SPEED-RELATED ISOKINETIC AND PSYCHOPHYSICAL RESPONSES OF FEMALE MILITARY PERSONNEL

BY

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ABSTRACT

The present study aims to contribute in an area that has long been neglected, the indigenous female population, about whose physical strength and work-capacity very little is known. Speed-related isokinetic and psychophysical responses of female military personnel were assessed (N=32). Furthermore benchmark data was established for Work-Simulation isokinetic responses where there appears to be limited publication.

Testing was conducted on a CYBEX 6000 isokinetic dynamometer and involved eight tests across a velocity spectrum $30°.s^{-1}$, $120°.s^{-1}$ and $210°.s^{-1}$. The velocity spectrum for gripping was, $30°.s^{-1}$, $60°.s^{-1}$ and $90°.s^{-1}$. Subjects were required to complete two testing sessions with the order of the tests randomized. The first test session consisted of trunk, knee, wrench-turning and gripping and the second session consisted of elbow, pulling/pushing, valve-tightening and shoulder. Cardiovascular responses were measured by using heart rate monitors, and perceptual measures were assessed using Borg's (1971) RPE scale.

Analysis of the data showed significant differences in torque, work and power outputs as velocity increased. Only wrench-turning left and right rotation for peak torque and total work did not show significant reductions. Consistency of effort-level recorded an average of 72% across the selected isokinetic tests. No discernible morphological and strength expression differences were observed between military office workers and infantry personnel, and no significant correlations were recorded between heart rate and RPE values.

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CHAPTER ONE

INTRODUCTION

BACKGROUND TO THE STUDY

An increasingly important factor in the military is the inclusion of female participation in all aspects of military operations, both internationally and nationally. Protzman (1979) noted that females were first accepted into the United States military in 1976, and more recently the South African armed forces have incorporated female recruits. Due to past political constraints not much is known about the morphological diversity of a large percentage of the South African population, more specifically military personnel. As a result the South African National Defence Force (SANDF) has initiated the "African Warrior" programme that promotes ongoing research into the make-up and capabilities of the South African soldier. The present study aims to contribute to an area which has long been neglected, the indigenous female population, about whose physical strength and work-capacity very little is known.

Brown and Weir (2001) maintain that the assessment of strength is fundamental to human performance. A great deal of research evaluating strength requirements has been conducted in the past, but has focussed almost exclusively on Caucasian males (Johnson **et al.**, 1995; Knapik **et al.**, 1996 and Rayson **et al.**, 2000). It is well documented that measurements obtained from Caucasians may have little applicability to other ethnic groups (Malina, 1971; Mueller **et al.**, 1987; Mueller and Malina, 1987 and Zillikens and Conway, 1990). Thus available Caucasian male data, which are primarily based on United States and European armed forces, have little relevance as indicators of the South African female soldier. With the inclusion of female soldiers, together with the mosaic of ethnic groups presently found in the South African armed forces, research into female strength profiles is critical in evaluating soldier requirements for completion of everyday military tasks.

Despite differences in gender and morphology female members of a platoon are required to function as efficiently and optimally as their male counterparts (Protzman, 1979). However, there is substantial evidence illustrating significant differences in the physical capabilities and limitations of males and females (Jones **et al.**, 1993) which in turn, impacts on military efficiency. It has been argued that the average woman has "a smaller inherent aerobic power and less muscular strength than a man, reflecting sociocultural influences, physical size, body composition and hormonal milieu" (Shephard, 2000 pp: 19).

Studies on United States military personnel conducted by Martin and Nelson (1986) and Frykman **et al.** (1994) found that task demands often exceeded the capabilities of troops. Despite increased mechanisation and sophistication of equipment the physical strain experienced by soldiers has not been alleviated. In fact Knapik **et al.** (1996) identified technological developments as being determining factors in a progressive increase in the soldiers' load, with the need for greater fire-power and protection requiring soldiers to carry more and heavier equipment. Despite the importance of strength requirements in military tasks, limited isokinetic musculo-skeletal assessments have been conducted to test the strength capabilities of soldiers. To date no task-relevant strength data for South

African female soldiers are available in the literature. As a consequence, little is understood about the effects of strenuous military tasks on the combat-readiness of SANDF personnel, particularly females.

In the past South African socio-political ethos, equipment design was based on Caucasian normative data and served a predominately Caucasian user population. As a consequence many of the environments in which indigenous workers now function were not designed for them, but for other user populations. This has a potential to lead to job-related fatigue and/or injury; operational difficulties that eventuate in soldier efficiency being compromised. The consequential effects of non-suitable, ill-fitted equipment, together with a lack of specific strength data on South African soldiers, could prove disastrous in a combat situation. It is therefore essential to the SANDF to establish specific ergonomic design criteria to provide a functional interface with the new user population. This will optimise user compatibility and minimise conditions that could degrade troop performance or contribute to human error under pressure.

Sex-related differences have been found in the biophysical responses to physical exertion (Grieve, 1968; Zatsiorky **et al.**, 1994 and Knapik **et al.**, 1996) and physiological responses (Åstrand, 1956; Bransford and Howley, 1977; Haisman, 1988 and Bhambhani and Maikala, 2000) even when differences in body size and composition are taken into consideration (Martin and Nelson, 1985 and Martin and Nelson, 1986). Evans **et al.** (1980) found significant sex-related differences in self-paced hard work, with females adopting absolute energy expenditure 39 to 60% lower than males, depending on the load carried. Differences in all physiological parameters measured when comparing sex-related differences in workloads at varying walking velocities were also noted. However, when the results were expressed relative to a percent of maximal aerobic power no apparent differences were found, with males and females adopting a similar self-paced workload of approximately 44-46% of $V0_2$max.

Numerous studies have reported substantial strength differences between males and females (Laubach, 1976; Fuster, 1998; Fuster **et al.**, 1998; Van der Beek **et al.**, 2000). Furthermore, Padmavathi **et al.** (1999) reported similar findings which persisted even when muscle area relative to males was taken into consideration.

It was argued by Evetovich **et al.** (1998) that males can produce higher torque than females due to greater muscle mass and length. Furthermore, several isokinetic studies have found that with female subjects there was a greater percentage decline in concentric peak torque production as velocity increases (Westing **et al.**, 1988; Colliander and Tesch, 1990 and Evetovich **et al.**, 1998). It is well documented that as the speed of muscular contraction increases the resultant force output diminishes in relation to the decrease in time available to produce that force. This decline in force output is observable throughout the range of motion (Hill, 1938; Wilkie, 1950; Thorstensson, 1976 and Charteris and Goslin, 1982). In a combat situation where tasks are often completed at speed, soldier efficiency may be compromised. Added to this sex-related disadvantage, the concomitant speed-related decrements in strength expression may be substantial enough to warrant design interventions where mixed-sex personnel are exposed to the hazards of military engagements.

The reported differences in absolute work, together with differences in strength expression, raises three critical issues which should be of concern to the SANDF: those of appropriate sex-differentiated training methods; of appropriate sex-based pre-selection criteria particularly in the context of strength expression capability; and of the need for design interventions to accommodate new human-machine interaction profiles.

The ergonomics literature is clear on the need to create an effective ergosystem by matching the task to the abilities of the worker. A poor match between worker and task could predispose the former to cumulative work-related injuries, resulting in poor worker performance, which in a military setting will impact negatively on efficiency in combat situations. In order to minimise the likelihood of a mismatch between soldiers and military requirements, especially during combat, where lives may depend on human efficiency, it is necessary to acknowledge the importance of basic strength requirement on military personnel. While studies have been conducted on the strength of males, there has been no such work completed on Black South African females.

STATEMENT OF THE PROBLEM

Despite the reported sex-based differences in biomechanical and physiological capabilities during loaded marching, military conditions often require that all members of a platoon perform uniformly. Soldiers are therefore being differentially taxed by the task demands, which will have a concomitant effect on overall military efficiency. The likelihood of injury is therefore increased, and strength and endurance become essential considerations in planning efficient upper- and lower-body gender specific training programmes.

No strength data have hitherto been collected on female military personnel in South Africa. The capabilities of female recruits are not yet known and many may in fact not possess sufficient strength for the safe completion of everyday training and working activities over prolonged periods of time. This study considers the effect of velocity on musculo-skeletal strength in female army personnel, as well as the significance these measurements may have for the design of military equipment and optimal performance of foot soldiers.

RESEARCH HYPOTHESES

The present study aims to provide good benchmark data in a comprehensive profile of the strength expression capabilities of the new SANDF female soldier. It is expected that, as the speed of muscular contraction increases, the resultant force output diminishes in relation to the reduction in time allowed to produce that force. It is as yet unknown what the extent of this decrement is in the population of interest.

It is expected moreover, that heart rates in the slow-speed tests, where exertions are of longer duration, will exceed those which are shorter duration responses during fast-speed exertions.

Ratings of Perceived Exertion (RPE) have been shown to correlate highly with measured heart rates during aerobic activities of prolonged duration (Borg, 1982). It is expected that no such strong relationship will be evident between measured heart rate and RPE ratings when short-burst (4-repetition) largely anaerobic maximal muscular contractions are made.

STATISTICAL HYPOTHESES

The statistical hypotheses, stated as Null (H_o) and alternative (H_a) hypotheses were as follows:

1.) No difference exists between slow ($30°.s^{-1}$), medium ($120°.s^{-1}$) and fast ($210°.s^{-1}$) isokinetic strength expression values for Female military personnel.

H_o1: $\mu\ TWP_{(30)} = \mu\ TWP_{(120)} = \mu\ TWP_{(210)}$

H_a1: $\mu\ TWP_{(30)} \neq \mu\ TWP_{(120)} \neq \mu\ TWP_{(210)}$

Where: T= Peak Torque ($Nm.kg^{-1}$); W= Total Work ($J.kg^{-1}$) (BWR); Average Power ($W.kg^{-1}$).

2.) No difference in heart rate exists between slow ($30°.s^{-1}$), medium ($120°.s^{-1}$) and fast ($210°.s^{-1}$) isokinetic tests on Female military personnel.

H_o2: $\mu\ HR_{(30)} = \mu\ HR_{(120)} = \mu\ HR_{(210)}$

H_a2: $\mu\ HR_{(30)} \neq \mu\ HR_{(120)} \neq \mu\ HR_{(210)}$

Where: HR = Heart Rate ($bt.min^{-1}$)

3.) No relationship exists between heart rate (HR) and Ratings of Perceived Exertion (RPE) when short-duration isokinetic strength tests are undertaken.

H_o3: $Rho_{(HR;\ RPE)} = 0$

H_a3: $Rho_{(HR;\ RPE)} \neq 0$

DELIMITATIONS

- The sample, which was one of convenience, comprised female army personnel stationed at the Sixth South African Infantry Battalion Base (6 S.A.I.), in Grahamstown. The study was delimited to the responses of 32 subjects.

- Strength assessments were confined to a laboratory environment. The influence of extreme environmental conditions (which could play a significant role considering South African conditions) was minimised by a controlled environment, thus enabling the data to serve as valuable general baseline indicators of musculo-skeletal capability.

- Strength testing was conducted on the CYBEX 6000 Isokinetic Dynamometer. Subjects were required to complete eight strength test conditions each at three different speeds. The various tests were chosen to best represent the requirements of military tasks in general.

LIMITATIONS

- Subjects were required to perform maximally. Due to human variability, each subject has an attitudinal style which cannot be standardised. Subject performance is known to be influenced by psychological factors. Subject motivation was a component which could have affected the results of the present study. No extrinsic rewards were offered, although comprehensive feedback was given to the subjects and uniform verbal encouragement to perform maximally was given during each effort.

- Clinical history is a further factor in strength expression, although all subjects, by self-report, were apparently healthy and had no known muscular injuries. The present level of subject conditioning could have influenced the responses. There is a possibility that subjects could have been experiencing, but not reporting, slight muscle strain before the testing commenced.

- Ingestion of supplements which may improve strength expression, was not controlled. However as subjects were drawn from the same military battalion nutritional intake of the daily diet was deemed to be similar.

- Despite a period of habituation and the practice trials given to each subject prior to testing, it is possible that some of the subjects were still not comfortable with the equipment and procedures when test bouts were conducted.

CHAPTER TWO

REVIEW OF LITERATURE

INTRODUCTION

Soldiers are frequently required to carry heavy loads whilst marching. As a consequence symptoms of body soreness, aches, pains and tiredness could interfere with the accomplishment of the military mission (Johnson **et al.**, 1995 and Knapik **et al.**, 1996). Furthermore, female soldiers, despite differences in morphology, are often required to carry the same absolute loads as their male counterparts (Protzman, 1979). With increased inclusion of females in all aspects of military operations there is a need to assess female morphology, strength capabilities and efficiency of performance, an area of research that has hitherto been neglected in South Africa.

Understanding factors which influence strength expression may best be accomplished by a multi-factorial analysis, since strength expression involves biomechanical, physiological, psychological interactants. This multi-dimensional approach assists in addressing the problem of human variability in strength expression. While infantry platoons often operate as one unit, it must be noted that these units comprise 10 to 100 individuals, each with a unique personal physical and mental profile.

The "CENTRE-M: Man-in-motion" conceptual model proposed by Charteris **et al.** (1976) recommended that human movement should be studied as an ecological phenomenon of organism-environment interaction. The model in essence considers four disciplinary domains relevant for the study of all human activity: consideration of biophysical, physiological, psychological and conceptual domains are prerequisite to in fully understanding human ability to function effectively. The present study adopted an holistic view in attempting to analyse the strength expression of female army personnel.

Sex-based Factors

Westphal **et al.** (1996) reported that from 1948 to 1969 less than 2% of the U.S. armed forces were composed of females, who served exclusively in health-care and clerical positions. Females were first accepted as foot soldiers into the United States military in 1976. This introduction resulted in only a few "minimal essential adjustments" to training schedules in order to accommodate female participation (Protzman, 1979). Unfortunately most studies investigating military personnel have involved male soldiers, and this information has subsequently been extrapolated to female soldiers, often without appropriate rationale. Over the last two decades there has been an international trend for female participation in physically demanding combat-related activities (Scott and Ramabhai, 2000). This has led to an increased awareness of female capabilities to complete daily military tasks.

Bhambhani and Maikala (2000) argue that when carrying absolute loads women are more susceptible to fatigue and are at a greater risk of cardiovascular complications than men. Scott and Ramabhai (2000) support these arguments in their comparisons between male and female soldiers, where it was found that female soldiers were significantly more physically taxed than male soldiers were when carrying the same absolute loads. Regardless of these significant differences in physical capabilities between males and females, female members of a platoon are required to carry the same loads and function as efficiently in a post march situation as their male counterparts.

Bhambhani and Singh (1985) and Morgan and Craib (1992) identified the lack of consensus surrounding the metabolic efficiency of walking and running in males and females. Studies conducted by Ralston (1958) and Zarrugh and Radcliffe (1978) found no significant difference between male and female optimal energy expenditure during walking. More recently it was argued by Pivarnik and Sherman (1990) that there was no difference in the $V0_2$, heart rate and RPE responses of males and females in uphill and downhill walking and slow jogging, despite female subjects displaying a significant lower aerobic capacity. Daniels (1985) argued that gender-related differences should disappear when physical fitness levels, or similar $V0_2$ max, equate males and females. A study by Fothergill **et al.** (1996) supports this contention when they reported no significant differences between males and females when measured static lifting strength was corrected relative to stature and normalised for body weight. Bhambhani and Singh (1985) noted that when comparisons were made at self-selected walking paces, the metabolic cost of males and females was comparable. Shephard (2000) surmises that although the average female may be at a disadvantage, it is offset by females having a lower body weight and a tendency to metabolise fats rather than carbohydrates during exercise.

In contrast to the above studies, sex-related differences have been found in the biophysical responses to exercise (Grieve, 1968; Zatsiorky **et al.**, 1994; Knapik **et al.**, 1996) and physiological responses (Åstrand, 1956; Bransford and Howley, 1977; Haisman, 1988; Bhambhani and Maikala, 2000) even when differences in body size and composition are taken into consideration (Martin and Nelson, 1985; Martin and Nelson, 1986). Bhanbhani and Maikala (2000) found that with a 20kg load, $V0_2$ increased by a greater amount in females and exceeded their ventilatory threshold, but not in males. Furthermore heart rate responses were significantly higher in females. Van der Beek **et al.** (2000) found similar differences in VO_2 and heart rate responses for pushing and pulling activities executed by both males and females. It could therefore be argued that the ability of female soldiers to perform as efficiently as male soldiers may be dependent on maximum aerobic capacity and strength expression, rather than gender.

Substantial strength differences between males and females have been reported within the literature. In a review of nine papers comparing male and female strength, Laubach (1976) reported that female dynamic strength was on average 68% that of males. Fuster **et al.** (1998) and Van der Beek **et al.** (2000) found significant gender differences in strength expression. Females expressed only 53% of the pull strength of males, 59% of the handgrip strength and 66% of the vertical jump (Fuster **et al.**, 1998). Padmavathi **et al.** (1999) found similar results for handgrip strength, which persisted even when forearm muscle area was taken into consideration relative to males.

It is reasoned by Evetovich **et al.** (1998) that males can produce a higher torque than females due to greater muscle mass and length. Furthermore, several isokinetic studies found that with female subjects there was a greater percentage decline in concentric peak torque production as velocity increases (Westing **et al.**, 1988; Colliander and Tesch, 1990; Evetovich **et al.**, 1998).

However there is inconsistency within the literature as to whether differences between the sexes are a result of differences in training or as a result of intrinsic differences between males and females. Fuster **et al.** (1998) found a strong correlation between anthropometric and strength variables, while Evetovich **et al.** (1998) attributed differences in torque production capabilities to differences in muscle mass and length. Due to differences in morphology and physiological parameters between males and females Vogel **et al.** (1986) argued that it is evident that female ability at strength expression may differ from that of males. Therefore sex-related differences may be dependent on factors such as strength expression, muscle mass and length, stature, leg length, and maximal oxygen consumption rather than on gender itself.

Load Carriage Factors

Knowledge about body size is important in design specifications of the user population (Kroemer **et al.**, 1995). With the increase in technology, as reported by Knapik **et al.** (1996), soldiers are often required to carry and wear progressively heavier equipment. For example, with the trend towards chemical and biological combat many of the soldiers will increasingly require full body protection, which is undoubtedly an increased burden to the already loaded soldier. Correct fitting of these combat suits and equipment is fundamental to the ability to respond and work effectively in a combat situation.

As illustrated in Table I, British soldiers are reported to be carrying loads of at least 56.2kg. A recent study on female soldiers in South Africa found that the average body weight of a female soldier is 64.7kg (± 8.5kg), with an average body fat of 26% (Scott and Ramabhai, 2000). To amplify the problem in the SANDF, if female soldiers, with a documented minimum mass of 56.2kg, were to carry the reported maximum load of 56.2kg, carried by British soldiers, female soldiers could in a combat situation be required to carry 100% of their body weight, excluding the "dead weight" of, on average 16kg of body fat. Thus, the need for investigation into female load carriage and strength capabilities together with maximal load allowances is critical to the development of appropriate load carriage guidelines, resulting in less fatigue, and ultimately more efficient post-march combat performance.

TABLE I: Itemization of the Load carried by British soldiers (Adapted from Haisman, 1988).

Category		Specific Breakdown	Mass (Kg)	Cumulative Load (kg)
A	Dress	Clothing, boots, and helmet	7.0	7.0
B	Assault Dress	Clothing as in A, plus weapon, ammunition, digging tool and equipment	19.4	26.4
C	Combat order	Dress and equipment as in A and B, plus food and warm clothing	3.7	30.0
D	Marching order	Clothing as in A, B and C, plus spare clothing, rations, rucksack and sleeping bags	10.2	40.2
E	Additional Equipment	There are a number of additional items which could have to be carried ranging in weight up to 16kg	Up to 16.0	At least 52kg

Risk of Injury

Jones **et al.** (1992) argued that when equated for physical fitness and cardiovascular endurance, male and female soldiers experience the same risk of injury. Therefore it is contended that gender **per se** is not an independent risk factor, but that the underlying risk factor is the state of physical fitness in females and males within the military (Kowal, 1980: Brudrig **et al.,** 1983; Jones, 1983), which needs to be addressed in order to optimise female soldier efficiency (Jones **et al.**, 1993).

Martin and Nelson (1986) proposed that due to biomechanical and physiological differences between males and females, females should carry lower absolute loads than males. Scott and Ramabhai (2000) develop this in arguing that with the increase in female participation in combat sectors relativisation of the loads carried should be based on lean body mass. Cognizance should be taken of the individuality of morphology of the platoon so as to avoid soldiers being differentially taxed by the task demands. This is particularly relevant in terms of equalized levels of fatigue and post-march combat readiness (Scott and Ramabhai, 2000).

STRENGTH

Any human activity carries prerequisites of strength. Whether it involves a specific part of the body or the body as a whole; whether movement is associated with an external act, such as loading a gun, or internal activity, such as maintaining posture against gravity; all these activities involve muscular strength (Ishiko, 1974). Furthermore, Brown and Weir (2001) maintain that the assessment of strength is fundamental to human performance.

Strength is defined as the maximum tension that a muscle can produce (Asmussen, 1968), or as the peak force (newtons) or torque (newton-metres) developed during a maximal voluntary contraction (MVC) under a given set of circumstances (Sale, 1991). One can assume that strength is the ability to exert tension against a given resistance. Asmussen (1968) argued that it is very difficult to measure muscle strength in a given working environment. The reasons are two-fold: no muscle contracts in isolation and a muscle always contracts as part of a pattern of movement; in addition muscles act on skeletal lever arms when contracting. Asmussen (1968) concluded that the strength expressed is, therefore, not solely reflective of the muscle contraction, but rather a combination of muscle contraction, lever arm lengths and their changes during the movement. It is for these reasons that most measurements of strength are expressed as the maximal tension that a synergistic group of muscles can produce in a standard position or movement. As a consequence, Asmussen (1968) described strength as the maximum resistance that can be overcome by a muscle-group acting through the whole range of motion.

Abernethy **et al.** (1995) cautioned that there is little consistency between laboratories in terms of the rationale for, or execution of, strength assessments. To illustrate, in the past the main criterion in strength assessment was that of peak torque, the maximal output at any given point through the range of motion. However Charteris (1999b) argued that total work, or constant-tension throughout the range of motion, is a far more superior measure to use when assessing strength expression. In contrast Brown and Weir (2001) in their paper on procedures and recommendations in the accurate assessment of muscular strength and power do not mention the usefulness of total work as an indicator of an individual's strength ability, a criteria far more indicative of ones strength in completing tasks that require sufficient strength. Due to the elusive nature of strength expression the interaction of factors inhibiting or aiding strength needs to be considered when assessing functional capabilities of army personnel. Accuracy of strength testing depends on numerous variables; among the most important factors are the position of the joints involved, the speed and type of contraction and neural and psychological influences.

Body Composition and Strength

Physical performance can be greatly affected by variations in body weight composition (Novak **et al.**, 1968). Consequently the military have been concerned with the effect that excess body weight may have on soldier performance. This concern has intensified the emphasis on physical fitness as a component on military readiness (Knapik **et al.**, 1982 and Harman and Frykman, 1992). The evaluation of body composition permits a quantification of the major structural components of the body (McArdle **et al.**, 1996). There are two fundamental morphological components of interest in this context, Fat Mass (FM) which exists in two storage sites, that of essential fat and sex-characteristic fat, and Lean Body Mass (LBM) which represents body mass devoid of all non-essential body fat or extractable fat (McArdle **et al.**, 1996). The influence these components have on physical performance is complex, including both positive and negative effects depending on the type of physical activity (Cureton **et al.**, 1979; Knapik **et al.**, 1982; Tanaka and Matsuura, 1982 and Harman and Frykman, 1992).

Maximum strength has been reported in the literature to peak from 25 to 35 years (Fisher and Birren, 1947; Larson, 1982). According to Viitasalo **et al.** (1985) muscular strength has been shown to be dependent on body weight. Thus, the greater one's body weight the more absolute strength one is able to produce. However, contrary to Viitasalo **et al.** (1985), Daams (1993) argued that muscle strength does not keep pace with an increase in body mass. Factors to be considered are that larger individuals tend to be disadvantaged in manoeuvring their own bodies through obstacle courses, whereas smaller individuals are more able to perform tasks such as push-ups and sit-ups. However, they will not be able to lift the same absolute weight as people of greater weight. According to Daams (1993) correlations between exerted force and body weight and stature are fair. Nevertheless these correlations are not sufficient so as to justify the prediction of forces, due to human variability and level of conditioning. Kennedy (1963) suggested that larger soldiers would be able to carry a heavier load by virtue of having greater bone and muscle masses; while Berger (1982) cautioned that although those with a heavy body mass tend to have more absolute strength, they often have less relative strength than do those with lighter bodies.

A significant factor in load carriage, one of the more predominant military tasks, is that differential stresses are sustained under identical external loads, largely because of inter-individual differences in mass and in particular body composition. It is generally accepted that the human head, arms and trunk (HAT) in non-obese adults weighs about 75% of body mass (Williams and Lissner, 1962; Hause **et al.**, 1980; Thorstensson and Nilsson, 1982; Perrin, 1993). One of the effects of obesity, due to an increase in mass of the trunk-abdomen region, is to increase the percentage contribution of HAT to a percentage nearer to total body mass. This has implications for the position of the centre of mass relative to load-bearing joints, even before external loads, such as backpacks, are considered. Miller and Blyth (1955) suggested that obesity limited the capacity for strenuous exertion by increasing the energy cost without a proportional increase in maximal capacity for oxygen uptake.

Excess body fat is considered "dead weight" in the performance of work, and may degrade the performance of physical tasks which involve movement of the body with an external load. Adipose tissue serves as energy storage yet it is non-contractile and cannot assist in force generation. However, the weight of fat tissue increases the force generation requirements of the muscles to support body segments and to overcome inertia during acceleration (Boileau and Lohman, 1977). Cureton **et al.** (1979) found that there was a negative effect on running performance attributable to excess weight alone, independent of any changes in cardiovascular capacity. Thus, more ponderous soldiers will tend not to perform as well in loaded marching as do leaner soldiers (Harman and Frykman, 1992). Females are known to carry more adipose tissue than males. Scott and Ramabhai (2000) found that female soldier adiposity was on average 8kg more than male soldiers. In their study comparing South African male and female soldiers under "absolute load" conditions females were in fact carrying 40kg plus 17kg of fat and males 40kg plus 9kg of fat. Even during "relative load" conditions where females carried a mean load of 24kg plus 17kg of fat and the men carried a 27kg load plus 9kg of fat, the female soldiers were still at a disadvantage. These findings again reiterate the importance of relative load carriage corrected to lean body mass and not overall body weight. The consequential impact this additional adipose tissue may have on female strength expression warrants further investigation.

Behnke **et al.** (1942) introduced the concept of Lean Body Mass to describe similar, yet slightly different compartments consisting of muscle tissue, extracellular fluid and bone mineral. Perrin (1993) recommended correcting for

LBM saying that it permits comparisons of strength between persons markedly different in body size.

Harman and Frykman (1992) reported that soldiers with a greater total body weight would consequently have a larger lean body mass, resulting in greater strength profiles. In their study there was evidence that the more ponderous soldiers lifted more effectively than leaner soldiers did. This, in all probability, was due to the greater absolute strength of the larger muscles that can be effectively applied to the manipulation of objects external to the body. LBM is well correlated to total body weight, at least for the young military population (Harman and Frykman, 1992). They argued that fat-free weight is generally positively related to physical performance. In activities where force must be applied against external objects such as loading heavy artillery shells, a large fat-free weight is helpful, but excess fat mass is likely to have a detrimental affect on some activities in which the energy cost of the activity is important. In such activities a high relative fat free weight, as opposed to a high absolute fat free weight, would be advantageous.

Specificity of Strength

A great deal of research has been conducted on the specificity of strength for individuals of different body size, sex and age (Hettinger, 1961, Asmussen **et al.**, 1965, Lambert, 1965; Åstrand and Rodahl 1970). High levels of muscle strength are often related to general strength and the present occupation of subjects. For example foot soldiers that are required to execute physically demanding tasks and are involved in regular training would be expected to exhibit higher strength values than sedentary subjects. However, the performance of an individual in a once off strength test may not be a true reflection of their general body strength, nor a valid tool in predicting similar strength in other such tests. Hettinger (1961) cautioned that assumptions regarding general muscle strength should not be extrapolated from measurements in one single muscle group, but from a battery of selected, well-standardized muscle tests. These findings are pertinent to the present study where the objective was to establish reliable base-line data of female military personnel.

Higher over-all strength ratings will obviously enable stronger soldiers to cope more efficiently with the demands of daily tasks and training, whilst also enhancing overall combat readiness. Beyond this study, comparability of female strength profiles with those of male profiles merits evaluation, as well as comparisons with foreign infantry personnel. It is expected that specificity of strength expression will pertain, so that predictions focussed on isokinetic tests measuring different movements about comparable joints will be what James (2000) have reported as "kinesiologically meaningless". In a joint specific clinical test, for example the shoulder or knee, outputs are expected to relate poorly to those produced in "whole-body" strength tests like trunk extension-flexion or pulling and pushing, due to the specificity of strength principle. Isokinetic dynamometers allow one to align the centre of the joint being tested to the input axis of the dynamometer. This is expected to allow for more effective isolation of the specific muscle groups involved in the movement, for example, the back extensors and flexors. In contrast, tests conducted on the work-simulation system make it impossible to isolate muscle groups because of non-alignment of a specific axis of rotation with the dynamometer. In the "whole body" test for example the pulling-pushing test, mean responses would be expected to be greater than those movements which isolate muscle groups.

Strength Training and Work Hardening Programmes

There is a need for strength and endurance training for military soldiers. Infantry personnel are often required to perform tasks that entail manual materials handling (MMH) and load carrying; for example the carrying of ammunition boxes or loading artillery shells. Asfour **et al.** (1984) observed that injuries resulting from MMH activities in industry are a major source of lost time and compensation claims. According to Anderson (1997) low back pain alone cost the United States over $100 billion in 1997. With military personnel often carrying loads in excess of industrial safety limits soldiers are placed at high-risk of being injured. With the reported decrease in strength ability of females in comparison to males (Westing **et al.**, 1988; Colliander and Tesch, 1990; Evetovich **et al.**, 1998; Fuster **et al.**, 1998; Padmavathi **et al.**, 1999 and Van der Beek **et al.**, 2000) female soldiers are consequently at greater risk of injury when completing daily military tasks.

Asfour **et al.** (1984), Genaidy **et al.** (1989), Genaidy **et al.** (1992), Genaidy **et al.** (1994) and Scott and Jacka (1997) have proposed work-hardening programmes for strength improvement in industry. Work-hardening programmes are used as a prophylactic intervention strategy designed to condition workers to better meet the demands of their jobs. In a military environment work-hardening programmes could significantly improve performance of soldiers. Indeed, the likelihood of injury has been shown to decrease when effective strength and endurance training has been implemented (Asfour **et al.**, 1984; Genaidy **et al.**, 1989; Genaidy **et al.**, 1992, and Jones and Knapik, 1999). Effective training and recruit-hardening programmes specifically targeting weak areas could bring about the desired strength increases necessary for military work.

Knapik (1997) assessed the effect of training programmes on the MMH capabilities of women. The study aimed to examine the effects of a general strength-training programme on manual task efficiency. Following a 14-week programme significant improvements were seen in weight lifting and in coping with manual tasks. Sharp **et al.** (1980) conducted a similar study on male subjects over a 12-week period. Although male subjects showed a greater improvement in strength expression, both studies illustrated the effectiveness of work-hardening programmes with improvements in efficiency and strength expression ranging from 7% to 16%. Recruit screening tests and training programmes require effective guidelines in excluding individuals from service who may be ineffective in performing their assigned tasks or prone to injury due to congenital abnormalities.

Female soldiers, due to the reported sex-related differences, should complete specific work hardening programmes to help them cope with the physically demanding combat related activities. With the implementation of relativised load carriage and work hardening programmes female soldiers physical work capacity may be improved upon, which will assist them to complete military demands at an efficiency level similar to that of male soldiers.

ERGONOMIC IMPLICATIONS

With the exponential growth of technology the science of ergonomics and its application to work practices and equipment design has developed to ensure safe and productive work environments. Despite this technological advancement the human element remains a key factor in any work situation, particularly in the army. If one considers the recent changes in the South African military, in which the recruit population has become a cultural mosaic, many advanced equipment designs, imported from First World countries, are inappropriate. Ethnic groups vary in overall size, shape and bodily proportions, (Malina, 1971; Mueller **et al.**, 1987; Mueller and Malina, 1987 and Zillikens and Conway, 1990), and the effects of these morphological differences on strength expression, movement efficiency and equipment design should be investigated, particularly in cases where, as in South Africa, female military personnel has hitherto been neglected.

Ergonomic principles are not exclusive to the industrial sector. Many of the guidelines used in industry are also applicable in a military environment. Terms such as "normal" or "average" in describing the work-site have become redundant in modern work environments. In the military of the past, which comprised almost exclusively male Caucasians, similar morphologies aided in the design of military equipment, and arguably anthropotechnological transfer was more suited to the Caucasian army. However, due to the inclusion of female soldiers and the mosaic of ethnic groups in modern armies, equipment design needs to be modified to accommodate these diverse morphologies. For example, personal experience whilst testing equipment, has shown that of the 30-army soldiers tested for suitability and functionality of night vision goggles only three of the soldiers could wear them effectively. This was due to the design of the facemask being based on Caucasian male cranio-facial anthropometry. In order to meet the great diversity of military personnel work environments have to be designed around the specific user population for ease of use and efficient performance. Unfortunately in industrially developing countries such as South Africa there is a preponderance of ill-fitting machinery and sub-optimal equipment and operational environments due to the economic burden of adapting or replacing them. A sound understanding of strength profile of the armed forces will greatly aid in reducing the mismatch between the soldiers, their equipment and required tasks.

Capacity to perform mechanical work is determined by ability to exert muscular strength Mital and Karwowski (1985). The demands for human strength to accomplish physical activities remain strong despite increasing automation. The nature of many tasks and work situations, especially in South Africa where there is predominantly a manual labour force, mandates recruitment of muscle power. Thus, determination of human strength expression capabilities is an important consideration in the development of ergonomics guidelines for pre-employment screening of workers performing manual material handling jobs (NIOSH, 1981). To a great extent the military relies too on manual materials handling (MMH). Mamansari and Salokhe (1996) reported that effective manual work relies on muscular strength. The heavy loads which soldiers frequently carry will in all probability lead to symptoms of body soreness and tiredness, which in turn could interfere with the effective completion of the required task (Johnson **et al.**, 1995; Knapik **et al.**, 1996). Strength reserves are consequently critical factors in post-march combat-readiness (Knapik **et al.**, 1996), and the need for adequate strength among soldiers is fundamental in accomplishing many military tasks and avoiding the likelihood of work-related injuries. Assessments of strength capabilities and efficiency of military personnel appears to have been neglected in South Africa, despite availability of testing resources.

The most common physically demanding tasks in the army are lifting and carrying. Lifting tasks include loading artillery shells, lifting supplies on and off trucks and assembling or disassembling heavy equipment, amongst others. Packs in excess of 40kg may be lifted and carried several kilometers during marches (Harman and Frykman, 1992; Scott and Ramabhai, 2000). The loads carried by soldiers require high levels of upper-body strength, which often receives minimal attention in military training programmes. Dubik and Fullerton (1987) argue that although technological improvements in lighter materials have become available, the loads carried by foot soldiers have in fact increased. More equipment is now required and consequently soldiers have to carry significantly heavier loads (Johnson **et al.**, 1995). Knapik **et al.** (1996) supports these arguments by identifying technological developments, which require the need for greater firepower and protection, as being determining factors in the progressive increase in soldiers' load. After completing a demanding march foot soldiers may well be required to execute highly complex military objectives effectively and safely, then make a rapid retreat. In order for these tasks to be executed efficiently it is essential that the soldiers are mentally and physically alert and prepared for the task at hand. It is therefore essential to establish comprehensive strength profiles of SANDF soldiers in order to set guidelines to ensure a safety and efficiency in executing operational activities.

The maximal acceptable load in industry, according to NIOSH guidelines is 23kg, but only if ideal conditions prevail in respect of factors such as reach, vertical height, distance moved, duration, frequency, coupling and asymmetrical lifting. In industrially developing countries and arguably more so in the military, human muscle power is extensively used for operating and lifting equipment. Unfortunately soldiers are often required to lift and carry loads well in excess of those specified in industrial guidelines. Haisman (1988) provides a good example of how the load of infantrymen can increase when different battle gear is required. Should all the equipment necessary for operational maneuvers be required for one training march the load would be in excess of 52kg. This would entail many female soldiers carrying a load equal to or marginally less than personal body mass. Pack weights have been recorded at a mass exceeding 45kg in training and combat (Haisman, 1988), thus predisposing the soldier to a high risk of injury. Not surprisingly, Harmen and Frykman (1992) reported that large numbers of recruits have left the military due to failure to cope with physically demanding training and workload. The above revelations have implications particularly for female infantry personnel. Protzman (1979) argued that males have a higher capacity for physical performance and are therefore likely to accomplish military tasks "with fewer injuries or diseases and less apparent stress". If large numbers of recruits are leaving the military due to excessive workloads then either more stringent selection or revision of military doctrine must ensue, particularly if females are to be accommodated. Vogel and Patton (1978) argued that females will be at a greater risk than males in load carriage tasks due to lower body weight, $V0_2$ max and muscle strength and a higher percentage body fat.

Evaluation of muscle strength expression can provide valuable information relating to ones' working capacity. This information, according to Mamansari and Salokhe (1996), can be used in equipment and machine design to suit the strength requirements of specific populations and in designing work to reduce the force relative to the muscular strength available. Daams (1993) made the case that knowledge of the forces exerted by manual workers is of vital importance. Muscular strength is necessary to operate equipment and to control and sustain external loading without inflicting personal injury. Chaffin and Parks (1973) caution that if muscular strength does not match task demands serious problems are likely.

ISOKINETIC DYNAMOMETRY

Introduction

Perrin (1993) defines isokinetic dynamometry as the assessment of maximal musculature exertion and angular movement through a defined range of motion (ROM) in which there is effectively no acceleration of the limb. Baltzopoulos and Brodie (1989) define the term "isokinetics" as the dynamic muscular contraction when an electromechanical device controls the velocity of the movement. Isokinetic exercise, according to Brown and Weir (2001) is by definition at a constant velocity and represents a match between mechanically imposed velocity and the subject's movement.

Research has shown that isokinetic dynamometery is a reliable means of assessing strength expression (Frisiello **et al.**, 1994; Li **et al.**, 1996). Furthermore isokinetic strength assessments can be used to predict the maximum lift-weights acceptable to people. This is due to peak isokinetic strength expression being closely related to actual maximum lifting capabilities (Pytel and Kamon, 1981; Kamon **et al.**, 1982; Kroemer, 1983; Mital and Karwowski, 1985). The use of isokinetics, to predict maximum lift weights in an ergonomics context is useful in establishing safe lifting guidelines in any working environment.

Isokinetic assessments have focused more on lower-extremity than upper-extremity strength testing (Ghena **et al.**, 1991; Perrin, 1993; Li **et al.**, 1996; Wu **et al.**, 1997). Consequently normative data are far more comprehensive for lower-extremity tests (Perrin, 1993). According to Ellenbecker **et al.** (1988) and Hageman **et al**. (1989), studies conducted on upper-extremities have tended to focus on rehabilitation and strength training with focus on the shoulder muscles. Despite the increased scope in isokinetic there remain limited studies on female populations.

Interpretation of the Isokinetic Torque Curve

Isokinetic activity is based on the principle that at the extremes of the range of motion the lever system is at its lowest mechanical advantage so the ability to produce strength is minimal, and resistance from the dynamometer is at its lowest level. Towards the mid-range, where mechanical advantage is the greatest, the accommodating resistance increases proportionally to the increased ability to exert force. Figure 1 shows the torque output of the skeletal lever during isokinetic exercise.

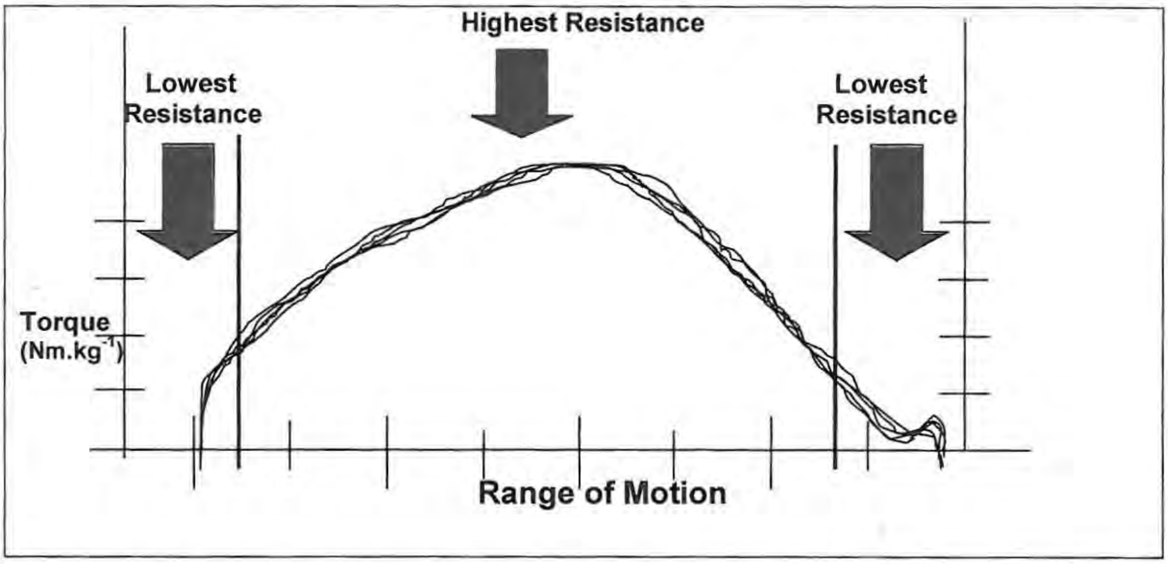

Figure 1: Torque output at the skeletal lever during isokinetic exercise (Adapted from Perrin, 1993).

Perrin (1993) pointed out that isokinetic devices allow individuals to exert as much force as they can generate up to a predetermined velocity. At the pre-set velocity the resistance of the dynamometer is equal to the force generated by the muscle ensuring a constant movement rate. Therefore the muscle is maximally loaded at all points through the ROM. As a result a muscle group may be exercised to its maximum potential, regardless of the limb's position, throughout the ROM of the joint concerned.

Normal and Deficient Isokinetic Curves

Values of torque (Nm), work (J) and power (W) are derived from the isokinetic torque curve. Figure 2 illustrates a normal isokinetic curve.

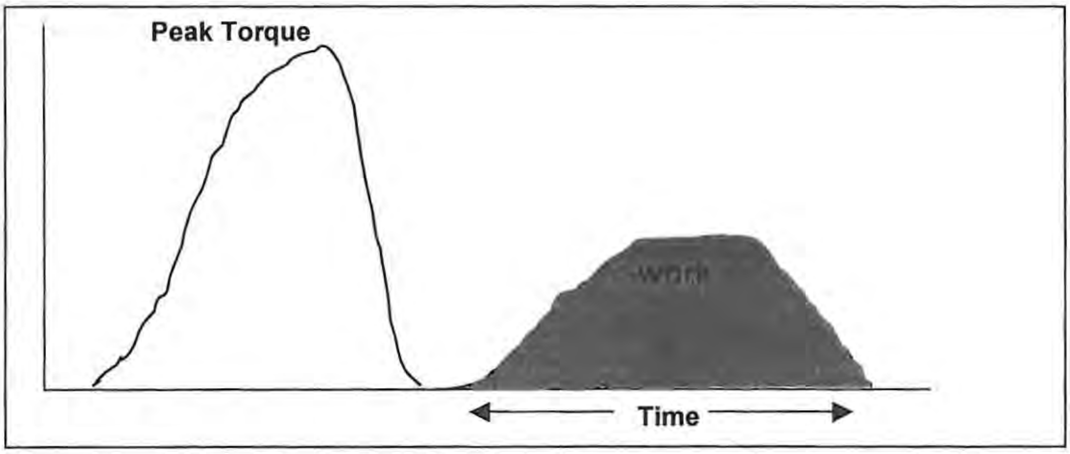

Figure 2: Normal isokinetic torque curves representing peak torque, work and power (Adapted from Perrin, 1993).

Charteris (1999b) argued that in isokinetic tests the measurement of peak torque, although useful, only represents the subject's performance at one specific point along the torque curve. A high peak torque is not necessarily a guarantee of great work or power output. Thus peak torque should not be used as the only criterion for strength expression. The area under the torque curve represents work produced ("summated torques"); a far better reflection of strength expression. However, even though total work is a superior measure of overall output, studies assessing the effects of speed have tended to focus on peak torque rather than total work or average power output (Wickiewicz **et al.**, 1984, Falkel **et al.**, 1985, Baltzopoulos and Broadie 1989; Charteris 1999b) because of ease of access to this measure in earlier models. Figure 3 illustrates the manner in which equal peak torque curves may be exhibited in performances of very different overall quality.

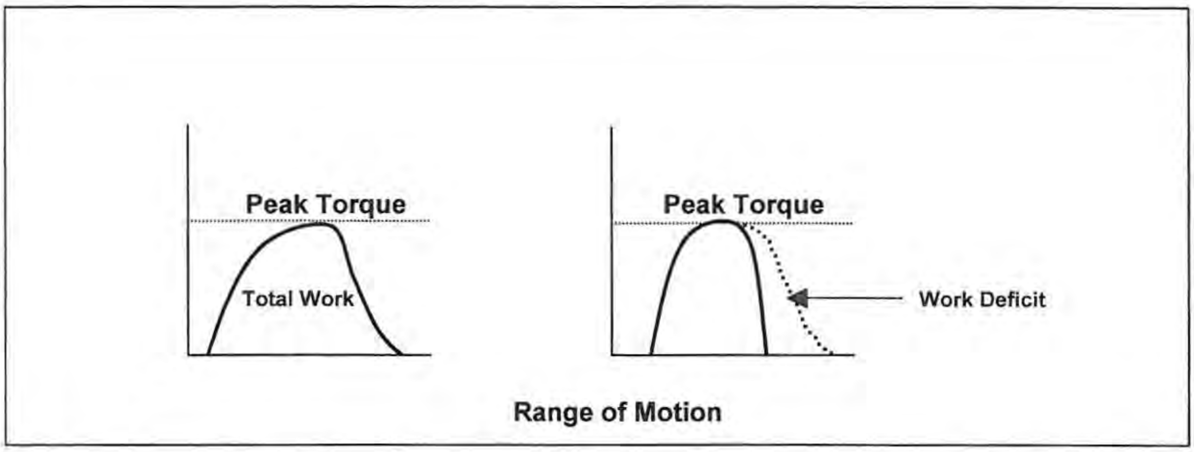

Figure 3: Equal peak torque curves, but different total work output. The curve on the left represents a far better whole-range performance. (Adapted from Perrin, 1993).

Although a subject may appear to produce high peak torque there may well be a work deficiency when the entire motion is considered. Perrin (1993) emphasized that the return of peak torque in a rehabilitating muscle may not be closely related to a specific muscle's work and power capabilities, a statement supported by the research of Charteris (1999b).

Isokinetic Assessments: Trunk

The trunk extension/flexion (TEF) modular component of the Cybex 6000 isokinetic dynamometer measures trunk ranges and musculo-skeletal outputs. Inexplicably, in contrast to the knee extension-flexion assessment the TEF unit does not make allowance for the gravitational effect of head arm and trunk (HAT) mass. Charteris and Scott (1997) pointed out that as manufacturers have not incorporated gravity correction into their TEF software configuration, all Cybex trunk data must be considered in light of the absence of gravity correction. Given that HAT may be considered to account for approximately 75% body weight in an adult male, the effects of gravity are sizeable (Williams and Lissner, 1962; Hasue **et al.**, 1980; Thorstensson and Nilsson, 1982; Perrin, 1993). It is crucial to stipulate whether or not isokinetic data have been gravity-corrected because this materially affects interpretation of those data. Though less correct, in an absolute sense, this technology-imposed limitation is the norm in the isokinetic literature (Charteris and Scott, 1997).

Charteris (1999a) found, in a study assessing the torque-velocity relationship of trunk muscles in manual workers, that doubling movement speed from 60 $^\circ.s^{-1}$ to 120$^\circ.s^{-1}$, resulted in an extensor decrement of 21.1% and a flexor decrement of 10.4% in respect of total work output. In absence of definitive normative data on female trunk strength and its relationship to morphology in an ethnically mosaic society such as South Africa, it is at least possible at this time to establish benchmark test expectations against which individual cases can be evaluated (Charteris, 1999a).

Isokinetic Assessments: Upper-Extremity

As a result of the high incidence of rotator-cuff injuries, the focus of upper-limb assessments has been predominantly on the shoulder (Ellenbecker **et al.**, 1988; Hageman **et al.**, 1989; Frisiello **et al.**, 1994; Voight **et al.**, 1996). Assessments of shoulder rotation are important in a military environment where tasks such as grenade throwing require optimal upper-extremity strength. Unfortunately isokinetic dynamometry is limited to test speeds up to $500°.s^{-1}$, whereas studies have shown that angular velocities as high as $4500°.s^{-1}$ have been recorded in elbow excursions during throwing actions (Pappas **et al.**, 1985; Charteris 1999b).

Optimal positioning for isokinetic assessments of shoulder rotation remains controversial according to Perrin (1993). For fear of inducing symptoms associated with shoulder impingement syndrome researchers have avoided the 90° abduction position. In healthy subjects this should not have a significant influence on responses. Shoulder internal rotation is produced by the subscapularis, teres major, pectoralis major, latissimus dorsi and anterior deltoid muscles, with relative contribution from these muscles related to variations in their respective length-tension relationships as the glenohumeral joint moves from the neutral to the 90° abducted position (Perrin, 1993). External rotation is produced by the infraspinatus, teres minor and posterior deltoid muscles.

Literature on isokinetic elbow extension-flexion is limited. This is attributed to the design of isokinetic dynamometers which has rendered testing of the upper-extremity more difficult than testing of the lower-extremity. As a consequence, establishment of a normative database for elbow extension and flexion values across a range of speeds has been relatively neglected and more research is warranted particularly with female subjects. Subject positioning, for example while assessing shoulder internal and external rotation, is not always as efficient or easily administered as it is for the lower-extremity, for example knee extension-flexion. Charteris and Goslin (1986) studied elbow extensor/flexor values in healthy young subjects. They found an agonist/antagonist ratio of approximately 1:1.0 at a testing velocity of $30^{\circ}.s^{-1}$.

Isokinetic Assessments: Lower-Extremity

Lower-extremity testing has tended to focus on knee extension and flexion (Ghena **et al.**, 1991; Bishop **et al.**, 1991; Cress **et al.**, 1992; Lin **et al.**, 1996; Li **et al.**, 1996; Wu **et al.**, 1997), due to the high incidence of injury. Perrin (1993) argued that the anatomical configuration of the knee joint renders it highly vulnerable to injury. As a result there has been an increased focus of research on the knee musculature. In a military environment load carriage, over extended marches and activities such as obstacle course running predispose soldiers to knee injuries. Indeed, knee pain has been associated with the practice of load carriage (Knapik **et al.**, 1989; 1996). Poor training practices and inadequate attention to the capabilities of the soldier during fatigue marches, all predispose the soldier to injury.

In general the hamstring muscle group has been shown to produce 60% of the torque values generated by the quadriceps muscles at slow isokinetic test velocities (Morris, 1983; Perrin, 1993 and Li **et al.**, 1996). Gravity correction is an important factor to consider in isokinetic knee assessments. The mass of the leg being tested has an influence on the quadriceps to hamstring (Q/H) ratio, as the effects of gravity disproportionately increase flexion torques and decrease extension torque.

Isokinetic Assessments: Work- Simulation Package

Military personnel complete a wide variety of tasks in training and daily living activities (Johnson **et al.**, 1995 and Knapik **et al.**, 1996). The Cybex 6000 Work-Simulation package allows one to assess isokinetic work performance capabilities of different occupational activities.

The hands' major functions entail gripping, manipulation and strength expression (Balogun **et al.**, 1991). It is through one's hands that most environmental manipulation occurs. Helliwell **et al.** (1987) points out that grip strength is one of the fundamental determinants of hand function, and has also been shown to provide an objective index about the functional integrity of the upper-extremities (Balogun **et al.**, 1991). With more sophisticated equipment available for isokinetic dynamometers, where calibration of the equipment is done at the commencement of each testing session, it is now possible to make more accurate assessments of hand strength.

Benchmark data for the pulling-pushing, valve-tightening, wrench-turning and gripping capabilities of female soldiers are not available and the present study will thus further the field of occupation-simulation isokinetics.

Reciprocal (Agonist/Antagonist) Ratios

Isokinetic strength testing can be used to identify muscle strength imbalances or weakness (Davimes and Levinrad, 1985). Comparisons can be drawn from reciprocal muscle groups in terms of torque, work and power. By assessing isokinetic agonist/antagonist ratios it becomes possible to highlight areas of relative weakness. Strength training specialists have long recognized the importance of training both muscle groups producing opposite actions about a joint (Perin, 1993). In the present study, female soldiers who place high stress on their lower-extremity through load carriage, marching and running, but who may neglect upper-extremities in training sessions are predisposed to injury. Training methods that focus not only on agonist muscle groups, but also includes antagonist needs to be implemented in the training of female soldiers to help them cope with the physical demands experienced in a military environment.

Visual Feedback

Investigators have identified a multitude of biomechanical, physiological, psychological and methodological variables which influence the assessment of human muscular strength. Hald and Bottjen (1987) argued that an area of isokinetics receiving limited attention is that of visual feedback (VF), in all probability, due to the discrepancy in the literature about its benefits. Studies completed have noted that provision of VF enhances the performance of strength tasks as demonstrated by Pierson (1964) and Berger (1967), while conversely, Peacock **et al.** (1981) found no statistical difference between groups receiving VF to those that did not. However, without the use of feedback, subjects are often more focused on the effects of the activity and are uncertain as to how much of the work still has to be completed. Subject motivation to complete the test could therefore decrease resulting in more rapid fatigue. Hald and Bottjen (1987) found that VF was limited in motivating subjects. Motivating subjects to continue producing maximal efforts, regardless of VF or not, remains a critical factor to accurate isokinetic testing.

Knowledge of Results

Knowledge of results (KR) is a factor closely linked to test feedback. In the present study KR was provided whenever possible. Figoni and Morris (1984) in their study on the effects of KR on muscular strength and fatigue concluded that KR, both verbal and visual, could be a motivator in eliciting maximal strength outputs.

Baltzopoulos **et al.** (1991) contended that VF could have a significant effect on torque production. However, the magnitude of the effect is dependent on the angular velocity of the movement. The study found that when VF was used at higher testing velocities, subjects were motivated to produce higher torque outputs. The effects of VF and KR still require further study to allow for a more comprehensive assessment of their effectivness.

Inter-Repetition Effort-Level Consistency

The study of inter-repetition consistency or submaximal efforts in isokinetic testing has not received much attention. Lin **et al.** (1996) suggested a possible method for evaluating sub-maximal efforts was to compare the coefficient of average torque, coefficient of variation of peak torque and slope to peak torque obtained from maximal and sub-maximal torque. Results illustrated that the best methods of evaluation for sub-maximal efforts was the combining of the coefficient of variation of average torque with slope to peak torque. Subjects who were performing below their potential could therefore be identified. This would be particularly useful in determining subjects who are malingering or have an inherent weakness.

Charteris (1999a) stated that an indication that subjects are working maximally is shown by the "Work per Set" output. He noted that performances of healthy and well-motivated workers, typically show that average work-per-repetition value should be within 15% of Best Work Repetition (BWR). Elite athletes who are adept at expressing maximal efforts, display inter-repetition differences around 5% of BWR when motivation is high and repetitions few (Charteris and Scott, 1997). More recently, Charteris (1999a) established that mean back flexion work output per repetition was within 10% of BWR and mean back extension was within 14% of BWR in the case of able-bodied workers regardless of speed tested. This suggests that overall performance was reasonably consistent and can be assumed to be an expression of maximal effort. Moreover, subjects who are malingering would be unlikely to replicate submaximal efforts with such high consistency: Mean work per repetition/BWR would show much larger discrepancies.

Adding to this work, Charteris and James, (2000) developed guidelines for maximal replication work output levels for able-bodied workers and candidates for disability assessments. The guidelines provide benchmark data of South African work output levels and will aid in the detection of sub-maximal outputs in future studies. For female soldiers, who are involved in regular physical activity, one would expect a high inter-repetition effort-level consistency. According to the guidelines stipulated by Charteris and James, when assessing strength expression for military personnel one should use as a criterion of effort-level consistency a minimum mean/max. work ratio of 90%. Figure 4 schematically illustrates the determination of effort-level consistency represented within a 4-repetition "maximal" torque curve. The upper and lower efforts highlighted in red.

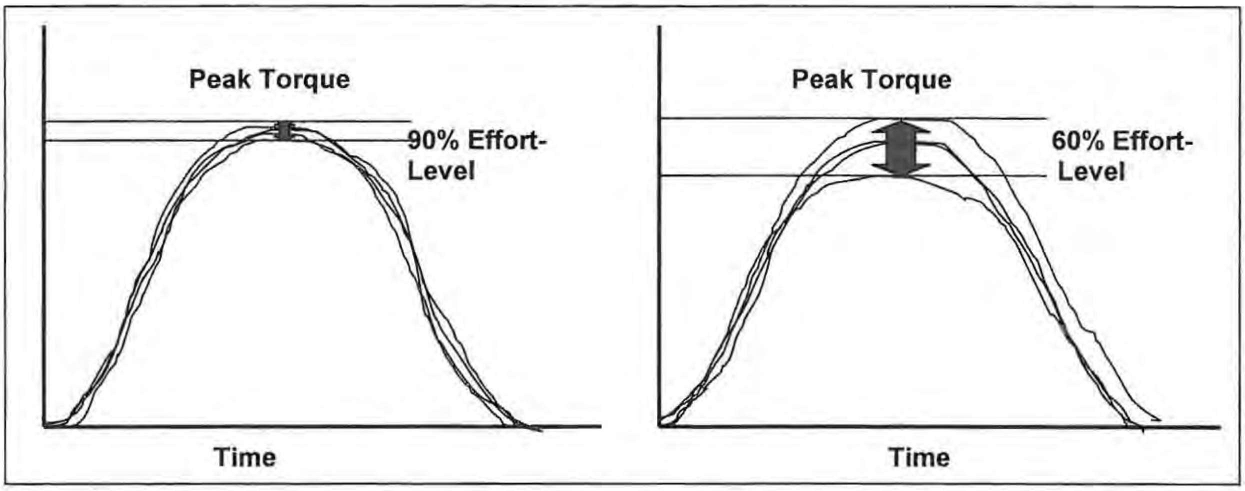

Figure 4: Effort-level Consistency represented within a 4-repetition "maximal" torque curve.

CARDIOVASCULAR RESPONSES

While heart rate is one of the most commonly measured physiological parameters, it is at the same time one of the most sensitive responses and as such it is very difficult to isolate and identify the major cause behind excitation or inhibition of the heart rate response. Vuori (1998) suggested that monitoring heart rate could provide useful information about the level and pattern of physical activity, as well as being a reliable indicator of cardiovascular strain. However, Kilbom (1995) had cautioned that many factors may contribute to, or detract from accurate heart rate measurements, including; type of activity, muscular activation, nutritional ingestion, heat exposure and psychological stress. Thus, heart rate is acknowledged as a tentative cardiovascular strain response, and interpretation must always be made taking cognisance of the circumstances.

PSYCHOPHYSICAL RESPONSES

Borg (1970) wrote that " ...as man reacts to the world as he perceives it and not as it really is, it is important to know more about the relation between objective and subjective measures of physical stress." Aminoff **et al.** (1998) argued that an important additional question in work physiology was how individuals perceive the amount of work they perform. They found the subjective measures identified by use of the Borg (1971) scale gave a cross comparison to the physical measures which allowed the investigator to explore how the person performing the task felt. Due to the complex nature of humans it was felt necessary to include some evaluation of the psychological factors which have been shown to exert a significant influence on the efficiency of performance generally and are therefore deemed essential considerations.

The thermal environment, protective clothing, battle conditions and intensity of effort all influence psychological perceptions (White **et al.**, 1991 and Aoyagi **et al.**, 1998). The importance of training military personnel to cope adequately with the demands of battle environments has therefore become central to successful task completion. Various researches (Knapik **et al.**, 1993 and Johnson **et al.**, 1995) have utilised psychophysical testing, such as the Borg Scale (1971) to assess the perception of effort and the efficiency of task performance in a military combat situation.

Extensive research investigating the relationship between heart rate and perceived exertion has been completed (Chow and Wilmore, 1984; Birk and Birk, 1987; Ljungren and Hassmen, 1991; Dunbar, 1992; O'Neill **et al.**, 1992; Robertson **et al.**, 1992 and Yamaji **et al.**, 1992). The Rating of Perceived Exertion (RPE) scale, utilised in this study, was constructed in the knowledge that heart rate increases linearly in relation to progressive increase in wholebody workload on a bicycle ergometer (Borg, 1970; Pandolf and Noble, 1973 and Pandolf, 1983). The RPE consists of a 15-point numerical scale ranging from 6 (minimal exertion) to 20 (maximal exertion), in which every second number has a verbal anchor. The accuracy of ratings may be influenced by the fact that verbal anchors are in English and therefore the associated scale cannot be regarded as universal. Translation into another language becomes difficult as terminology and concepts vary so much, and the reliability of the use of the scale is very dependent on a clear understanding of the concepts of a personalised rating.

The diverse cultural backgrounds and multitude of languages (11 official languages in SA) in the SANDF presents another problem for the use of RPE. Acknowledging the problem in South Africa, Scott (1986) adjusted the scale to include diagrams which best represented the associated English verbal anchor.

This was done to aid non-English speaking subjects to more readily understand the use of the scale (See Appendix A, p.129).

CONCLUSION

The primary concern in military ergonomics is to optimise soldier efficiency, by enhancing combat-readiness in cost-effective ways. As physical strength is a prerequisite for many military activities the assessment of strength expression in female soldiers is a critical first step to establishing benchmark data for occupational guidelines and further research. An awareness of morphological and psychophysiological factors influencing strength expression has been addressed in an holistic manner.

Isokinetic dynamometry is a useful tool for ergonomists in the assessment of human strength expression. Inevitably strength expression in military, industrial or other contexts will involve a compromise between the person's capabilities and requirements of the task, which may in some circumstances have important implications for health and safety of the individual, and the efficiency of completing the required task.

CHAPTER THREE

METHODS

INTRODUCTION

An important recent development in the South African National Defence Force is the inclusion of females in all aspects of military operations. At present, not much is known about the morphological diversity and strength capability of the female military population. The present study aimed to establish benchmark strength data on the South African female soldier. Various isokinetic tests were utilised in the assessment of strength. These assessments included tests of the upper and lower-extremities as well as whole-body exertions in order to better understand the strength profile of female military personnel in the SANDF. Test procedures relative to this investigation are depicted on pages 53 – 58.

Ellenbecker **et al.** (1988) and Perrin, (1993) have argued that the majority of isokinetic assessments have focused largely on rehabilitation and strength training with the reliability of these tests, according to Voight **et al.** (1996) and Li **et al.** (1996) being well established. The more recent introduction of the Work-Simulation System (WSS) package to isokinetic dynamometry has allowed research to expand into areas of occupation-simulating tasks exemplified in activities such as valve-tightening and pulling or pushing.

Subject Characteristics

A sample of thirty-two healthy female soldiers was drawn from the local infantry base "6 SAI" in Grahamstown. The sample was assumed to be broadly representative of females involved in the South African army, but the possibility of the sample being ethnically biased has to be considered. All subjects, by self-report, were free from any recent or ongoing injury. An assumption was made that determinations of preferred writing hand and kicking leg would suffice as the criteria to identify limb dominance.

Demographic Data

The following basic demographic data were recorded prior to experimentation: age (yr), stature (mm), body mass (kg), and body fat (%). Calculated indices derived from these included lean body mass (kg), body mass index (BMI) and reciprocal ponderal index (RPI). These demographic data are presented in Table II. The subject pool was sub-divided into clerical workers (N=13) and active foot soldiers (N=19). Statistical analysis by means of a Mann-Whitney U-Test showed that the sample was homogeneous i.e. no significant differences were established. As a result the sample was pooled.

TABLE II: Basic demographic data of the sample (N=32).

Measure	Mean	SD	C.V.
Age (yr)	28.5	4.2	14.7
Stature (mm)	1610	70.7	4.4
Body mass (kg)	76.1	12.6	16.5
Body Fat (%)	36	6.9	19.3
Lean Body Mass (%)	64	7.9	12.5
BMI (kg/m^2)	29.5	5.4	18.2
RPI ($Stature/Mass^{0.333}$)	382	26.8	7.0

Body Mass

A Toledo Scale was used to measure body mass. Subjects were required to be minimally clothed, dressed in their undergarments, during weighing and body mass was recorded to the nearest 0.1kg.

Stature

Stature, defined as the vertical distance from the floor to the vertex, was measured with a portable Harpenden Stadiometer. The subject stood erect, with heels, buttocks, upper back and rear of the head in contact with the vertical section of the stadiometer. The head was oriented in the Frankfurt Plane with arms pendant.

Bioelectrical Impedance

The measurement of body fat via bioelectrical impedance was done by the "whole body method". The placement of the two electrodes was standardized according to the instruction manual provided by Body Track 2000. The sensor and current electrodes were placed at least 55mm apart to ensure that no field interference between the electrodes was artificially affecting the resistance readings. A current was applied at the distal electrodes of the hand and foot and the voltage drop due to impedance was detected by the proximal electrodes.

RESEARCH PROTOCOL

Informed Consent

Institutional regulations in this regard were complied with. All subjects were required to read and complete a letter of information and an informed consent form (see Appendix B). Both verbal instructions and written explanatory documentation were supplied to the subjects and an interpreter was used where necessary. All questions about the nature of the project were addressed. The subject, researcher and witness signed and dated the informed consent form. The project as a whole received prior approval from the University Research Ethics Committee.

Pilot Study

A pilot study was carried out to assess the logistical viability of the test protocol. The pilot work was conducted under conditions reflecting the actual test environment as closely as possible.

A number of standardisation adjustments were made to the original test protocol. The subjects' starting position for each work simulation test was seen as an essential variable to control. A demarcated, raised plinth ensured that subjects were not able to move beyond the blocked area. This plinth was utilised in both the valve-tightening and wrench-turning tests. In the pulling/pushing test a demarcated leading foot area was used to ensure that all subjects started from the same point. Grip strength pilot work showed that subjects were unlikely to achieve machine speeds of $120°s^{-1}$and $210°s^{-1}$. This test was thus the only exception in test protocol in terms of dynamometer speed, with $30°s^{-1}$, $60°s^{-1}$ and $90°s^{-1}$ being selected.

INSTRUMENTATION AND PROCEDURES

Strength Measures

Testing was conducted on the CYBEX 6000 Isokinetic Dynamometer. Test procedures and positions were set-up according to the manufacturer's protocols.

The dynamometer height was adjusted to accommodate the morphological characteristics of each subject.

The Work-Simulation System package allows one to simulate a particular aspect or task and reproduce the task in a controlled laboratory environment. New methods of evaluation were used in the occupation-simulating tests with the manufacturer's protocol used as a guideline.

Selection of Test Velocity

One of the difficulties in performing an isokinetic evaluation is selecting the appropriate velocity or velocities (Arnold **et al.**, 1997). The present study used velocities of $30°.s^{-1}$, $120°.s^{-1}$ and $210°.s^{-1}$, for the shoulder, elbow, trunk, knee, push-pull, wrench-turning and valve-tightening test bouts. The gripping tests were not deemed to be possible at these machine speeds, with the result that speeds of $30°.s^{-1}$, $60°.s^{-1}$ and $90°.s^{-1}$ were selected. Consideration had to be given to the ability of the test subjects, who were all involved in military training and were capable of performing isokinetic work at a slow and fast speed.

Warm-up

Five minutes of light activity was completed before commencing with the maximal exertion tests. The warm-up consisted of a 5 min cycle on the Monark^{TM} cycle ergometer at a power output of 50 W. The warm-up was aimed at minimising the risk of injury as well as preparing the subject for laboratory testing.

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Familiarisation

Perrin (1993) cautions that isokinetic resistance is a novel sensation, and that the dynamometer will only resist the movement of the body segment once force is exerted by the subject at a pre-set velocity. Furthermore, Brown and Weir (2001) caution that the dynamometer is a unique piece of equipment that may not be familiar to most subjects. Thus it was seen as essential, due to subject inexperience with isokinetic testing as well as to ensure validity of results, that subjects complete familiarisation trials. These were completed prior to the commencement of actual test bouts. A rest period between familiarisation trials and actual testing was given to ensure full recovery prior to testing. The administration of the familiarisation trials was standardised for each test protocol with three near-maximal trials permitted at each of the speeds subjects would encounter in the actual experiment.

Procedures

Test procedures that require centre of joint alignment were set-up following the instructions provided in the CYBEX 6000 (Lumex Inc.) manual. Occupation-simulation tests procedures were those used by James (2000) in which project the present author served as a research assistant. Tests such as valve-tightening, wrench-turning, pulling/pushing and gripping record input variables not referable to any specific joint. As a result the dynamometer height was individually adjusted to suit the morphological characteristics of each subject as well as to facilitate the broad ranges of motions required to adequately complete the task.

Figure 5: Set-up procedure: Trunk Flexion-Extension.

Trunk flexion-extension was assessed through a range of motion of 100°. The set-up procedure was standardised according to the manufacturer's protocol.

Figure 6: Set-up procedure: Shoulder Internal-External Rotation.

Shoulder internal-external rotation was assessed through a 160° range of motion. Only the dominant arm was tested using the manufacturer's protocol (90° abduction).

Figure 7: Set-up procedure: Elbow Flexion-Extension.

The entire range of motion assessed in elbow flexion-extension was 150°, with the dominant arm being tested.

Figure 8: Set-up procedure: Knee Flexion-Extension.

Knee extension-flexion was conducted on the dominant side only with a range of motion of 95° being tested.

Figure 9: Set-up procedure: Valve-tightening.

Subjects were required to stand on a raised plinth during the execution of the valve-tightening test. Figure 9 illustrates the standardised set-up procedure used for this assessment. The range of motion tested in the valve-tightening test was approximately 140°. Movement was not restricted, allowing subjects to incorporate the larger musculature of the shoulders and back in completing this test. Consequently greater force could then be exerted, due to the greater degree of freedom. This action was deemed more reflective of actual military tasks performed.

Figure 10: Set-up procedure: Wrench-turning.

During the wrench-turning test subjects were stabilised by an assistant and the range of motion was restricted to forearm use only. This ensured that incorporation of the larger shoulder and back musculature could not interfere with maximal forearm exertion efforts. The total range of motion tested was 130°. Figure 10 illustrates the subject positioning utilised in the study.

Figure 11: Set-up procedure: Pulling/pushing.

The push-pull test was standardised in respect of foot placement only. Subjects were required to place the leading foot over an allocated starting position demarcated on the floor and were not allowed to raise this foot during the execution. The test commenced with each subject in the full pull position. Subjects were required to exert maximal efforts over a distance of 2m across the floor in either direction. The range of motion assessed was approximately 130°.

Figure 12: Set-up procedure: Gripping-test.

The gripping test was conducted at different testing velocities than were used in the other isokinetic tests. Subjects were required to complete a "squeezing" action at the following speeds; $30°s^{-1}$, $60°s^{-1}$ and $90°s^{-1}$. A small range of motion of 15° was tested to accommodate variability in grip sizes in subjects. The gripping device was placed in the neutral position for testing. Subjects were required to stand with the left thigh against the seat of the CYBEX 6000 dynamometer as represented in Figure 12.

Experimental Procedures

The experiment took place over a period of three weeks. Sessions were organised to allow a minimum rest period of one day between test bouts. Subjects were given standardised instructions prior to each test bout. A familiarisation trial was administered to each subject, consisting of three near-maximal efforts. A rest period of 30s was given to subjects to ensure full recovery prior to testing. A 5s warning period was given to subjects who where then asked to perform the maximal repetitions. After each set of 4 repetitions a period of 30s was permitted to ensure that subjects were rested before completing the following test speed. Speed settings were randomised and rest periods between isokinetic tests involved the time it took to set-up the dynamometer with the various attachments and the time taken to test the other subjects. Thus, each subject was given approximately 15 minutes recovery time between each test bout.

Order of Testing

The following test order was used:

Session 1: 1.)Trunk flexion/extension
2.) Knee flexion/extension
3.) Wrench-turning right/left rotation
4.) Gripping (closed only)

Session 2: 1.) Elbow flexion/extension
2.) Pulling/pushing
3.) Valve-tightening right/left rotation
4.) Shoulder internal/external rotation

The tests comprising Sessions 1 and 2 were standardised, but the order in which tests were administered within each session was random. Subject rest period between tests was approximately 15min. This involved the time it took to set-up the dynamometer (with relevant attachments) and the time taken to test other subjects in a group.

Inter-Repetition Effort-Level Consistency

An important criterion in isokinetic strength testing is the determination of inter-repetition consistency, to ensure that subjects are not malingering, or intentionally affecting mean isokinetic responses. Charteris and James (2000), offer an effective method for the detection of work effort-level. They argue that the ability to exert tension through the entire range of motion (full-range tension) is more pertinent in the interpretation of strength expression than the peak tension one can exert at any given point along the range of motion (point tension). Their criterion measure for inter-repetition effort-level consistency is: (mean work per repetition/best work repetition) x 100. For female soldiers, who are involved in regular physical activity, one would expect a high inter-repetition effort-level consistency. According to the guidelines stipulated by Charteris and James (2000), when assessing strength expression for military personnel one should use as a criterion of effort-level consistency a minimum mean/maximum. work ratio of 90%.

CARDIOVASCULAR MEASURES

Cardiovascular responses were recorded telemetrically using Polar^{TM} heart rate monitors. Heart rate measures are a reliable assessment of cardiovascular strain

Vuori (1998). Due to subject inexperience with heart rate monitoring a period of habituation was provided to subjects. Subjects were fitted with heart rate transmitters and the purpose of the heart rate monitor was explained. An individual's heart rate is highly likely to increase in anticipation of a physical demand. Therefore subjects were required to sit quietly and relax so as to obtain a "reference" heart rate prior to testing. Reference heart rate was then used to compare isokinetic-induced cardiovascular changes across the velocity spectrum. "Working" heart rates were measured immediately after each isokinetic test because the fast-speed tests were over in a matter of seconds and valsalva effects, among others, resulted in the cardiac responses to the short-burst activities lagging somewhat behind. In short, the higher exertion-related heart rates were typically achieved immediately after, rather than during, the exertions.

PSYCHOPHYSICAL MEASURES

Perception of exertion ratings were taken using Borg's (1971) RPE scale. An adapted African language (Xhosa) version was used for subjects who were not fluent in English. An interpreter was present to minimise loss of understanding that may have occurred during translation of the scale. Prior to each testing session care was taken to define the procedures of the rating scale to the subjects involved in testing. RPE responses were recorded at the completion of each maximal testing bout.

Statistical Analysis

Analysis of the data was carried out using the STATGRAPHICS (Version 6.0: Manugistics, Inc. and StatGraphics Corporation, 1992) programme. An example of the print-out used in the analysis appears in Appendix E. Data were tested for symmetry, which included the use of normal distribution analysis. The Criterion for significance was set at $p \leq 0.05$. Statistical analyses comprised the following:

Because the sample (N=32) comprised 13 staffers and 19 foot soldiers it was necessary to determine whether these occupational categories within the infantry battalion affected strength expression of the sample as a whole. To assess this a Mann-Whitney U-Test (See Appendix G, p 145) was conducted.

In respect of H_o1:	Kruskall-Wallis Test, comparing the isokinetic test responses through the velocity spectrum.
In respect of H_o2:	Kruskall-Wallis Test, comparing the measured heart rate responses through the velocity spectrum.
In respect of H_o3:	Pearsons Product-Moment Correlation Analyses determining strength of relationship between: - Heart rates and Ratings of Perceived Exertion (RPE)

Judgements of correlation strength involved coefficients of "determination" and "non-determination", following Silverstein (1978,1988).

The data were not able to meet the statistical criteria in respect of homogeneity of variance, normal distribution and random selection necessary for parametric analysis. Therefore an equivalent non-parametric test was applied in analysing the data; in this case the Kruskall-Wallis Test.

CHAPTER FOUR

RESULTS AND DISCUSSION

INTRODUCTION

The performance characteristics of the indigenous female population, about whose physical strength and work-capacity very little is known are of major concern to the South African Defence Force. Female soldiers need to be as efficient and motivated as their male counterparts in completing everyday military tasks. Muscular strength, cognitive ability, cardiovascular status and motivation are attributes that soldiers are required to possess. Isokinetic dynamometers allow for the rapid assessment of musculo-skeletal capacity. The accuracy and reliability of the equipment makes isokinetic dynamometry a very effective means of strength assessment.

Isokinetic assessments involve the measurement of torque, work and power through a range of motion in which the limb is moving at a constant velocity. The present study quantified the strength expression of female infantry personnel through a velocity spectrum: $30°.s^{-1}$, $120°.s^{-1}$ and $210°.s^{-1}$ in all tests but grip strength, which involved speed settings of $30°.s^{-1}$, $60°.s^{-1}$ and $90°.s^{-1}$.

The subjects were offered no extrinsic rewards for participation. This factor could have influenced the level of strength expression. The author found it extremely difficult, despite energetic attempts, to motivate these women to produce maximal efforts, which undoubtedly explains the low consistency of effort-level achieved in this study. The consistency of effort level, as measured according to the guidelines of Charteris and James (2000), ranged between 60% and 93% over the 4-repetition exertions. These authors recommend that a criterion effort-level consistency ratio of 90% be used when testing military personnel and assert that effort-level consistency ratios lower than 80% indicate that, for reasons physical and psychological, the subject is failing to exert maximally. While their findings were based on benchmark isokinetic data relative to male subjects, there is no reason to expect females would not respond similarly.

Definitive comparisons between the present study and the literature could not be made, partly because there is much less published on female isokinetic responses and no data, to date, on female Work-Simulation outputs.

ISOKINETIC RESPONSES

The test battery used incorporated a variety of assessments deemed relevant to most military tasks. Traditionally only single-joint actions have been measured by isokinetic dynamometers. This has limited the generalisability of isokinetics in the past. The present study, however, made use of the Work-Simulation isokinetic innovation, which increases the functionality of the CYBEX 6000 isokinetic dynamometer, by allowing simulation of real-life working conditions. A great variety of testing protocols may be followed when using the Work Simulation package, which allows great diversity in test movements. Despite the usefulness of the package, limited research has heretofore been conducted, and none is known in which females have been the subjects.

The results were analysed as follows, given that assumptions of normality of data, homogeneity of variance and randomness of sampling could not be met and non-parametric alternatives were used:

1. Mann-Whitney U-Test comparison was made between the clerical staffers and the foot soldiers. Since overall these sub-groups performed similarly, their data were pooled for further analysis.

2. The Kruskall-Wallis alternative to a parametric ANOVA was used to investigate isokinetic outputs through the velocity spectrum, as detailed below.

Analysis of the responses by Kruskall-Wallis Test (isokinetic response over speed) showed significant differences in torque, work and power outputs as velocity increased. In respect of peak torque and total work, only wrench-turning did not show significant reductions in outputs over the velocity spectrum (See Appendix F (a) p. 142). Furthermore, no significant differences were found between clerical workers and foot soldiers across the velocity spectrum. Only knee flexion (total work) was found to be significantly different between clerical workers and foot soldiers (See Appendix G (b) p. 143). The isokinetic results are summarised in the following three tables.

TABLE III: Peak Torque (Nm.kg^{-1}) responses across a velocity spectrum. Means, with SD in brackets and medians in bold type.

Joint	Motion	Slow (30°.s^{-1})	Medium (120°.s^{-1})	Fast (210°.s^{-1})
Trunk	**Extension**	2.16 (0.52) **2.11**	1.51 (0.37) **1.50**	0.89 (0.39) **0.90**
	Flexion	2.10 (0.25) **2.06**	1.90 (0.35) **1.93**	1.43 (0.56) **1.43**
Shoulder	**Internal**	0.34 (0.07) **0.33**	0.29 (0.07) **0.27**	0.25 (0.06) **0.24**
	External	0.26 (0.06) **0.25**	0.21 (0.04) **0.20**	0.18 (0.04) **0.19**
Elbow	**Extension**	0.63 (0.12) **0.64**	0.49 (0.09) **0.47**	0.48 (0.10) **0.45**
	Flexion	0.50 (0.10) **0.51**	0.38 (0.09) **0.39**	0.35 (0.09) **0.37**
Knee	**Extension**	1.96 (0.47) **1.95**	1.34 (0.24) **1.36**	1.01 (0.19) **1.02**
	Flexion	1.10 (0.29) **1.13**	0.89 (0.21) **0.88**	0.75 (0.16) **0.73**
Valve-tightening	**Left Rotation**	0.78 (0.14) **0.77**	0.67 (0.14) **0.66**	0.58 (0.11) **0.57**
	Right Rotation	0.72 (0.13) **0.70**	0.62 (0.14) **0.58**	0.54 (0.13) **0.53**
Wrench-turning	**Left Rotation**	0.18 (0.06) **0.18**	0.16 (0.04) **0.15**	0.16 (0.04) **0.15**
	Right Rotation	0.14 (0.05) **0.15**	0.14 (0.04) **0.14**	0.13 (0.05) **0.13**
Pulling/ pushing	**Pulling**	3.30 (0.64) **3.17**	2.53 (0.59) **2.59**	1.51 (0.53) **1.67**
	Pushing	2.69 (0.36) **2.67**	2.29 (0.45) **2.31**	1.58 (0.52) **1.67**
Gripping	**Squeezing**	**(30°.s^{-1})**	**(60°.s^{-1})**	**(90°.s^{-1})**
		0.58 (0.17) **0.53**	0.47 (0.16) **0.45**	0.41 (0.17) **0.37**

Note: None of these tests involved gravity-correction.
Gripping was carried out at different speeds.
Statistical Analysis by means of Kruskall-Wallis Test (Peak Torque over Speed) **$p \leq 0.05$**

TABLE IV: Total Work (J.kg^{-1}) BWR responses across a velocity spectrum. Means, with SD in brackets and medians in bold type.

Joint	Motion	Slow (30°.s^{-1})	Medium (120°.s^{-1})	Fast (210°.s^{-1})
Trunk	**Extension**	2.58 (0.58) **2.54**	1.65 (0.08) **1.67**	0.83 (0.45) **0.82**
	Flexion	2.91 (0.34) **2.95**	2.36 (0.49) **2.45**	1.45 (0.67) **1.53**
Shoulder	**Internal**	0.72 (0.15) **0.67**	0.60 (0.14) **0.59**	0.47 (0.12) **0.45**
	External	0.51 (0.11) **0.50**	0.41 (0.11) **0.38**	0.33 (0.09) **0.33**
Elbow	**Extension**	0.95 (0.21) **0.97**	0.71 (0.15) **0.68**	0.53 (0.14) **0.53**
	Flexion	0.73 (0.16) **0.77**	0.52 (0.14) **0.55**	0.35 (0.13) **0.37**
Knee	**Extension**	1.83 (0.41) **1.87**	1.34 (0.24) **1.39**	0.95 (0.18) **0.97**
	Flexion	1.16 (0.37) **1.15**	0.99 (0.30) **0.97**	0.71 (0.22) **0.69**
Valve-tightening	**Left Rotation**	1.22 (0.19) **1.22**	1.10 (0.23) **1.06**	0.97 (0.18) **0.94**
	Right Rotation	1.09 (0.19) **1.03**	0.99 (0.22) **0.93**	0.86 (0.18) **0.84**
Wrench-turning	**Left Rotation**	0.30 (0.09) **0.29**	0.27 (0.09) **0.24**	0.27 (0.07) **0.24**
	Right Rotation	0.23 (0.07) **0.22**	0.22 (0.08) **0.22**	0.20 (0.06) **0.21**
Pulling/ pushing	**Pulling**	3.88 (0.68) **3.72**	2.93 (0.69) **3.11**	1.43 (0.66) **1.57**
	Pushing	3.22 (0.43) **3.14**	2.41 (0.43) **2.55**	1.28 (0.47) **1.43**
Gripping	**Squeezing**	**(30°.s^{-1})**	**(60°.s^{-1})**	**(90°.s^{-1})**
		0.10 (0.04) **0.10**	0.08 (0.03) **0.08**	0.06 (0.04) **0.05**

Note: None of these tests involved gravity-correction.
Gripping was carried out at different speeds.
Statistical Analysis by means of Kruskall-Wallis Test (Total Work over Speed) **$p \leq 0.05$**

TABLE V: Average Power (W.kg^{-1}) responses across a velocity spectrum. Means, with SD in brackets and medians in bold type.

Joint	Motion	Slow (30°.s^{-1})	Medium (120°.s^{-1})	Fast (210°.s^{-1})
Trunk	**Extension**	0.64 (0.14) **0.50**	1.51 (0.46) **1.45**	1.39 (0.81) **1.31**
	Flexion	0.72 (0.09) **0.74**	2.42 (0.53) **2.52**	2.43 (1.20) **2.62**
Shoulder	**Internal**	0.12 (0.03) **0.12**	0.44 (0.11) **0.41**	0.59 (0.15) **0.56**
	External	0.09 (0.03) **0.08**	0.29 (0.08) **0.27**	0.42 (0.12) **0.39**
Elbow	**Extension**	0.22 (0.05) **0.23**	0.63 (0.15) **0.62**	0.82 (0.25) **0.80**
	Flexion	0.17 (0.04) **0.17**	0.47 (0.13) **0.48**	0.54 (0.20) **0.53**
Knee	**Extension**	0.55 (0.12) **0.57**	1.51 (0.32) **1.52**	1.81 (0.51) **1.80**
	Flexion	0.37 (0.11) **0.38**	1.18 (0.33) **1.14**	1.31 (0.45) **1.17**
Valve-tightening	**Left Rotation**	0.28 (0.05) **0.27**	0.97 (0.19) **0.94**	1.45 (0.27) **1.45**
	Right Rotation	0.25 (0.05) **0.24**	0.86 (0.20) **0.81**	1.28 (0.30) **1.36**
Wrench-turning	**Left Rotation**	0.06 (0.02) **0.06**	0.24 (0.07) **0.23**	0.42 (0.12) **0.40**
	Right Rotation	0.04 (0.02) **0.04**	0.18 (0.05) **0.19**	0.31 (0.10) **0.31**
Pulling/ pushing	**Pulling**	1.11 (0.22) **1.10**	3.26 (0.83) **3.54**	2.57 (1.26) **2.74**
	Pushing	0.90 (0.12) **0.90**	2.57 (0.46) **2.65**	2.22 (0.88) **2.51**
Gripping	**Squeezing**	**(30°.s^{-1})**	**(60°.s^{-1})**	**(90°.s^{-1})**
		0.13 (0.05) **0.14**	0.19 (0.07) **0.18**	0.22 (0.10) **0.20**

Note: None of these tests involved gravity-correction.
Gripping was carried out at different speeds.
Statistical Analysis by means of Kruskall-Wallis Test (Average Power over Speed) **$p \leq 0.05$**

a) Trunk Flexion-Extension

At the slow test velocity the trunk produced higher mean outputs for peak torque and total work compared to medium and fast test velocities. Peak torque was higher for extension (2.16 $Nm.kg^{-1}$) than flexion (2.10 $Nm.kg^{-1}$) at the slow test speed. Conversely total work and power elicited greater outputs in flexion than in extension at the slow test velocity, a trend that remained constant through the velocity spectrum. The findings confirm those of Thompson **et al.** (1985) that trunk extensors tend to elicit greater torque than flexors at slow speed and comparisons of total work and power flexion-extension values show higher outputs for flexion than extension regardless of velocity. However Charteris (1999a) cautions that given the weight of head, arms and trunk (HAT), which constitute about 75% of body mass (Williams and Lissner, 1962; Hause **et al.**, 1980; Thorstensson and Nilsson, 1982 and Perrin, 1993), the recorded extensor values are significantly undervalued and trunk flexors significantly overvalued in the absence of gravity correction. Application of a gravity correction factor would thus have significantly increased the values for trunk extension, and resulted in lower flexor responses, whatever the test speeds.

Torque and work output responses decreased steadily with speed increments, as expected in terms of the "force-velocity" relationship (Hill, 1938). The effect of a speed increase of $90°.s^{-1}$, under conditions in which gravity was not corrected-for, resulted in a disproportionate disadvantage to anti-gravity extension outputs (a 30% torque decrease and 36% work decrease) relative to gravity-assisted flexion outputs (a 10% torque decrease and 19% work decrease). Thus the slow-speed peak torque dominance ratios were shifted in favour of flexion at the medium speed and fast speeds.

Trunk extension total work (0.83 $J.kg^{-1}$) at 210°.s^{-1} showed 68% decrement relative to the slow-speed work output (2.58 $J.kg^{-1}$) and the flexors dropped-off by 50% from slow output (2.91 $J.kg^{-1}$) to the fast output (1.45 $J.kg^{-1}$). Peak torque outputs concur with those of work, with extensor values showing a greater reduction (59%) in output relative to the flexors (32%). The large drop-off in extensor work output is due to the fact that at a higher testing velocity there is less time for subjects to overcome the effects of gravity, thus significantly lowering torque outputs in extension.

Power output during trunk extension and flexion increased with test velocity increments. These finding were expected due to the fact that reduction in available time to produce work outstripped the "force-velocity" drop-off rate. Average power output was higher in flexion than extension regardless of the test speed.

Medium speed extension power outputs increased by 58% relative to slow speed outputs. Although an increase in power was noted at the fast speed (1.39 $W.kg^{-1}$) in relation to slow speed (0.64 $W.kg^{-1}$), fast speed average power dropped-off by 8% relative to the medium speed (1.51 $W.kg^{-1}$). It would be expected that average power would increase with speed increments in accordance to the "force-velocity" relationship. The poor effort-level consistency elicited by the subjects may explain this finding.

b) Shoulder Internal-External Rotation

Shoulder internal rotation is produced by the subscapularis, teres major, pectoralis major, latissimus dorsi and anterior deltoid muscles, with relative contribution from these muscles related to variations in their respective length-tension relationships as the glenohumeral joint moves from the neutral to 90° abducted position (Perrin, 1993). External rotation is produced by the infraspinatus, teres minor and posterior deltoid muscles.

Angular excursion was an important consideration when assessing work values for joint-aligned isokinetic tests. In order to ensure that subjects were indeed working through comparable ranges of motion, randomised data were selected and compared at the slow and fast isokinetic speeds using STATGRAPHICS. Wilcoxon Signed Ranks Tests showed no significant differences between ranges of motion completed during shoulder internal and external rotation, thus permitting relevant work comparisons across the velocity spectrum.

Shoulder strength is essential in completing military tasks such as grenade throwing, object lifting, load carrying and wall climbing. The weakness of the upper-extremity relative to the lower-extremity in terms of peak torque outputs has been shown by numerous authors, including Charteris and Goslin, (1982) and Falkel **et al.** (1987), and the upper-extremity has received less attention in the literature in comparison to lower-extremity assessments. Due to the high incidence of shoulder injury, related to activities involving high rotational speeds, most of the limited upper-extremity strength research has been conducted on the shoulder (Alderink and Kuck, 1986; Appen and Duncan, 1986 and McMaster **et al.**, 1992).

Tables III and IV show substantially higher torque and work outputs for internal rotation than for external rotation, a finding confirming the majority of isokinetic shoulder research (Alderink and Kuck, 1986; Hageman **et al.**, 1989; Voight **et al.**, 1996 and Ellenbecker and Mattalin, 1997). Regardless of test speed, shoulder torque and work outputs continued to show the internal rotators stronger than the external rotators.

TABLE VI: Present study compared to the data from Connely Maddux **et al.** (1989) for shoulder internal and external rotation Peak Torque (Nm.kg^{-1}).

	Velocity Spectrum					
	Slow Speed		**Medium Speed**		**Fast Speed**	
Studies	**Internal**	**External**	**Internal**	**External**	**Internal**	**External**
Present Study	0.34	0.26	0.29	0.21	0.25	0.18
Connely Maddux **et al.**, (1989)*	0.40	0.25	0.35	0.22	0.29	0.19
Congruence	85%	96%	83%	95%	86%	95%

* Results were interpolated, via regression analysis, in order to compare findings relative to different test speeds.

Data from the present study were compared against those available in the literature (Table VI). The mean congruence level established was 90%, which indicates that the female military subjects of this study compared similarly to the "able-bodied" female subjects utilised in the Connely Maddux **et al.** (1989) study, with respect to peak torque values for shoulder internal and external rotation. The present findings confirm those of Connely Maddux **et al.** (1989) that internal rotation is stronger than external rotation regardless of test velocity and speed-related decrements for both internal and external rotation are noticeable.

The medium speed shoulder internal rotator peak torque mean was 85% of the slow speed and external rotator peak torque was 80% of the slow speed. The fast speed internal rotator peak torque mean was 73% that of the slow speed and the external rotator peak torque was 69%. Research has shown that external rotators produce about 65% of the internal rotator torque over a wide range of testing velocities (Ivey **et al.**, 1985; Alderink and Kuck, 1986; Connely Maddux **et al.**, 1989 and Pawlowski and Perrin, 1989). In the present study the external rotators produced 76% at the slow speed and 72% of the internal rotator torque for medium and fast speeds respectively.

On average the external rotators elicited 69% of the total work output produced by the internal rotators. Although shoulder work outputs decreased with velocity increments from slow speed (internal rotation 0.72 $J.kg^{-1}$ and external rotation 0.51 $J.kg^{-1}$ to fast speed internal rotation 0.47 $J.kg^{-1}$ and external rotation 0.33 $J.kg^{-1}$) respectively, the decrement was not as pronounced as was the decline in work of the trunk or lower-limb. These findings follow the research by Berg **et al.**, (1985) who state that incrementing velocity has a less pronounced affect on upper-than on lower-limb values.

Shoulder average power output elicited characteristic isokinetic values (Table V). Internal rotation produced consistently higher power outputs, regardless of test speed, and power increments were noted across the velocity spectrum. Internal rotators increased by 73% at the medium speed relative to slow speeds and increased a further 25% at the fast test velocity relative to medium outputs. Internal rotation elicited a similar pattern with a 69% increase noted at medium speed and a 31% increase at fast test speed relative to medium average power values.

c) Elbow Extension-Flexion

Elbow extension values (triceps brachii), were higher than flexion outputs (biceps brachii, brachialis and brachioradialis), regardless of speed. Research by Charteris and Goslin (1986) has shown that the extensor (E) and flexor (F) muscles often exhibit similar strength, with torque E/F ratios reported around 1.10. Through the velocity spectrum elbow extension peak torque and work outputs remained consistently higher than flexion outputs, flexion being on average 77% of the extension value for torque and 72% for work respectively. These findings, which are not congruent with the reported literature, may well be related to the training programmes of SANDF personnel, where training routines appear to be biased towards the elbow extensors, such as occurs with push-ups.

Medium speed peak torque responses were 77% and 76% of the slow speed, for extension and flexion respectively. Similarly medium speed work outputs achieved 75% for extension and 71% for flexion. Fast speed torque values (0.48 $Nm.kg^{-1}$ for extension and 0.35 $Nm.kg^{-1}$ for flexion) declined minimally relative to medium speed responses (0.49 $Nm.kg^{-1}$ for extension and 0.38 $Nm.kg^{-1}$ for flexion). The elbow extensor value dropped-off only 2% for fast speed elbow extension relative to medium speed and 8% for elbow flexion. These data follow the findings of Berg **et al.**, (1985), that incrementing velocity has a less pronounced affect on upper limb values than to lower limb values.

Work values showed a greater decrement at the fast test speed relative to medium speed outputs when compared to torque findings. Work values dropped-off from medium speed outputs of 0.71 $J.kg^{-1}$ for extension and 0.52 $J.kg^{-1}$ for flexion to fast speed outputs of 0.53 $J.kg^{-1}$ for extension and 0.35 $J.kg^{-1}$ for flexion, which illustrates velocity decrements of 25% and 33% for extension and flexion respectively.

The peak torque data showed that subjects are able to produce similar efforts during medium and fast speed conditions, thus velocity appears not to detract significantly from elbow strength expression. This finding suggests that subjects are equally strong at faster test velocities. However, if one considers work output, which is more reflective of actual strength (Charteris, 1999b) this may be an inaccurate conjecture: velocity noticeably reduces the ability of subjects to exert maximal tension through the range of motion. Thus when one considers total work, velocity increments do reduce the subjects' ability to express strength.

Table VII compares extrapolated data from Berg **et al.** (1985) to the present data. The mean level of congruence between these studies for peak torque output in elbow extension and flexion was 89%. Thus SANDF females exhibit similar elbow torque excursions when compared to female college basketball players. Slow and medium extension values were higher than those extrapolated from Berg **et al.**, (1985). The nature of military training programmes in which activities such as push-ups train the elbow extensors, may explain the higher elbow extensor values.

TABLE VII: Present study compared to the data from Berg **et al.** (1985) for elbow extension-flexion Peak Torque ($Nm.kg^{-1}$).

	Velocity Spectrum					
	Slow Speed		Medium Speed		Fast Speed	
Studies	**Extension**	**Flexion**	**Extension**	**Flexion**	**Extension**	**Flexion**
Present Study	0.63	0.50	0.49	0.38	0.48	0.35
Berg **et al.** (1985) *	0.56	0.54	0.44	0.46	0.54	0.39
Congruence	89%	93%	90%	83%	89%	90%

* Results were interpolated, via regression analysis, in order to compare findings relative to slightly different speeds.

Elbow extension produced more power than did flexion across the velocity spectrum. Slow speed elbow extension values (0.22 $W.kg^{-1}$) produced 35% of the power elicited at the medium test speed (0.63 $W.kg^{-1}$). The fast speed power output value (0.82 $W.kg^{-1}$) increased by 73% when compared to the slow value. Flexion values increased by 64% at medium speed and 69% at the fast speed relative to the slow speed output.

d) Knee Extension-Flexion

In isokinetic dynamometry the knee is, according to Perrin (1993), probably the most commonly tested joint. Torque values, as expected, were higher in knee extension than in knee flexion across the velocity spectrum even without gravity correction. This follows the results of previous research by Charteris and Goslin (1982); Appen and Duncan (1986); Figoni **et al.**, (1988) and Zakas **et al.**, (1995).

Velocity-related decrements are well documented for knee extension and flexion isokinetic tests (Poulmedis, 1985; Appen and Duncan, 1986; Cress **et al.**, 1992 and Perrin, 1993). Peak torque values for extension (1.34 $Nm.kg^{-1}$) at $120°.s^{-1}$ dropped-off by 32% and for flexion (0.89 $Nm.kg^{-1}$) by 19% when compared to extension (1.96 $Nm.kg^{-1}$) and flexion (1.10 $Nm.kg^{-1}$) values at $30°.s^{-1}$, the hamstring muscles declining at a slower rate than the quadriceps. With a further increase in test velocity of $90°.s^{-1}$ a greater drop-off in peak torque responses was evident. Fast speed peak torque was 52% of that elicited at the slow speed for extension, and 68% of the slow speed value for flexion.

Table VIII provides extrapolated data from Berg **et al.** (1985) who investigated collegiate female basketball players. Comparison with the present study, across the velocity spectrum, illustrates a mean congruence level of 72%. All subjects in Berg's study were free of clinical histories. The comparison shows noticeable differences between the peak torque responses. Clearly the present sample under-performed in comparison to an athletic female sample.

Medium speed decrements in extension when compared to slow speed outputs were 32% in the present study and 23% in Berg **et al.** (1985), whilst fast speed torque outputs showed 48% and 58% decrements respectively, when compared to slow speed values. Medium speed flexion values (0.89 $Nm.kg^{-1}$) produced 81% of the slow speed value (1.10 $Nm.kg^{-1}$), whilst Berg **et al.** (1985) showed medium speed values (1.29 $Nm.kg^{-1}$) achieving 68% of the slow speed value (1.56 $Nm.kg^{-1}$). Fast speed excursions illustrate similar velocity-related decrements of 32% (present study) and 34% (Berg **et al.**,1985). The data suggest that velocity-related decrements are comparable.

TABLE VIII: Present study compared to the data from Berg **et al.**, (1985) for knee extension and flexion for Peak Torque ($Nm.kg^{-1}$).

	Velocity Spectrum					
	Slow Speed ($30°.s^{-1}$)		**Medium Speed ($120°.s^{-1}$)**		**Fast Speed ($210°.s^{-1}$)**	
Studies	**Extension**	**Flexion**	**Extension**	**Flexion**	**Extension**	**Flexion**
Present Study	1.96	1.10	1.34	0.89	1.01	0.75
Berg **et al.**,(1985)*	2.48	1.56	1.91	1.29	1.45	1.04
Congruence Level	79%	71%	71%	69%	70%	72%

* Results were interpolated, via regression analysis, in order to compare findings relative to slightly different test speeds

Work decrements followed a similar pattern to those of peak torque with extension values being higher than flexion values regardless of velocity. The knee extensor and flexor total work values dropped-off from 1.83 $J.kg^{-1}$ (extensor) and 1.16 $J.kg^{-1}$ (flexor) at the slow speed to 1.34 $J.kg^{-1}$ and 0.99 $J.kg^{-1}$ respectively, at the medium speed. These shifts were expected as the increase in velocity resulted in lower peak torque values, with the hamstring muscle group tapering off at a slower rate (15% decrease) than the quadriceps (27% decrease). The knee extensor group showed a large decrement in total work responses at the fast test speed. Extensor total work was down to 52% of that elicited at the slow speed, whilst flexors produced 61% of the total work produced at the slow speed.

Of the 48 test conditions examined, only medium speed knee flexion for total work was found to be significantly different across the velocity spectrum (Mann-Whitney U-Test) when clerical workers and foot soldiers were compared. Charteris (1999b) argues that peak torque measures, although useful, are limited in assessing strength expression. A far superior measure of full range tension output is that of total work. Indeed, the work values achieved in this study for knee flexion show significant differences between the samples. Thus the foot soldiers were able to produce a greater constant tension throughout the range of motion relative to the clerical workers, which is supported by the significant difference established at the slow speed for peak torque.

Knee extension power values were shown to be higher than flexion values regardless of test speed. Power values showed the expected speed increments for both extension and flexion. Medium outputs increased by 64% for extension and 68% for flexion relative to slow speed outputs. Extension and flexion values increased similarly at fast test speeds by 70% and 71% respectively when compared to slow output values.

e) Valve-tightening

The valve-tightening test protocol allowed subjects to complete the action in a personally selected manner. This test enabled subjects to recruit muscle groups of the forearm, upper-arm and the shoulder regions as they saw fit to complete the movement. Throughout the velocity spectrum peak torque outputs were higher for left than for right rotation. This may be due to the dominant hand being in an optimal position during left rotation. For example, most subjects reported right hand dominance, therefore during left rotation the right hand is able to turn the valve towards the body resulting in a "higher" torque output for left rotation (See Figure 9, p.55).

Valve-tightening responses showed expected velocity-related decrements in peak torque and total work. Peak torque for left (0.78 $Nm.kg^{-1}$) and right (0.72 $Nm.kg^{-1}$) rotation both decreased by 14% from the slow to medium speed, whereas total work showed velocity induced decrements of 10% and 9% respectively. At the fast test speed, peak torque values dropped-off by 25% for both left and right rotation. Velocity increments of $180°.s^{-1}$ resulted in a total work decrement of 20% for left rotation (1.22 $J.kg^{-1}$ for slow speed to 0.97 $J.kg^{-1}$ for fast speed), whilst right rotation showed a similar decrement of 21% (1.09 $J.kg^{-1}$ for slow speed to 0.86 $J.kg^{-1}$ for fast speed).

Due to similar torque and work decrements, it was expected that power increments would be similar. Indeed power outputs increased almost identically between left and right rotation. Medium speed outputs for left and right rotation increased by 71% and fast speed values increased by 81% for left rotation and 80% for right rotation.

f) Wrench-turning

The wrench-turning test relied on much smaller muscle groups to turn the adapter through a smaller range of motion, relative to the valve-tightening test. Subject execution was restricted via the use of velcro strapping to ensure that forearm and upper-arm muscle groups were isolated during strength expression. The adapter used for the wrench-turning test was small and considered uncomfortable by many of the subjects (See Figure 10, p. 56). This perceptual factor may well have influenced the test responses of the soldiers, but more accurately reflects responses under "real-world" conditions.

The peak torque decrement, due to test speed increments of $90°.s^{-1}$ was 11% for left rotation at medium test speed. Peak torque outputs for right rotation were not affected by an increase in test speed of $90°.s^{-1}$. Peak torque production at the medium test speed for left rotation (0.16 $Nm.kg^{-1}$) remained unchanged in relation to the slow speed output. Whilst the only velocity-related decrement for right rotation (0.14 $Nm.kg^{-1}$) at the fast test speed relative to slow speed output (0.13 $Nm.kg^{-1}$), a 7% decrease. These data suggest that velocity does not appear to detract significantly from peak torque production for wrench-turning. Statistical analysis by means of a Kruskall-Wallis Test showed no significant differences for peak torque and total work across the velocity spectrum for either left or right rotation.

Work values for wrench-turning followed similar patterns to torque outputs. Left rotation work values dropped off by 10% between slow (0.30 $J.kg^{-1}$) and medium (0.27 $J.kg^{-1}$) test speeds with no further decrease noted in work output with speed increments. A 4% decrease was noted between medium and slow speed conditions with a further 9% decline at the fast speed relative to medium speed values. Regardless of test speed left rotation elicited higher outputs than right rotation.

Similar torque and work values were reported between medium and fast test bouts regardless of the increase in testing velocity. The consequential result is that power output appears much greater than what would have been achieved if torque and work outputs decreased with velocity increments. For example if there is no velocity-related decrease in total work production, associated with an 57% reduction in time to produce it, there will obviously be a predictable increase in power output as explained by Charteris (1999b). Thus, average power output values significantly increased for both left (0.42 $W.kg^{-1}$) and right (0.31 $W.kg^{-1}$) rotation at fast test speed relative to medium speed left (0.24 $W.kg^{-1}$) and right (0.18 $W.kg^{-1}$) power outputs.

g) Pulling/pushing

Due to the nature of the pulling/pushing test, the body mass-relative torque outputs were significantly higher than those of any of the other isokinetic tests. The pulling action allows for the use of a number of different muscle groups of the upper-and lower-extremity, as well as the large muscle groups of the trunk. The research protocol allowed subjects to choose their own execution techniques, with only the placement of the leading foot being controlled (See Figure 11, p. 57).

Torque outputs were affected by an increase in the dynamometer speed in accordance to the force-velocity nature of concentric muscular contraction. Pulling torque outputs decreased by 23% at the medium speed and by 54% at the fast speed relative to slow pulling outputs. The pushing peak torque outputs elicited similar results. The medium speed test bout resulted in a decrease of 14% and the fast test speed resulted in 41% decrement relative to slow speed output.

Table IV shows that at the fast test speed (210°.s^{-1}) pushing produced a slightly higher torque output relative to pulling. These results are in contradiction to the force output pattern found in the slower and medium testing bouts. Pulling was significantly stronger than pushing at the slow and medium test speeds. (Wilcoxon Signed Ranks Test). Placement of the forefoot, which was standardised, allowed subjects to use their leg for leverage during pulling, which may explain the significantly higher torque and work outputs achieved. However no significant difference was found between pulling and pushing at the fast speed. The reduced time allowed to incorporate the larger muscle groups of the trunk and the legs during the fast test speed condition may well explain the variability found in peak torque production during the fast isokinetic test speed.

Work outputs for pulling and pushing decreased consistently with a concomitant increase in test velocity. Medium pulling (2.93 J.kg^{-1}) and pushing (2.41 J.kg^{-1}) responses decreased significantly by 24% and 25% respectively, when compared to slow pulling (3.88 J.kg^{-1}) and pushing (3.22 J.kg^{-1}) speed responses.

Medium pulling total work output was the only pulling/pushing effort found to be significantly different between clerical workers and foot soldiers. This finding, in all probability, is due to the significant difference achieved for medium trunk flexion and knee excursions. As mentioned, subjects were able to incorporate trunk and lower-extremity musculature in order to complete the task. Thus foot soldiers, which exhibit stronger trunk and lower-extremity excursions, when compared to clerical workers are able to produce a more constant-tension through the range of motion at the medium test velocity. A 63% decrement for pulling and a 60% decline for pushing were found at the fast test speed relative to slow test speed. Pushing, regardless of velocity, achieved on average 85% of the total work values achieved in pulling.

Pulling and pushing power outputs increased by 66% for pulling and 65% for pushing at medium test velocities relative to slow test bouts. Interestingly both variables dropped-off in power output between medium (pulling 3.26 $W.kg^{-1}$ and pushing 2.57 $W.kg^{-1}$) and fast test (pulling 2.57 $W.kg^{-1}$ and pushing 2.22 $W.kg^{-1}$) velocities. A decrement of 21% for pulling and 14% for pushing was found. The reduced power output is probably indicative of subject difficulty in exerting maximal effort at the fast test speed. Subjects may have been concentrating their effort in trying to maintain their balance during the push phase and thus not exerting a maximal effort. Pulling power values are dominant over pushing values regardless of test velocity. However the dominance is reduced at fast test speeds.

h) Gripping

The gripping test involved assessment through a very limited (15°) range of motion (See Figure 12, p.58) Peak torque values are reflective of the strength expression of the muscles of the hand and forearm at a specific point and may be influenced by the nature of training conducted by soldiers. Gripping peak torque values showed a decrement of 19% at the medium speed (0.47 $Nm.kg^{-1}$) relative to slow speed (0.58 Nm.kg^{-1}). Further speed increments resulted in a reduced torque production (0.41 Nm.kg^{-1}) relative to the fast speed, a 29% decrement.

The squeezing action dropped off by 20% for total work at medium speed relative to slow speed, whilst fast speed squeezing only elicited 60% of the slow speed work output. As the available performance time increases the resultant work output will decrease. Thus the ability of the hand to exert constant tension for squeezing at speed is thus reduced.

Power values for gripping showed the expected power increments over the velocity spectrum. Power increased by 32% at the medium test velocity and by 41% at the fast testing velocity when compared to slow speed output.

EFFORT- LEVEL CONSISTENCY

It is argued that, when assessing strength expression, a subject's ability to exert force through a large range of motion is more important than peak strength at any particular point in the range of motion (Charteris 1999b and Charteris and James 2000). In a military environment, where sustained load carriage is essential, the ability of the soldier to produce constant tension is more relevant to soldier performance than once-off peak strength output. Thus the important variable to consider is not the strongest point in the range of motion but the tension produced throughout the range of motion. For this reason the above authors established guidelines for inter-repetition effort-level consistency.

Research by Charteris and James (2000) as well as unpublished findings in the Department of Human Kinetics and Ergonomics has established that regardless of sex-based differences, type of isokinetic test or test velocity, effort-level consistency ratios for well-motivated able-bodied subjects should be above 85%. Based on calculated effort-level consistency values (Table IX) it is clear that the subjects, deemed representative of females in the SANDF, failed to produce maximal efforts regardless of test velocity and nature of isokinetic excursion. This, despite careful explanation of experimental procedures, familiarisation trials and energetic efforts to motivate subjects. Furthermore, no significant differences were evident between foot soldiers and clerical workers in comparing effort-level consistency outputs.

Failure of subjects to produce maximal excursions can be attributed to the dynamic interaction of psychological, emotional and physical variables. Poor values could be attributed to intra-group variability in commitment, the sample being one of convenience. The natural morphology (BMI of 29.94, body fat 36%) of the sample, which classifies as endomorphic (See Figures 5 to 12) may well have contributed to poor effort-level consistency outputs. Fat patterning, with high deposition around the lower trunk and hip regions may undoubtedly have influenced strength expression in this sample. For example, difficulty was experienced in adequately palpating the iliac crest for centre-of-joint alignment during trunk extension/flexion set-up. Fat deposition affected not only subject set-up, but completion of the full range of motion and may well account for the high inter-repetition variability displayed.

TABLE IX: Percentage based level of consistency of effort across a 4–repetition bout in diverse strength tests.

Joint	Motion	Consistency of Effort-Level (%) (Mean work per repetition/Work repetition). 100				
		(30°.s^{-1})	(120°.s^{-1})	(210°.s^{-1})	Mean (SD)	C.V. (%)
Trunk	**Extension**	70	67	60	66 (5.13)	7.72
	Flexion	73	71	65	70 (4.16)	5.94
Shoulder	**Internal**	71	74	73	73 (1.52)	2.08
	External	69	72	70	70 (1.52)	2.17
Elbow	**Extension**	71	72	70	71 (1.00)	1.41
	Flexion	70	71	71	71 (0.58)	0.82
Knee	**Extension**	68	69	69	69 (0.57)	0.83
	Flexion	70	68	68	69 (1.15)	1.67
Valve-tightening	**Left Rotation**	72	72	72	72 (0.31)	0.43
	Right Rotation	71	71	71	71 (0.12)	0.17
Wrench-turning	**Left Rotation**	73	74	76	74 (1.52)	2.05
	Right Rotation	76	78	74	76 (2.00)	2.63
Pulling/ pushing	**Pulling**	72	72	83	76 (6.35)	8.36
	Pushing	72	68	65	68 (3.51)	5.16
Gripping	**Squeezing**	**(30°.s^{-1})**	**(60°.s^{-1})**	**(90°.s^{-1})**	-	-
		78	80	93	84 (8.14)	9.69

Note: Gripping was carried out at different speeds.

It must be noted that a high level of congruence was established between the present study torque outputs for shoulder and elbow excursions when compared to the literature, as represented in Tables VI and VII. However, these congruency levels are based on peak torque expression values. Thus, although soldiers appear to compare similarly to able bodied subjects in executing maximal peak torque efforts, the same may not hold true when comparing full range tension.

A deficiency in lower-extremity isokinetic knee excursions was identified. Comparisons with the literature indicate that female SANDF members under-performed in relation to an athletic female sample when peak torque values were compared; a finding supported by the poor effort-level consistency values achieved for knee flexion-extension, which were amongst the lowest attained. Although knee flexion ($J.kg^{-1}$) was one of the only isokinetic excursions found to be significantly different between clerical workers and foot soldiers, no significant differences were found between effort-level consistency values. Thus, against expectations, subjects illustrated a weakness in the lower-extremity knee test.

SELECTED PHYSIOLOGICAL AND PSYCHOPHYSICAL RESPONSES

Cardiovascular Responses

Heart rate monitoring is an objective, reliable and feasible evaluation of cardiovascular strain (Vuori,1998). The present study, in an attempt to assess the impact of isokinetic exercise on exertional heart rate responses, attests to the importance of including cardiovascular strain measures. McArdle **et al.**, (1991) highlighted factors that could influence heart rate such as oxygen consumption, temperature, emotion and food intake. Although these variables were not controlled, cognisance was taken of the fact that they may influence heart rates.

However, the sample was drawn from a single military base, where daily tasks and training activities as well as food intake are similar. Thus it was felt, in balance, that these variables could be ignored.

Monitoring of heart rate responses was standardised across all test bouts. "Working heart rates" were measured immediately after each isokinetic test because fast-speed tests were over in a matter of seconds and valsalva effects, among others, resulted in the cardiac responses to the short-burst activities lagging somewhat behind. Reference heart rate was recorded prior to the first test session whilst subjects were calmly seated. The mean reference heart rate of the group was 82 bt.min^{-1}.

TABLE X: Mean Heart rate responses across the battery of tests. Means, with SD in brackets and medians in bold type.

Test	**HEART RATES**					
	Slow Speed (30°.s^{-1})	**Relative to reference heart rate (1)**	**Medium Speed (120°.s^{-1})**	**Relative to reference heart rate**	**Fast Speed (210°.s^{-1})**	**Relative to reference heart rate**
Trunk	142 (15.81) **142**	1.73	141 (14.14) **139**	1.72	134 (13.66) **134**	1.63
Shoulder	126 (21.78) **127**	1.54	120 (20.14) **120**	1.46	110 (20.58) **113**	1.34
Elbow	121 (21.39) **120**	1.47	119 (15.60) **116**	1.45	112 (14.25) **112**	1.37
Knee	127 (20.24) **130**	1.55	124 (15.32) **126**	1.51	120 (13.62) **119**	1.46
Valve-tightening	155 (17.52) **158**	1.89	154 (15.79) **154**	1.87	146 (16.44) **149**	1.78
Wrench-turning	128 (18.55) **129**	1.56	126 (15.30) **128**	1.54	120 (15.25) **122**	1.46
Pulling/ pushing	154 (19.52) **156**	1.87	156 (13.24) **154**	1.90	152 (15.06) **155**	1.85
Gripping(2)	**(30°.s^{-1})**	-	**(60°.s^{-1})**	-	**(90°.s^{-1})**	-
	103 (9.70) **104**	1.26	101 (9.28) **102**	1.23	100 (9.76) **100**	1.22

Notes: **1** Ratio for observed Mean/Reference Mean
2 Gripping was carried out at different speeds

Analysis of these data by Kruskall-Wallis Test (Heart Rate over speed) showed no significant decrements in heart rates (See Appendix F (a), p.142). Only one of the six isokinetic tests (shoulder internal-external rotation) was found to show a significant decrement in heart rate over the velocity spectrum. Test bouts that include whole body actions elicited noticeably higher heart rates than tests that isolated one specific movement. Although test speed was randomised and recovery phase maximised, the trunk, valve-tightening and pulling/pushing tests appeared to place greater demand on the cardiovascular system, regardless of test velocity, as represented in Table X. These tests involve large muscle groups, thus the requirements for oxygen to the working muscle are increased as subjects meet the demands of the task. In contrast to tests incorporating large muscle groups, tests dependent on smaller muscle groups showed the lowest increases in heart rate from the reference mean value. The smaller range of motion and the relative cross-sectional area of the muscles involved may explain these findings. Although subjects were completing a maximal effort, the muscle groups involved were smaller, with lower overall demands being placed on the active muscle groups.

Shoulder internal-external rotation was the only isokinetic test that recorded significant decrements in heart rates over the velocity spectrum. Fast speed exertional heart rate (110 $bt.min^{-1}$) dropped off by 13% relative to the slow speed heart rate (126 $bt.min^{-1}$), whereas fast speed heart rates for the other isokinetics test bouts showed, on average, a 5% decrease due to velocity increments. It is probable that subject positioning, and an increase in intra-thoracic pressure could have contributed to the higher cardiac frequencies during the slow and medium shoulder rotation test bouts. Greater intra-thoracic pressure would result in greater aortic pressure and a concomitant affect on immediate post-exertional heart rate.

The intensity of effort required as well as the nature of the test have been shown to be critical factors in evaluating cardiovascular strain. In addition there appears to be a relationship between heart rate and proximity of active muscle groups to the heart. Exertional heart rate increments relative to the reference heart rates appear to be greater for isokinetic tests that involve large muscle groups in proximity to the heart. The average mean/reference mean ratios, for isokinetic tests of this nature, are; 1.69 for trunk extension-flexion; 1.89 for valve-tightening and 1.87 for pulling/pushing. In comparison, tests in which large muscles are working distal to the heart, elicited lower heart rates during exertion. For example the average mean/reference mean ratio for knee extension-flexion was 1.52.

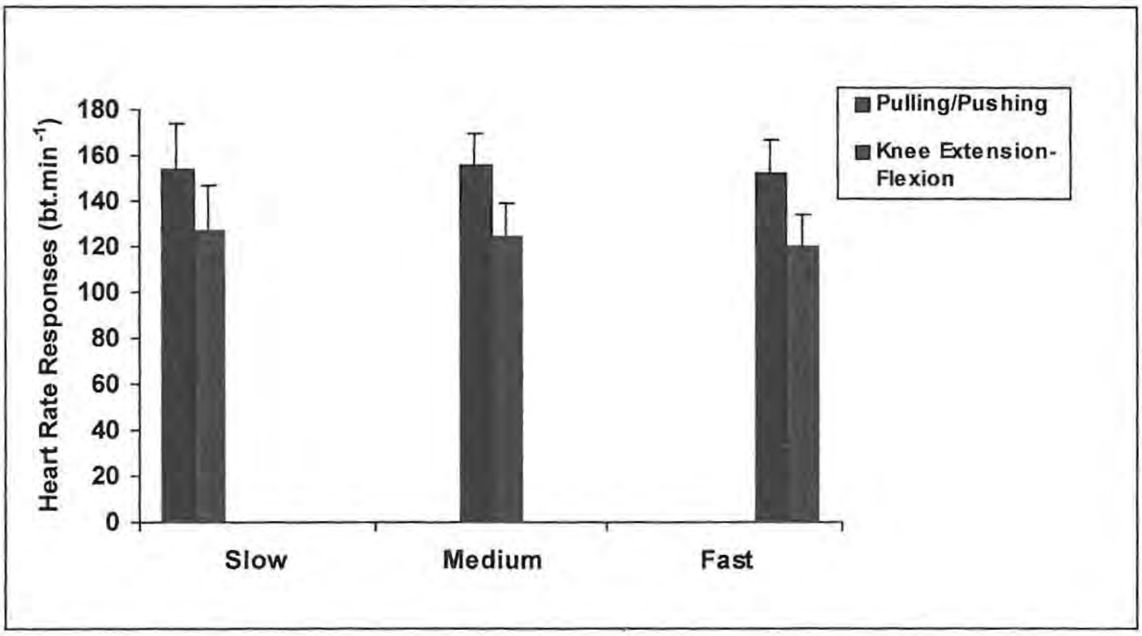

Figure 13: Selected mean heart rate responses of large working muscles in proximity to the heart.

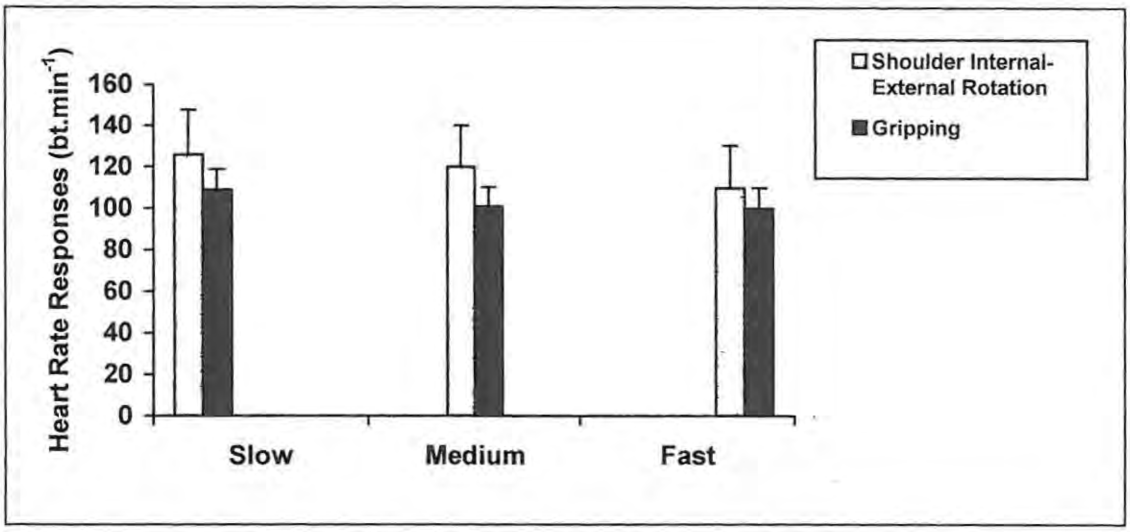

Figure 14: Selected mean heart rate responses of small working muscles in proximity to the heart.

In comparison to larger muscle groups, as represented in Figure 13, isokinetic tests that incorporate smaller musculature in proximity to the heart, such as the shoulder internal-external rotation, also illustrate elevated mean heart rate increments of 1.45, when compared tests distal to the heart utilising small muscle groups such as the gripping test, which showed lower mean heart rate increments of 1.24 with respect to reference heart rate, as illustrated in Figure 14.

Psychophysical Responses: Ratings of Perceived Exertion (RPE)

Borg (1982) found, across a spectrum of working situations, that individual perceptions of exertion during sustained aerobic work are informative, with ratings of perceived exertion providing useful indicators of physical work involved. Aminoff **et al.** (1998) supports this in stating that an important additional question in work physiology is how individuals perceive the amount of work they perform. They found the subjective measures identified by use of the Borg (1971) scale gave a cross comparison to the physical measures obtained and allowed the investigator to explore how the person performing the task felt.

In order to ensure accuracy of ratings, clear instructions and rigorous administration are critical. Subjects were given specific guidelines as to the use of the scale, including verbal explanations given in both English and Xhosa (the most commonly spoken language in the sample). One of the major limitations with ratio-scaling methods, according to Borg (1982), is that they do not provide direct "levels" of inter-individual comparisons. As conditions change some subjects may rate tasks significantly different from others. Thus when assessing RPE values it is critical to scrutinize the data prior to making generalizations about the way in which subjects perceived the tasks. It is, however, possible to identify some trends over the slow, medium and fast speed. These trends are represented in Table XI.

Analysis of these data by Kruskall-Wallis Test (RPE over speed) showed significant differences in perceived exertion as speed increased. Table XI illustrates that the highest values were recorded during slow speed tests. This was expected as subjects exerted maximal efforts for, on average, 30s at the slow speed, compared to the fast test speed where subjects exerted maximally for 5s. The mean RPE scores for the slow test was 15; for the medium test 12; and for the fast test 9. The lowest RPE value for a slow test bout was for gripping. This could well be as a result of the test set-up, requiring subjects to move through a small range of motion whilst only exerting a squeezing action. Both the shoulder and valve-tightening tests recorded the highest RPE (16).

TABLE XI: Mean RPE responses for isokinetic tests across the velocity spectrum. Means with SD in brackets and medians in bold type.

	Speed					
	Slow (30°.s^{-1})		**Medium (120°.s^{-1})**		**Fast (210°.s^{-1})**	
Trunk	15 (2.37)	**16**	12 (2.17)	**12**	9 (1.93)	**9**
Shoulder	16 (2.35)	**16**	13 (2.12)	**13**	9 (1.90)	**9**
Elbow	15 (1.78)	**15**	12 (2.32)	**12**	10 (3.47)	**9**
Knee	15 (2.39)	**15**	11 (2.26)	**11**	9 (2.14)	**9**
Valve-tightening	16 (2.63)	**17**	12 (2.32)	**13**	10 (2.23)	**11**
Wrench-turning	15 (2.51)	**15**	11 (2.45)	**11**	9 (1.99)	**9**
Pulling/pushing	15 (2.42)	**16**	11 (1.91)	**12**	9 (2.58)	**9**
Gripping[1]	**(30°.s^{-1})**		**(60°.s^{-1})**		**(90°.s^{-1})**	
	12 (2.98)	**11**	9 (2.63)	**9**	7 (2.51)	**7**

Note: Gripping was carried out at different testing speeds

A comparison between the mean cardiovascular responses for slow, medium and fast test velocities and mean psychophysical values is represented in Figure 15. A multiplication factor of 10 is used to compare heart rate responses of subjects based on their perceived exertion. Psychophysical responses to slow speed isokinetic exertions showed that subjects tended to over-predict their intensity of effort. Conversely, subjects tended to under-predict their intensity of effort at the medium and fast test speeds. This, in all probability, is as a result of the time taken to complete the maximal exertions at given test velocities. The slow test speed required subjects to exert maximally for, on average 30s, as opposed to the average 5s exertional time required to complete tests at the fast speed.

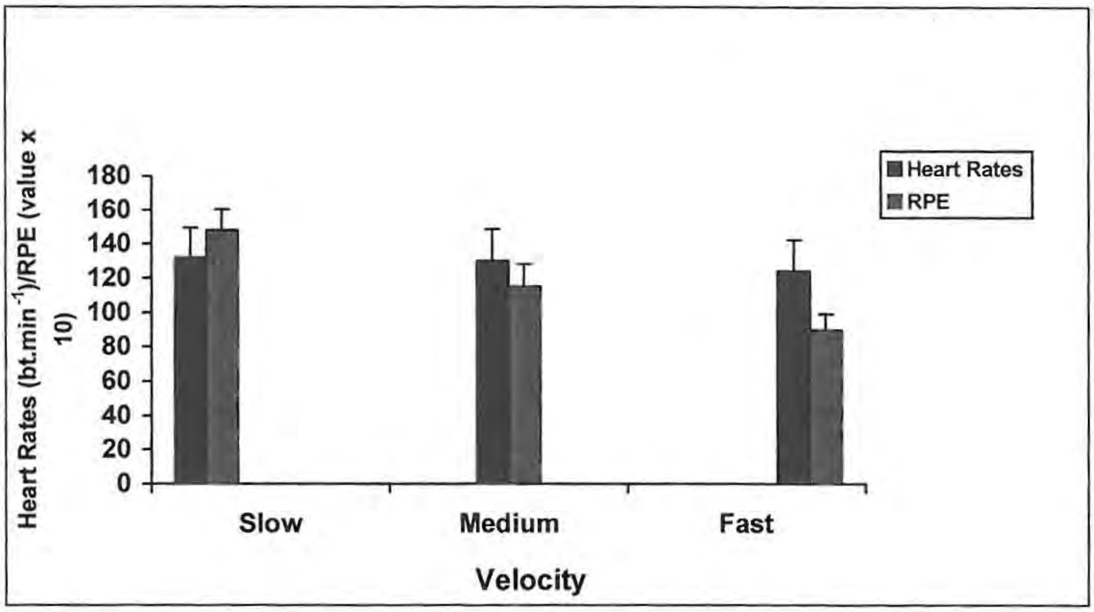

Figure 15: Mean heart rate responses compared with mean RPE responses across the velocity spectrum.

Although adequate rest periods were allowed, the importance of rest time should be regarded as a major factor affecting heart rate.

TABLE XII: Correlation between Heart Rate and RPE. (Under test H_o (Rho=0) Statgraphics found NO significant correlation).

	Correlation					
Test	**Slow (30°.s^{-1})**		**Medium (120°.s^{-1})**		**Fast (210°.s^{-1})**	
	r	**"Explained Variance" (%)**	**r**	**"Explained Variance" (%)**	**r**	**"Explained Variance" (%)**
Trunk	**0.17**	**2.89**	**0.04**	**0.16**	**0.31**	**9.61**
Shoulder	**0.20**	**4.00**	**0.22**	**4.84**	**0.27**	**7.29**
Elbow	**0.21**	**4.41**	**0.01**	**0.01**	**0.09**	**0.81**
Knee	**0.08**	**0.64**	**0.03**	**0.09**	**0.22**	**4.84**
Valve–tightening	**0.21**	**4.41**	**0.19**	**3.61**	**0.20**	**4.00**
Wrench–turning	**0.07**	**0.49**	**0.17**	**2.89**	**0.04**	**0.16**
Pulling/pushing	**0.01**	**0.01**	**0.22**	**4.84**	**0.01**	**0.01**
Gripping	**Slow (30°.s^{-1})**		**Medium (60°.s^{-1})**		**Fast (90°.s^{-1})**	
	0.17	**2.89**	**0.11**	**1.21**	**0.17**	**2.89**

Note: Gripping was carried out at different speeds.

Correlation between heart rates and RPE responses was carried out using Pearsons Product-Moment Correlation Analyses. The findings are represented in Table XII. Statgraphics correlation is evaluated under a null hypothesis; that is statistically independent values have a correlation of zero.

Of the 8 tests conducted at three speeds no significant correlations (that is significantly above zero) were identified between recorded heart rate and predicted RPE values. The RPE response has been shown to correlate highly during testing of cardiovascular endurance (Borg, 1982). However, as expected, no such strong relationship was evident in the present study, as evidenced by the low coefficients of determination between measured heart rate and RPE ratings. Thus, although the use of the RPE scale is an effective means of assessing the psychophyscial responses to long sustained aerobic exercise, it appears that the use of RPE during isokinetic, short-burst (4-repetition) largely anaerobic maximal muscular contractions, is limited.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

SUMMARY

It has already been argued that female isokinetic strength data have been limited both internationally and nationally in the past, and as a result current data are scarce. Even less is understood about the strength capabilities of the indigenous female population. Thus, comparisons between the sexes and between populations are hindered. Data of this nature are of critical importance to the South African National Defence Force (SANDF) not only for the training of female recruits, but to facilitate understanding of the limitations imposed on female soldiers by their morphology. There is substantial literature on sex-based differences in the biophysical realm (Grieve, 1968; Zatsiorky **et al.**, 1994 and Knapik **et al.**, 1996) and in the physiological realm (Astrand, 1956; Bransford and Howley, 1977; Haisman, 1988 and Bhambhani and Maikala, 2000). Much has also been said on the subject of sex-related differences in strength expression (Westing **et al.**, 1988; Colliander and Tesch, 1990 and Evetovich **et al.**, 1998). Despite this, conditions often require that members of a platoon perform uniformly and optimally regardless of sex. Thus female soldiers are differentially taxed by task demands, and this has ramifications for overall military efficiency.

The present study establishes benchmark data in an attempt to understand female military strength profiles and contributes to a topic long neglected, that of the indigenous female of South Africa. The significance of these data is that they help establish a general female strength profile specific to the SANDF, while contributing to the limited knowledge of female responses to isokinetic testing. Furthermore benchmark data were established for Work-Simulation isokinetic responses on which, limited published data exist.

South Africa is an industrially developing country with a large percentage of work in industry being manually intensive. The present project has contributed to ergonomic research by establishing indigenous female strength profiles. This is helpful to those involved in formulating lifting and carrying guideline criteria. These data could be added to ergonomic risk assessment programmes, such as Liftrisk, which is specifically designed to assess inherent task risks.

The accuracy and reliability of calibrated equipment makes isokinetic dynamometry a very effective means of strength assessment. Tests used in the study ranged from clinical tests (where the centre of the joint under test, for example, the knee, is aligned with the axis of rotation of the input arm of the dynamometer), to occupational simulating tests, for example pulling/pushing (which do not allow joint alignment, but do simulate more natural working conditions). The various isokinetic tests utilised in the study were chosen on the basis of their relevance to military needs.

PROCEDURES

The experiment was conducted on the CYBEX 6000 Isokinetic Dynamometer. Test procedures and positions were set up according to the manufacturer's protocols. The dynamometer height was adjusted to accommodate to the morphological characteristics of each subject. New methods of evaluation were used in the occupation-simulating tests with the manufacturer's protocol used as a guideline.

A familiarisation trial, consisting of three near-maximal efforts, was administered to each subject and after a brief recovery period subjects were required to perform 4-maximal exertions. After each set of 4-repetitions a period of 30s was permitted to ensure that subjects were rested before comencing the following test speed. The three speed settings used were randomised and rest periods between isokinetic tests were maximised to ensure recovery.

"Working" heart rates were measured immediately after each test as pilot work had shown that higher exertion-related heart rates were typically achieved immediately after, rather than during, the exertions. Ratings of Perceived Exertion were taken directly after heart rate measurements.

RESULTS

Analysis of these data showed significant differences in torque, work and power outputs as velocity increased. Only wrench-turning peak torque and total work did not show significant reductions in outputs over the velocity spectrum. Thus results obtained in the present study concur with the force-velocity relationship proposed by Hill (1938).

Pulling/pushing showed the highest peak torque values of all the isokinetic tests conducted. The use of a whole-body action in this test in all probability resulted in the relatively higher strength expression values. Variations in execution style, as well as the large muscle groups required in both the upper and lower-extremity to exert a maximal effort were seen as contributing factors to the significantly higher values obtained.

Upper-extremity output comparisons with the literature found high levels of congruence in peak torque achieved. Shoulder rotation and elbow flexion-extension established levels of congruency of 90% and 89% respectively. However, although high levels of congruence were established for peak torque, effort-level consistencies in the respective tests were low (72% on average for shoulder rotation and 71% for both elbow extension-flexion), indicating that subjects failed to execute maximally over the 4-repetition sets. Thus although peak torque (an "instantaneous" effort) may compare favourably with the literature, total work ("full-range" tension), which has been established as an output of greater relevance in interpreting strength expression, may not.

Comparisons with the literature established a poor level of congruence for peak torque knee extension-flexion, a finding supported by the poor effort-level consistency (66% for both extension and flexion) which was one of the lowest achieved in the study. Although total work ($J.kg^{-1}$) in knee flexion was one of the few isokinetic excursions found to be significantly different between the clerical workers and the foot soldiers, no significant differences were found between effort-level consistency values. Thus, against expectations, even the better-conditioned subjects illustrated a weakness in the lower-extremity knee test, when compared to an athletic sample.

Based on calculated effort-level consistency values across the tests it is clear that the subjects, deemed representative of females in the SANDF, failed to produce maximal efforts regardless of test velocity and nature of isokinetic excursion; this, despite careful explanation of experimental procedures, familiarisation trials and energetic efforts to motivate subjects. Furthermore, no significant differences were evident between foot soldiers and clerical workers in comparing effort-level consistency outputs.

Physiological and psychophysical responses were assessed to augment this strength expression profile of SANDF personnel. Tests which required whole-body actions such as the trunk extension-flexion and pulling/pushing tests elicited higher mean heart rates than other isokinetic tests. Shoulder internal-external rotation was the only isokinetic test which recorded significant decrements in heart rates over the velocity spectrum. Fast speed exertional heart rate (110 $bt.min^{-1}$) dropped off by 13% relative to the slow speed heart rate (126 $bt.min^{-1}$), whereas fast speed heart rates for the other isokinetics test bouts showed, on average, a 5% decrease due to velocity increments.

Significant decreases in the ratings of perceived exertion were elicited by increases in speed. Furthermore, comparisons between average cardiovascular responses for slow, medium and fast test velocities and mean psychophysical values showed that subjects tended to over-predict their intensity of effort at slow test speeds. Conversely, subjects tended to under-predict their intensity of effort at the medium and fast test speeds.

No significant correlations (that is, significantly above zero) were identified between heart rate and predicted RPE values. As expected, no relationship was evident between measured heart rate and RPE ratings, the highest level of "explained variance" (r^2) being 9.61%. Thus, although the use of the RPE scale is an effective means of assessing psychophyscial responses to aerobic exercise (Borg, 1982), it appears that the use of RPE during isokinetic, short-burst (4-repetition) largely anaerobic maximal muscular contractions is unwarranted.

CONCLUSIONS

The present study has provided benchmark data on a population that has long been neglected, the indigenous female South African population. The experiments undertaken to test hypotheses raised in this study yielded the following conclusions:

In respect of H_o1 the results force rejection of the null hypothesis: (μ $TWP_{(30)}$ = μ $TWP_{(120)}$ = μ $TWP_{(210)}$). Statistical analysis showed significant differences between all isokinetic tests conducted over the velocity spectrum with the exception of wrench-turning at the medium and fast test velocities (torque and work). The overwhelming result is, as expected, a confirmation of the force-velocity relationship, with actual strength expression values now being available as benchmark data on indigenous S.A females.

In respect of H_o2 the results force retention of the null hypothesis: (μ $HR_{(30)}$ = μ $HR_{(120)}$ = μ $HR_{(210)}$). Statistical analysis by means of the Kruskall-Wallis Test established significant differences in heart rate over speed for only one of the eight test conditions (shoulder internal-external rotation). Thus, heart rates do not appear to be affected by isokinetic test speed. Similar studies with which the author has been associated have found higher heart rates at slower (long duration) test speeds, but these have involved effort levels in excess of 90% (compared to 72% of the present sample) suggesting again that the females in the present study probably failed to exert maximally.

In respect of H_o3 the results encourage retention the null hypothesis: (H_o3: Rho $_{(HR;\ RPE)}$ = 0). Statistical analysis by means of Pearsons Product - Moment Correlation showed no relationship between heart rate and RPE values. It would seem that the use of RPE as a predictor of working heart rate in short-bout isokinetic strength expression tests is unproductive.

RECOMMENDATIONS

The findings of the present study lead to the following recommendations:

(1) Comparison between male and female peak strength expression as well as effort-level consistency values is warranted in an attempt to further facilitate understanding of the limitations, if any, imposed on female soldiers by their morphology. Furthermore, these data can be used to develop female-specific training, workloads and load carriage guidelines for the SANDF.

(2) Further study is needed to compare the effort-level consistency values achieved in this project to non-military effort level work excursions amongst the female population.

(3) These data can be used in ergonomic risk assessment programmes as a proactive tool in assessing maximal lifting and carrying guidelines.

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APPENDIX A: PSYCHOPHYSCIAL RESPONSE SCALES

Borg's (1971) Rating of Perceived Exertion (RPE) scale

Rating of Perceived Exertion	(Borg, 1971)
6	
7	VERY, VERY LIGHT
8	
9	VERY LIGHT
10	
11	FAIRLY LIGHT
12	
13	SOMEWHAT HARD
14	
15	HARD
16	
17	VERY HARD
18	
19	VERY, VERY HARD
20	

(after: Borg G (1971). **The Perception of Physical Work.** In: Shephard RJ (Ed.) Fronteirs of Fitness, Springfield, Illinois: C Thomas).

Scott's (1986) Universal RPE scale

UNIVERSAL RPE SCALE

NUMERICAL	VERBAL	DIAGRAM
6		
7	VERY, VERY LIGHT	
8		
9	VERY LIGHT	
10		
11	FAIRLY LIGHT	
12		
13	SOMEWHAT HARD	
14		
15	HARD	
16		
17	VERY HARD	
18		
19	VERY, VERY HARD	
20		

(In: Scott PA (1986). The ratings of perception of exertion in a multi-ethnic society: A review of the problem and some preliminary solutions. **Proceedings: First Annual Conference of the Ergonomic Society of Southern Africa**. Pretoria, 5-6 February.1-4.)

APPENDIX B: LETTER OF INFORMATION AND INFORMED CONSENT

SPEED-RELATED ISOKINETIC AND PSYCHOPHYSICAL RESPONSES OF FEMALE MILITARY PERSONNEL

LETTER OF INFORMATION

Thank you for offering to participate as a subject in the above mentioned Masters research thesis. In this study I will be investigating the effect of force-velocity relationship on isokinetic strength performance. You will be required to participate in two data collection sessions, comprised of eight strength testing sessions. Strength data will be conducted on the Cybex 6000 Isokinetic Dynamometer and the Work-Simulation System. Once your position has been standardised, according to the type of strength test and the manufacturers specifications, you will then be required to exert a maximal voluntary contraction (MVC). The way in which you will be required to exert the force will be explained verbally prior to test commencement. All four repetitions in the various strength test conditions will be at three speeds, $30°.s^{-1}$, $120°.s^{-1}$ and $210°.s^{-1}$, except for gripping which will be conducted at $30°.s^{-1}$, $60°.s^{-1}$ and $90°.s^{-1}$, which will be set by the CYBEX machine.

Please note that you will be required to exert a **maximal** effort, for all strength tests. Therefore muscular discomfort and/or pain will be experienced. Please report any excessive pain to me, and if this pain happens to become unbearable for whatever reason, the test will be terminated.

Following the completion of the data collection period, I will gladly discuss your test results, should you be interested, as limited feedback will be available during the test period. There are no additional risks that may be encountered during the data collection sessions. However, Professor J Charteris and/or Professor P Scott (the research supervisors) will be present at all times to oversee the procedures and protect your best interests.

This project will have no direct benefit to you, although your participation will contribute to our knowledge about strength expression abilities of the SANDF female soldiers. Knowledge in this specific area of ergonomics may be useful in attempting to decrease the frequency of work-related injuries that occur in the military as well as establish benchmark test expectations for further studies. I should only require approximately five hours twice a week for one week. Once, again many thanks for your interest. Please do not hesitate to let me know should you have any further questions.

Yours sincerely

Dale Kennedy
Department of Human Kinetics and Ergonomics

INFORMED CONSENT

I ______________________________, having been fully informed of the research entitled:

SPEED-RELATED ISOKINETIC AND PSYCHOPHYSICAL RESPONSES OF FEMALE MILITARY PERSONNEL

do hereby give my consent to act as a subject in the above mentioned research. I am fully aware of the procedures involved as well as the potential risks and benefits attendant to my participation as explained to me verbally and in writing. In agreeing to participate in this research, I waive any legal recourse against the researchers, the Human Kinetics and Ergonomics Department, or Rhodes University, from any and all claims resulting from personal injuries sustained. This waiver shall be binding upon my heirs and personal representatives. I realize that it is necessary for me to promptly report to the researchers any signs or symptoms indicating any abnormality or distress. I am aware that I may withdraw my consent and may withdraw from participation in the research at any time. I am aware that my anonymity will be protected at all times, and agree that the information collected may be used and published for statistical or scientific purposes.

I have read the information sheet accompanying this form and understand it. Any questions which may have occurred to me have been answered to my satisfaction.

(PRINT NAME)	(SIGNED)	(DATE)

Subject /legal representative:

(PRINT NAME)	(SIGNED)	(DATE)

Person administering Informed Consent:

(PRINT NAME)	(SIGNED)	(DATE)

Witness:

APPENDIX C: GENERAL TESTING PROTOCOL

GENERAL TESTING PROTOCOL

ISOKINETIC TESTING OF FEMALE MILITARY PERSONNEL

1. BASIC DEMOGRAPHIC DATA

Collection of subject data will be done at the commencement of the testing session. The following will be collected: hand and leg dominance, blood pressure, age, stature, body mass, bioelectrical impedance and body mass index (BMI) and reciprocal ponderal index (RPI) then calculated.

2. INFORMED CONSENT AND LETTER OF INFORMATION TO SUBJECTS

Prior to strength testing subjects will be asked to sign an informed consent form and read the letter of information as to familiarize themselves to the particulars of this study. Subjects will be informed both verbally and in writing form as to the contents of the informed consent and subject requirements.

3. WARM-UP

A warm-up programme prior to the commencement of strength testing will be completed by each subject. For this, 5 minutes of light activity will be completed on the Monark^{TM} cycle ergometer at a low resistance (2 kg) and a stretching programme will be followed for both upper- and lower-extremities.

4. SUBJECT FAMILIARIZATION

The subject will be asked to complete a number of mock trials in the present study. Practice bouts are deemed essential for both accurate isokinetic data collection and subject familiarization. No subjects have had prior experience with isokinetic testing and the machine-type strength assessment demands a period of familiarization. Three trials will be conducted at each of the machine speeds for the occupation-simulating tests prior to data collection.

5. STRENGTH MEASURES

PROCEDURES

Testing positions will be standardised according to the instruction manual provided by Cybex (Lumex Inc.) The dynamometer will be adjusted for subject morphology and the subject data recorded in the event of data loss or machine complications.

ORDER OF TESTING

Subjects will be required to perform 8 maximal tests and the order will be set-up so as to allow for maximum recovery time in the rest phases. The rest period will involve the time it takes to set-up the dynamometer with the various attachments and the time taken to test the other subjects. The time will be approximately 15 minutes between each test for the subject concerned.

6. PHYSIOLOGICAL AND PSYCHOPHYSICAL RESPONSES

CARDIOVASCULAR RESPONSES

Heart rate responses will be recorded during the maximal testing using a POLAR^{TM} heart rate monitor. The readings will be taken at the end of each maximal test bout. Reference heart rates were also recorded at the commencement of the study.

PSYCHOPHYSICAL RESPONSES

Ratings of perceived exertion will be taken using Borg's (1971) RPE scale. An adapted African language (Xhosa) version will be used for subjects who are not fluent in English. An interpreter will be available to aid those subjects in understanding the instructions. Care will be taken to adequately define the procedures of the rating scale to the subject involved in the testing. Measures will be taken at the completion of each testing bout and recorded for data reduction.

TEST PROTOCOL

1) The test protocol will be verbally explained to you (the subject) before the testing commences.
2) Subjects will then be allocated to various groups and given a number.
3) The following information will be obtained:

    Name
    Age
    Body
    Stature
    Bioelectrical impedance
    Mass Hand and leg dominance

4) A warm-up will be carried out on the Monark$^{\text{TM}}$ Cycle Ergometer prior to maximal testing.
5) The testing procedures of the Cybex 6000 will be explained to you.
6) Familiarization trials will be conducted prior to each specific strength test. The RPE scale will be clarified.
7) Maximal testing will follow on the Cybex 6000. The order of testing will be as follows:

    Session 1: 1.)Trunk flexion/extension
    2.) Knee flexion/extension
    3.) Wrench-turning right/left rotation
    4.) Gripping (Closed only)

    Session 2: 1.) Elbow flexion/extension
    2.) Pulling/pushing
    3.) Valve-tightening right/left rotation
    4.) Shoulder internal/external rotation

8) Prior to each test the subject will be placed into the correct position and given the opportunity to become familiar with test procedures.
9) Subjects will be asked the question “are you ready?” The test will then commence on the word “go.”
10) The subject will be verbally encouraged.
11) Once the four repetitions have been completed a rest period will be allowed.
12)The next bout of maximal testing will follow on the Cybex6000. You will be placed into the correct position and the instructions above will be repeated.
13) The test protocol procedure will be repeated for each of the eight tests.

APPENDIX D: SUBJECT DEMOGRAPHIC AND DATA SHEETS

Department of Human Kinetics and Ergonomics

SPEED-RELATED ISOKINETIC AND PSYCHOPHYSICAL RESPONSES OF FEMALE MILITARY PERSONNEL

(Dale Kennedy)

Subject details	**Cybex code:** ________________
Name	
Age (yr)	
Stature (mm)	
Body Mass (kg)	
RPI (stature. Mass $^{0.333}$)	
BMI (kg/m^2)	
Body Fat % (BI)	
LBM (%)	
Arm dominance:	**R** **L**
Leg dominance:	**R** **L**

Heart Rate and RPE responses:

Cybex Code:	
Session	
Group	
Reference Heart rate (b.min^{-1})	

Test Session 1	**Speed**	**Heart Rate (bt.min^{-1})**	**RPE**
Back	30°.s^{-1}		
	120°.s^{-1}		
	210°. s^{-1}		
Knee	30°.s^{-1}		
	120°.s^{-1}		
	210°. s^{-1}		
Gripping	30°.s^{-1}		
	60°.s^{-1}		
	90°. s^{-1}		
Wrench-turning	30°.s^{-1}		
	120°.s^{-1}		
	210°. s^{-1}		

Test Session 2	Speed	Heart Rate (bt.min^{-1})	RPE
Elbow	30°.s^{-1}		
	120°.s^{-1}		
	210°. s^{-1}		
Pulling/ pushing	30°.s^{-1}		
	120°.s^{-1}		
	210°. s^{-1}		
Valve-turning	30°.s^{-1}		
	120°.s^{-1}		
	210°. s^{-1}		
Shoulder	30°.s^{-1}		
	120°.s^{-1}		
	210°. s^{-1}		

APPENDIX E: SUMMARY REPORTS

Example print-out from the Cybex Computer

```
FACILITY     : HUMAN MOVEMENT STUDIES        CYBEX EVALUATION  PG 1 OF 1
CLIENT NAME:                                        CLIENT ID     :  1100
REPORT DATE: 19.07.1999  00:20                      REPORT TYPE   :  ISKF
STATUS
MUSCLE GRP : INTERNAL ROTATORS/EXTERNAL ROTATORS CURR BW (KGS):  80
DAP/ACTION : 0109 SHOULDER INTERNAL/EXTERNAL ROTATION CON/CON

SIDE (s) TESTED / DATE : R                               18.07.1999
BW (KGS) / MAX GET (Nm): 80                                       0
REPS                           4       4      4

                                                              CONCENTRIC
EXTERNAL ROTATORS
SPEED (S) (deg/sec)              30    120    210
PEAK TORQUE (Nm)                 18     15     11
PEAK TORQUE % BW                22%    18%    13%
ANGLE OF PEAK TORQUE             13     30    -58
TORQUE @     deg
TORQUE @     deg
ACCEL TIME (sec)               0.03   0.06   0.08
TOTAL WORK (BWR) BW (J)          35     28     22
TOTAL WORK (BWR) % BW           43%    35%    27%
AVG POWER (BWR) (watts)           6     21     28
AVG POWER (BWR) % BW             7%    26%    35%
TAE (J)                         0.5    2.6    4.5
ASD (Nm)                          1      0      0
SET TOTAL WORK (J)              136    107     83
ENDURANCE RATIO
50% FATIGUE WORK (J)
50% FATIGUE TIME (sec)
50% FATIGUE REPS
WORK RECOVERY RATIO

                               CONCENTRIC INTERNAL ROTATORS
SPEED (S) (deg/sec)             30    120    210
PEAK TORQUE (Nm)                23     19     16
PEAK TORQUE % BW               28%    23%    20%
ANGLE OF PEAK TORQUE           -21    -25     -2
TORQUE @     deg
TORQUE @     deg
ACCEL TIME (sec)               0.01   0.07   0.10
TOTAL WORK (BWR) BW (J)          52     43     33
TOTAL WORK (BWR) % BW           65%    53%    41%
AVG POWER (BWR) (watts)           9     31     39
AVG POWER (BWR) % BW            11%    38%    48%
TAE (J)                         0.6    3.3    6.0
ASD (Nm)                          1      0      0
SET TOTAL WORK (J)              188    161    125
ENDURANCE RATIO
50% FATIGUE WORK (J)
50% FATIGUE TIME (sec)
50% FATIGUE REPS
WORK RECOVERY RATIO
                               RATIO AND ROM : EXTERNAL ROTATORS/INTERNAL
ROTATORS
PEAK TORQUE (Nm)                78%    78%    68%
TORQUE @     deg
TORQUE @     deg
TOTAL WORK (BWR)                67%    65%    66%
AVG POWER  (BWR)                66%    67%    71%
SET TOTAL WORK                  72%    66%    66%
AVERAGE ROM (160)               154    153    153

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Sample print-out from the STATRAPHIC PROGRAMME.

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VARIABLE:               HFTI              HFWI              HFP1
-------------------------------------------------------------------------

Sample Size             19                19                19
Average                 0.256316          0.488421          0.587895
Median                  0.25              0.47              0.57
Mode                    0.25              0.38              0.48
Geometric mean          0.251019          0.477925          0.575418
Variance                3.0.567E-3        0.0116696         0.0163731
Standard deviation      0.0550969         0.108026          0.127957
Standard error          0.0126401         0.0247828         0.0293554
Minimum                 0.18              0.35              0.43
Maximum                 0.38              0.76              0.85
Range                   0.2               0.41              0.42
Lower quartile          0.21              0.4               0.48
Upper quartile          0.3               0.57              0.68
Interquartile range     0.09              0.17              0.2
Skewness                0.727581          0.91299           0.658582
Standardized skewness   1.29474           1.62468           1.17196
Kurtosis                -0.157103         0.561347          -0.684973
Standardised kurtosis   -0.139784         22.1174           21.7654
Coeff. Of variation     21.4957           22.1174           21.7654
Sum                     4.87              9.28              11.17

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VARIABLE:               HFTI              HFWI              HFP1
-------------------------------------------------------------------------

Sample Size             19                19                19
Average                 0.2278947         0.538421          0.0926316
Median                  0.26              0.52              0.09
Mode                    0.25              0.48              0.1
Geometric mean          0.272594          0.524227          0.0880184
Variance                4.15439E-3        0.0159696         8.4269E-4
Standard deviation      0.0644545         0.126371          0.0290291
Standard error          0.0147869         0.0289915         6.65974E-3
Minimum                 0.2               0.33              0.04
Maximum                 0.45              0.83              0.15
Range                   0.25              0.5               0.11
Lower quartile          0.23              0.48              0.07
Upper quartile          0.31              0.62              0.12
Interquartile range     0.08              0.14              0.05
Skewness                1.17848           0.339571          0.179968
Standardized skewness   2.09711           0.604271          0.320255
Kurtosis                1.55987           0.243791          -0.264852
Standardised kurtosis   1.3879            0.216915          -0.235654
Coeff. Of variation     23.1063           23.4706           31.3383
Sum                     5.3               10.23             1.76

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APPENDIX F: STATISTICAL TABLES

a) Kruskall-Wallis Test of variance (isokinetic response over speed) across the velocity spectrum.

		Isokinetic response		
Measure		**Peak Torque ($Nm.kg^{-1}$) BWR**	**Total Work ($J.kg^{-1}$) BWR**	**Average Power ($W.kg^{-1}$)**
Trunk	**Flexion**	0.0000*	0.0000*	0.0000*
	Extension	0.0000*	0.0000*	0.0000*
Shoulder	**Internal rotation**	0.0000*	0.0000*	0.0000*
	External rotation	0.0000*	0.0000*	0.0000*
Elbow	**Flexion**	0.0000*	0.0000*	0.0000*
	Extension	0.0000*	0.0000*	0.0000*
Knee	**Flexion**	0.0000*	0.0000*	0.0000*
	Extension	0.0000*	0.0000*	0.0000*
Valve-tightening	**Left rotation**	0.0000*	0.0000*	0.0000*
	Right rotation	0.0000*	0.0000*	0.0000*
Wrench-turning	**Left rotation**	0.4360	0.5204	0.0000*
	Right rotation	0.5487	0.2120	0.0000*
Pulling/ pushing	**Pulling**	0.0000*	0.0000*	0.0000*
	Pushing	0.0000*	0.0000*	0.0000*
Gripping	**Squeezing**	0.0000*	0.0000*	0.0000*
		0.0000*	0.0000*	0.0000*

Note: Only wrench-turning, left and right rotation, showed NO significant torque and work decrements $p \leq 0.05$.

b) Kruskall-Wallis Test of variance for cardiovascular (Heart Rate over speed) and psychophysical responses (RPE over Speed) across the velocity spectrum.

Measure	**Heart Rate ($bt.min^{-1}$)**	**RPE**
Trunk	0.0860	0.000*
Shoulder	0.0163*	0.000*
Elbow	0.1234	0.000*
Knee	0.2367	0.000*
Valve-tightening	0.0576	0.000*
Wrench-turning	0.0831	0.000*
Pulling/pushing	0.6367	0.000*
Gripping	0.3326	0.000*

Note: Only heart rates in the shoulder test showed a significant decrement ($p = 0.05$).

APPENDIX G: COMPARISONS BETWEEN CLERICAL WORKERS AND FOOT-SOLDIERS PERSONNEL: TORQUE, WORK AND POWER

a) Clerical workers (CW) versus foot-soldiers (FS) isokinetic **Peak Torque responses** at three speeds. Means, with SD in brackets, medians in bold type.

Joint	Motion		Slow (30°.s^{-1})	Medium (120°.s^{-1})	Fast (210°.s^{-1})
Trunk	**Extension**	**CW**	2.07 (0.42) **2.00**	1.39 (0.34) **1.33**	0.81 (0.38) **0.80**
		FS	2.22 (0.58) **2.16**	1.59 (0.37) **1.63**	0.94 (0.38) **0.90**
	Flexion	**CW**	2.01 (0.20) **2.00**	1.73 (0.33) **1.77**	1.30 (0.61) **1.26**
		FS	2.16 (0.26) **2.11**	2.01 (0.33) **2.01**	1.52 (0.51) **1.56**
Shoulder	**Internal**	**CW**	0.33 (0.47) **0.33**	0.28 (0.54) **0.27**	0.25 (0.62) **0.24**
		FS	0.36 (0.08) **0.34**	0.31 (0.07) **0.28**	0.26 (0.05) **0.25**
	External	**CW**	0.25 (0.50) **0.24**	0.20 (0.32) **0.19**	0.16 (0.03) **0.17**
		FS	0.28 (0.06) **0.26**	0.22 (0.05) **0.20**	0.19 (0.03) **0.20**
Elbow	**Extension**	**CW**	0.61 (0.10) **0.64**	0.47 (0.09) **0.44**	0.46 (0.13) **0.43**
		FS	0.64 (0.14) **0.64**	0.49 (0.08) **0.48**	0.47 (0.08) **0.46**
	Flexion	**CW**	0.49 (0.10) **0.47**	0.37 (0.10) **0.37**	0.34 (0.10) **0.34**
		FS	0.51 (0.14) **0.53**	0.40 (0.10) **0.41**	0.36 (0.09) **0.37**
Knee	**Extension**	**CW**	1.99 (0.47) **1.91**	1.38 (0.24) **1.40**	1.05 (0.23) **1.06**
		FS	1.94 (0.48) **2.06**	1.31 (0.24) **1.35**	0.98 (0.16) **1.00**
	Flexion	**CW**	0.95 (0.29) **0.88**	0.86 (0.24) **0.82**	0.76 (0.22) **0.71**
		FS	1.20 (0.24) **1.27**	0.92 (0.21) **0.95**	0.75 (0.12) **0.78**
Valve-tightening	**Left Rotation**	**CW**	0.74 (0.11) **0.74**	0.64 (0.10) **0.63**	0.55 (0.12) **0.54**
		FS	0.81 (0.17) **0.81**	0.69 (0.16) **0.70**	0.61 (0.11) **0.60**
	Right Rotation	**CW**	0.72 (0.11) **0.69**	0.56 (0.11) **0.55**	0.49 (0.13) **0.51**
		FS	0.73 (0.14) **0.73**	0.67 (0.14) **0.72**	0.58 (0.12) **0.60**
Wrench-turning	**Left Rotation**	**CW**	0.16 (0.07) **0.13**	0.16 (0.06) **0.14**	0.16 (0.04) **0.14**
		FS	0.19 (0.05) **0.19**	0.17 (0.04) **0.16**	0.16 (0.04) **0.15**
	Right Rotation	**CW**	0.14 (0.05) **0.13**	0.12 (0.04) **0.11**	0.13 (0.04) **0.13**
		FS	0.16 (0.04) **0.15**	0.15 (0.04) **0.15**	0.14 (0.04) **0.15**
Pulling/ pushing	**Pulling**	**CW**	3.04 (0.55) **3.00**	2.24 (0.59) **2.27**	1.44 (0.60) **1.54**
		FS	3.44 (0.66) **3.22**	2.72 (0.51) **2.82**	1.59 (0.49) **1.77**
	Pushing	**CW**	2.66 (0.32) **2.67**	2.21 (0.53) **2.25**	1.56 (0.61) **1.82**
		FS	2.76 (0.42) **2.85**	2.35 (0.38) **2.34**	1.63 (0.46) **1.62**
Gripping	**Squeezing**		**(30°.s^{-1})**	**(60°.s^{-1})**	**(90°.s^{-1})**
		CW	0.56 (0.16) **0.16**	0.45 (0.19) **0.45**	0.44 (0.21) **0.43**
		FS	0.60 (0.16) **0.58**	0.47 (0.12) **0.46**	0.39 (0.14) **0.37**

Note: Only the shaded areas were significantly different (p= 0.05):
Trunk Flexion at 120 °.s^{-1}p=0.0314.
Knee Flexion at 30 °.s^{-1} p=0.0192.
Pulling at 120 °.s^{-1} p=0.0101.

b) Clerical workers (CW) versus foot-soldiers (FS) isokinetic **Work (BWR) responses** at three speeds. Means, with SD in brackets, medians in bold type.

Joint	Motion		Slow (30°.s^{-1})		Medium (120°.s^{-1})		Fast (210°.s^{-1})	
Trunk	**Extension**	**CW**	2.39 (0.48)	**2.27**	1.48 (0.45)	**1.33**	0.77 (0.49)	**0.76**
		FS	2.72 (0.60)	**2.77**	1.76 (0.43)	**1.79**	0.88 (0.41)	**0.88**
	Flexion	**CW**	2.76 (0.23)	**2.79**	2.08 (0.46)	**2.08**	1.25 (0.71)	**1.21**
		FS	2.76 (0.41)	**3.00**	2.55 (0.40)	**2.57**	1.59 (0.61)	**1.67**
Shoulder	**Internal**	**CW**	0.72 (0.10)	**0.69**	0.59 (0.13)	**0.56**	0.47 (0.13)	**0.44**
		FS	0.73 (0.17)	**0.67**	0.62 (0.15)	**0.59**	0.49 (0.12)	**0.47**
	External	**CW**	0.48 (0.08)	**0.48**	0.37 (0.07)	**0.36**	0.31 (0.06)	**0.28**
		FS	0.54 (0.13)	**0.52**	0.43 (0.12)	**0.42**	0.35 (0.09)	**0.37**
Elbow	**Extension**	**CW**	0.89 (0.17)	**0.96**	0.68 (0.16)	**0.65**	0.51 (0.15)	**0.15**
		FS	0.98 (0.23)	**1.01**	0.73 (0.15)	**0.75**	0.54 (0.13)	**0.54**
	Flexion	**CW**	0.71 (0.10)	**0.47**	0.49 (0.12)	**0.50**	0.32 (0.12)	**0.30**
		FS	0.75 (0.16)	**0.78**	0.54 (0.15)	**0.58**	0.36 (0.13)	**0.38**
Knee	**Extension**	**CW**	1.79 (0.42)	**1.65**	1.34 (0.24)	**1.32**	0.91(0.22)	**0.91**
		FS	1.86 (0.39)	**1.94**	1.35 (0.24)	**1.43**	0.97 (0.16)	**1.00**
	Flexion	**CW**	0.96 (0.35)	**0.86**	0.87 (0.29)	**0.76**	0.62 (0.26)	**0.55**
		FS	1.30 (0.31)	**1.31**	1.06 (0.28)	**1.12**	0.76 (0.17)	**0.72**
Valve-tightening	**Left Rotation**	**CW**	1.16 (0.12)	**1.15**	1.04 (0.16)	**1.03**	0.92 (0.20)	**0.89**
		FS	1.26 (0.23)	**1.29**	1.14 (0.25)	**1.14**	1.01 (0.16)	**1.00**
	Right Rotation	**CW**	1.08 (0.17)	**1.03**	0.91 (0.17)	**0.88**	0.80 (0.21)	**0.74**
		FS	1.12 (0.23)	**1.09**	1.06 (0.23)	**1.13**	0.91 (0.17)	**0.93**
Wrench-turning	**Left Rotation**	**CW**	0.27 (0.11)	**0.23**	0.26 (0.10)	**0.23**	0.26 (0.07)	**0.24**
		FS	0.31 (0.09)	**0.32**	0.28 (0.08)	**0.26**	0.27 (0.07)	**0.25**
	Right Rotation	**CW**	0.20 (0.08)	**0.20**	0.20 (0.06)	**0.18**	0.19 (0.06)	**0.18**
		FS	0.25 (0.07)	**0.24**	0.23 (0.06)	**0.23**	0.22 (0.06)	**0.24**
Pulling/ pushing	**Pulling**	**CW**	3.62 (0.52)	**3.70**	2.33 (0.96)	**2.35**	1.29 (0.72)	**1.50**
		FS	4.04 (0.73)	**3.98**	3.15 (0.61)	**3.33**	1.58 (0.65)	**1.59**
	Pushing	**CW**	3.13 (0.41)	**3.09**	2.30 (0.46)	**2.22**	1.43 (1.05)	**1.44**
		FS	3.34 (0.53)	**3.41**	2.38 (0.64)	**2.55**	1.36 (0.44)	**1.43**
Gripping	**Squeezing**		**(30°.s^{-1})**		**(60°.s^{-1})**		**(90°.s^{-1})**	
		CW	0.10 (0.05)	**0.10**	0.08 (0.04)	**0.08**	0.07 (0.05)	**0.06**
		FS	0.10 (0.03)	**0.10**	0.07 (0.02)	**0.07**	0.05 (0.03)	**0.05**

Note: Only the shaded areas were significantly different (p= 0.05):

Trunk Flexion at 120 °.s^{-1}p=0.0085.

Knee Flexion at 30 °.s^{-1} p=0.0080; at 120°.s^{-1} p=0.0511; at 210 °.s^{-1} p= 0.0399.

Pulling at 120 °.s^{-1}p=0.0064.

c) Clerical workers (CW) versus foot-soldiers (FS) isokinetic **Average Power responses** at three speeds. Means, with SD in brackets, medians in bold type.

Joint	Motion		Slow (30°.s^{-1})		Medium (120°.s^{-1})		Fast (210°.s^{-1})	
Trunk	**Extension**	**CW**	0.61 (0.12)	**0.57**	1.34 (0.49)	**1.26**	1.25 (0.89)	**0.97**
		FS	0.67 (0.15)	**0.66**	1.63 (0.40)	**1.67**	1.50 (0.74)	**1.43**
	Flexion	**CW**	0.70 (0.08)	**0.69**	2.16 (0.59)	**2.15**	2.11 (1.31)	**2.06**
		FS	0.74 (0.10)	**0.75**	2.59 (0.41)	**2.64**	2.65 (1.07)	**2.87**
Shoulder	**Internal**	**CW**	0.13 (0.02)	**0.12**	0.43 (0.10)	**0.41**	0.59 (0.17)	**0.57**
		FS	0.13 (0.03)	**0.12**	0.45 (0.11)	**0.45**	0.59 (0.13)	**0.57**
	External	**CW**	0.07 (0.02)	**0.08**	0.27 (0.05)	**0.26**	0.40 (0.08)	**0.35**
		FS	0.09 (0.03)	**0.09**	0.31 (0.09)	**0.31**	0.45 (0.12)	**0.47**
Elbow	**Extension**	**CW**	0.21 (0.04)	**0.23**	0.62 (0.14)	**0.61**	0.81 (0.27)	**0.72**
		FS	0.22 (0.06)	**0.23**	0.64 (0.15)	**0.65**	0.82 (0.23)	**0.80**
	Flexion	**CW**	0.16 (0.04)	**0.17**	0.45 (0.11)	**0.44**	0.50 (0.20)	**0.46**
		FS	0.17 (0.46)	**0.18**	0.49 (0.14)	**0.49**	0.57 (0.21)	**0.61**
Knee	**Extension**	**CW**	0.57 (0.13)	**0.57**	1.60 (0.33)	**1.63**	1.78 (0.70)	**1.80**
		FS	0.55 (0.12)	**0.55**	1.45 (0.29)	**1.45**	1.83 (0.33)	**1.81**
	Flexion	**CW**	0.31 (0.12)	**0.27**	1.09 (0.34)	**1.04**	1.19 (0.53)	**1.02**
		FS	0.40 (0.09)	**0.40**	1.24 (0.33)	**1.19**	1.40 (0.39)	**1.31**
Valve-tightening	**Left Rotation**	**CW**	0.27 (0.03)	**0.27**	0.92 (0.15)	**0.91**	1.41 (0.31)	**1.35**
		FS	0.29 (0.06)	**0.29**	1.01 (0.23)	**1.05**	1.48 (0.25)	**1.50**
	Right Rotation	**CW**	0.25 (0.04)	**0.23**	0.80 (0.17)	**0.76**	1.14 (0.30)	**1.08**
		FS	0.26 (0.06)	**0.24**	0.92 (0.21)	**0.95**	1.39 (0.27)	**1.14**
Wrench-turning	**Left Rotation**	**CW**	0.06 (0.03)	**0.05**	0.24 (0.09)	**0.21**	0.41 (0.12)	**0.39**
		FS	0.07 (0.02)	**0.07**	0.25 (0.07)	**0.23**	0.43 (0.12)	**0.40**
	Right Rotation	**CW**	0.04 (0.02)	**0.03**	0.18 (0.05)	**0.16**	0.30 (0.11)	**0.29**
		FS	0.05 (0.02)	**0.05**	0.21 (0.05)	**0.21**	0.35 (0.10)	**0.39**
Pulling/ pushing	**Pulling**	**CW**	1.05 90.17)	**1.03**	2.86 (0.83)	**2.69**	2.37 (1.39)	**2.63**
		FS	1.14 (0.25)	**1.10**	3.44 (0.77)	**3.58**	2.70 (1.15)	**2.79**
	Pushing	**CW**	0.90 (0.13)	**0.93**	2.49 (0.49)	**2.44**	2.13 (0.99)	**2.45**
		FS	0.92 (0.15)	**0.90**	2.63 (0.44)	**2.65**	2.33 (0.79)	**2.52**
Gripping	**Squeezing**		**(30°.s^{-1})**		**(60°.s^{-1})**		**(90°.s^{-1})**	
		CW	0.13 (0.06)	**0.11**	0.19 (0.10)	**0.17**	0.25 (0.13)	**0.20**
		FS	0.13 (0.04)	**0.14**	0.18 (0.04)	**0.18**	0.20 (0.06)	**0.20**

Note: Only the shaded areas were significantly different (p= 0.05):

Trunk Flexion at 120 °.s^{-1}p=0.0085 and Trunk Extension p=0.0400.

Knee Flexion at 30 °.s^{-1} p=0.139.

Pulling at 120 °.s^{-1}p=0.0287.

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