PC does not have the characters you need, or when using longhand, it is important to differentiate between: K and k; X, x and × (multiplication); asterisks intended to appear when published as multiplication signs and those intended to remain as asterisks; etc. Special symbols, and others used to stand for symbols not available in the character set of your PC, should be highlighted in the text and explained in the margin. In some cases it is helpful to supply annotated lists of symbols for the guidance of the subeditor and the typesetter, and/or a 'Nomenclature' section preceding the 'Introduction'.

In both displayed equations and in text, scalar variables must be in italics, with non-variable matter in upright type.

For simple fractions in the text, the solidus '/' should be used instead of a horizontal line, care being taken to insert parentheses where necessary to avoid ambiguity. Exceptions are the proper fractions available as single type on keyboards and in character sets (e.g. ¼, ½, ¾).

The solidus is not generally used for units: m s-1 not m/s, but note electrons/s, counts/channel, etc.

Displayed equations referred to in the text should be numbered serially ((1), (2), etc.) on the right-hand side of the page. Short expressions not referred to by any number will usually be incorporated in the text.

Symbols used to represent tensors, matrices, vectors and scalar variables should either be used as required from the character set of the application you are using or marked on hardcopy by underlining with a wavy underline for bold, a straight underline for italic and a straight red underline for sans serif.

The following styles are preferred: upright bold sans serif **r** for tensors, bold serif italic ***r*** for vectors, upright bold serif for matrices, and mediumface sloping serif *r* for scalar variables. In mathematical expressions, the use of "d" for differential should be made clear and coded in roman, not italic.

Typographical requirements must be clearly indicated at their first occurrence, e.g. Greek, Roman, script, sans serif, bold, italic. Authors will be charged for corrections at proof stage resulting from a failure to do so.

Braces, brackets and parentheses are used in the order {[( )]}, except where mathematical convention dictates otherwise (e.g. square brackets for commutators and anticommutators; braces for the exponent in exponentials).

For units and symbols, the SI system should be used. Where measurements are given in other systems, conversion factors or conversions should be inserted by the author.

Mathematical equations should preferably be typewritten, with subscripts and superscripts clearly shown. It is helpful to identify unusual or ambiguous symbols in the margin when they first occur. Please ensure all symbols are described in the text. If equations are numbered, consecutive Arabic numbers in parentheses should be used. Equations may be referred to in the text as 'equation (1)', 'equations (2)–(4)'. To simplify typesetting, please use: (1) the "exp" form of complex exponential functions; (2) fractional exponents instead of root signs; and (3) the solidus (/) to simplify fractions e.g. 3/4, exp $x1/2$. Other letters not marked will be set in roman type. Please supply reproducible artwork for equations containing ring formulae and other complex chemical structures. Schemes should also be numbered with consecutive Arabic numbers.

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Footnotes

Authors are encouraged to minimize the use of footnotes. A footnote may include the designation of a corresponding author of the paper, current address information for an author (if different from that shown in the affiliation), and traditional footnote content. Information concerning grant support of research should appear in a separate Acknowledgements section at the end of the paper, not in a footnote. Acknowledgements of the assistance of colleagues or similar notes of appreciation also properly belong in an Acknowledgements section, not in footnotes.

Footnotes should be indicated in the text by the following symbols: *(asterisk or star), † (dagger), ‡ (double dagger), ¶ (paragraph mark), § (section mark), || (parallels), # (number sign). Do not use numerals for footnote call-outs, as they may be mistaken for bibliographical reference call-outs or exponents. Type each footnote at the bottom of the typescript page on which its text call-out appears.

Footnotes within a table should be indicated by the same symbols listed above. Reinitialize symbol sequence within tables. Type footnotes to a table directly beneath the table.

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Acknowledgments

Any acknowledgments authors wish to make should be included in a separate headed section at the end of the manuscript preceding any appendixes and before the references section. Please do not incorporate acknowledgments into notes or biographical notes.

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References

References should be indicated in the text using the name/date system. Citations in the text: (Smith 1985, Jones 1986, Trevor and David 1987, Bloggs *et al.* 2001) or see Smith (1985). References should be cited in chronological order, *et al.* should be used for 2 or more authors. Listed references should be complete in all details. Please see the examples below for style. References should be listed alphabetically, then chronologically.

BLOGGS, A.B., SIMON, S., CAINE, M. and HEPBURN, A., Year, Style guides are fun. Available online at: www.makeituptheyllneverbelieveit.co.uk (accessed XX Month Year).

BROWN, J. (Ed.), 1988, *Style Manuals Past and Present*, pp.xx-yy (London: Taylor & Francis).

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SMITH, J., 1985, The importance of using the correct format. *Journal of Style*, **15**, pp. 25–30.

TREVOR, P. and DAVID, C., 1993, This is a paper presented at a conference. In *4th International Meeting of Minds*, 24–26 March 1993, Los Alamos, CA (Philadelphia: Taylor & Francis), pp. xx–yy.

FRENCH, F., 1988, *Title of a Book in Another Language*, P. Smith (Transl.) (New York: Dover) (original work published 1923).

Biographies: (Where applicable.) Photo (tif or jpg image) should be supplied for each author, with a concise academic biography.

Book reviews: Should be formatted as shown below:

Title, edited by A. Author and B. Author, Publisher, Location, Year, pages, price, hardback (ISBN XXXXX), paperback (ISBN XXXXX).

One line space before text starts (first paragraph: no indent). At end of text, one line space and then reviewer's name and affiliation to appear as:

Professor John Smith

University of Milton Park, UK

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APPENDIX B

Informed Consent Form

Informed Consent Form

Strength Capabilities – 2002

1. WHO IS DOING THE STUDY?

ERGOTECH have been contracted to complete this project on behalf of the SANDF in conjunction with the University of Potchefstoom, School of Biokinetics, Sports Science and Human movement.

2. WHAT IS THE PURPOSE OF THIS STUDY?

The objective of the project is to establish a baseline of the strength capabilities of the ammunition handlers with regards to their ability to lift and carry loads. The optimal outcome of the project is to ensure the health and safety of the personnel during manual handling tasks.

3. WHERE WILL THE STUDY TAKE PLACE AND HOW LONG WILL THE STUDY LAST?

Two hundred and fifty experienced ammunition handlers or related personnel, will be asked to participate in the study. The study will take place over the month of November 2002 at the School of Biokinetics, University of Potchefstroom. The aerobic capacity bleep test and strength testing using the Cybex machine will be conducted over one day and the functional lifting evaluation will be undertaken on a separate day. Members will be required to attend a full day session for both sets of measurements (i.e. two days in total).

4. WHAT WILL I BE ASKED TO DO?

You will be briefed and asked to sign this informed consent form. Basic general information will be asked of you. Trained university personnel will take your blood pressure while you are seated. Some body dimensions will be taken such as height, weight, arm and leg length as well as grip strength and hand and eye dominance.

There are three sets of measurements that will be taken on different days.

Aerobic VO_2 sub max test : Persons will be asked to participate in an aerobic capacity test which requires you to walk/run 20m repetitively while wearing a heart monitor. You will stop the test when you are tired, the test typically takes no longer than 20 minutes.

Cybex strength test : The procedure will be demonstrated to you and then you will be asked to perform the strength test to the best of your ability. Both arms, legs and back strength will be evaluated.

Functional Lifting/carrying evaluation : You will be asked to lift and carry objects of 3 different masses over 30m and to lift to different heights as you would do when loading an artillery gun. You will be asked to wear a heart rate monitor and rate how "difficult" the task is at different stages, You will be allowed to stop the evaluation at any time.

5. WHAT ARE THE POSSIBLE RISKS AND DISCOMFORT?

The study will not pose any more risks than those you experience in everyday situations when lifting and carrying ammunition. All precautions have been taken to sterilize the physiological equipment used. Trained medical support will be on standby for the duration of the project. You may experience some fatigue following the testing days that should resolve within two days. Report any discomfort experience during the tests immediately to a member of the research team.

6. BENEFITS

There will be no direct benefits to yourself for the duration of the testing, however the results of the investigation will be used to determine how and where to improve your working environment.

7. WHO WILL SEE THE INFORMATION I GIVE

All of the information obtained during this study will remain classified and confidential, to be used as a data base only. No one individual's data will be released to any party.

8. WILL I RECEIVE ANY PAYMENT OR REWARDS FOR TAKING PART IN THIS STUDY?

Participation in and for the duration of this study is voluntary and will not be compensated.

9. WHAT IF I HAVE QUESTIONS?

You will be free to ask any questions to the research team at any time or by contacting the following people:

Lorraine Mac Duff at Ergotech, PO Box 6264, Pretoria, 0001. Tel (012) 665 9400 or Fax (012) 665 0787.
Professor Dawie Malan, School of Biokinetics, University of Potchefstroom, (018) 299-1795
Col de Villiers, School of Artillery (018) 289-3800.

10. DECLARATION OF PARTICIPANT

I confirm that I have read this document and that I understand the contents thereof. I declare that I have been fully informed and that I hereby consent to voluntarily participate in this study and understand that I can stop participation in the study at any stage without experiencing duress from any parties. Furthermore that I have been given the opportunity to ask questions regarding these procedures and that I can ask questions at any time of the research team.

Signatures of participant and witness

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Print name (block letters)	**Force number**	**Signature of Participant**	**Date**

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Print name (block letters)	**Force number**	**Signature of Witness**	**Date**

11. DECLARATION OF RESEARCH MEMBERS

I have fully explained the procedures to be followed during the research project. I have provided the opportunity for the participants to ask any questions or raise any concerns and answered these to the best of my ability. All reasonable actions have been taken to ensure the safety and well being of the participants for the duration of the project.

Signature of research members

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Print name	**Signature of ERGOTECH Research Team**	**Date**