PHYSIOLOGICAL, PERCEPTUAL AND OTHER PERFORMANCE DECREMENTS IN COMBAT RELATED TASKS FOLLOWING PROLONGED HEAVY-LOAD MARCHING

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ABSTRACT

In response to challenging situations physiological and psychological adaptations result in elevated levels of arousal and when these levels are 'optimal' performance is enhanced. There are however, limitations to the amount of physiological and mental stimulation one can tolerate, with cumulative fatigue effects being the outcome when stressful conditions are imposed on the individual over an extended period of time. As a result of the extreme physical and cognitive demands placed on military forces while in combat, with soldiers being thrust into battle and required to make critical life-or-death determining decisions followed by appropriate motor responses, the physical and psychological capabilities of the troops are pushed to maximal limits, often resulting in undesirable decrements in physical and mental performance, with consequential human and materiel losses.

Thirty-two soldiers participated in a battery of combat-related field and laboratory tests, first under 'normal' conditions with no prior physical activity and then immediately after the participation of an intensive bout of exercise. Physiological and perceptual responses plus standard of performance were measured at various stages of testing.

Results of the Rating of Perceived Exertion (RPE), Body Discomfort Scale and heart rate responses revealed significantly higher levels of psychophysical strain in response to the strenuous physical activity. Despite these findings, the electromyographic (EMG) activity and efficiency of the combat-related skills were not negatively affected. Rather, nominal improvements in post-activity performance were noted, specifically response time, and this was attributed to elevated arousal and activation as a result of the exercise that was of sufficient duration to enhance arousal without imposing long term cumulative fatigue effects.

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CHAPTER I

INTRODUCTION

INTRODUCTION

The primary purpose of an armed military force is to protect, defend and fight for the safety of a country and its people. It has been pointed out by Danielsson (1998) that in a fighting situation a series of interdependent decisions about an external environment, which is continuously changing, have to be made. Speed and accuracy of response is critical because appropriate judgements and reactions must be formulated, not only in a correct order, but also at specific points in time. This important responsibility lies in the hands of human beings who, under the command of superiors, undertake specific rigorous physical training in preparation for unpredictable combat situations that could occur at any time. Their task is to fight to the best of their ability, and this may entail the possibility of giving up their life in the course of duty.

As a result of these demands, there are several different forms of stress associated with the military, all of which are exacerbated with a need for a high level of performance during critical situations. Cost effectiveness is naturally a military concern and therefore improved military efficiency, in terms of the safety and general well-being of personnel in relation to combat readiness, is necessary in reducing costs. These costs are twofold in nature and no modern military operation can afford to disregard them: they are the relatively less important cost of equipment lost as a result of inefficient military operations, and the critical cost of failed engagements with consequent unnecessary loss of lives.

A fact which appears to often be ignored is that infantrymen are human, and despite the rigorous training and discipline undertaken, soldiers are not automated marching robots. They are individual people with a variety of mental and physiological functions that are continually having to adapt to the dynamic external, and their own internal, environments. It is therefore inevitable that under extreme conditions of stress, the human factor may falter.

The stressors easiest to recognise are the external physical ones such as noise, vibration, temperature, extremes of humidity and acceleration forces. However, internal strains are also prevalent, and Vaernes **et al.** (1991) mention the importance of recognising psychological stressors, such as work/rest patterns, circadian rhythm changes and emotional stress associated with family separation. Although these factors may not be as immediately obvious, they are nevertheless as important.

The literature has revealed that the heavy loads carried by the foot soldier are not getting lighter. Rather, they are increasing due to modern technological developments which require the infantryman to carry more equipment for greater protection and firepower (Nordeen, 1986; Dubik and Fullerton, 1987; Johnson and Knapik, 1995). This may appear to be beneficial in terms of combat readiness, but Knapik **et al.** (1996) observed that soldiers who are required to march with heavy loads are likely to show reductions in military efficiency due to decreased motivation, fatigue and other psychological and physiological factors. Similarly, Scott and Charteris (1996) argued that "human efficiency is not solely specified in mechanical terms" and point out that perceptual factors dictate motivation and willingness to perform, components which consequently affect task efficiency, whether in civilian or military contexts.

Physiologically, when the loaded individual commences marching energy expenditure rises as a result of a number of factors, notably the load carried, the terrain, temperature and/or humidity and the speed and gradient of marching (Goslin and Rorke, 1986). As these factors increase, so too do the cumulative fatigue effects resulting in a deterioration in perceptual-motor skills which are known to be adversely affected by metabolic and/or musculo-skeletal fatigue (Scott and Charteris, 1996).

A great deal of military-relevant ergonomics has focussed on load carriage and its effect on the marching soldier (Levine **et al.,** 1982; Goslin and Rorke, 1986; Haisman, 1988; Johnson and Knapik, 1995; and Knapik **et al.,** 1996), while the effect of long term physical demands, especially that required in an actual combat situation, on the efficiency of fighting performance has received little attention. This is a critical area that tends to go unnoticed, probably due to the inability to test *in situ*. It is evident that intense bouts of physical activity resulting from a combination of the load carried and the distance covered by the marching soldier will lead to a fatigued state which will, over an extended period, ultimately result in a deterioration in the proficiency of executing the required military tasks such as loading of guns, marksmanship and grenade throwing (Asmussen, 1979; Haisman, 1988; Johnson and Knapik, 1995; Knapik **et al.,** 1996).

In any investigation into human responses under stressful situations the interdependence between the human mind and body is extremely prevalent. Therefore, an in-depth investigation needs to be conducted into the differentiation of mental and physical fatigue arising from stressful conditions in order to discover how these may influence the performance outcome. The diversity of military tasks require both physical and mental alertness, and while there are no tasks that are exclusively either physically or mentally demanding, one may tend to be more prominent than the other depending on the given situation.

In life-threatening military situations where fighting soldiers are surrounded by the chaos, destruction and confusion of brutal violence directed towards themselves and others, arousal levels will be elevated substantially with an increase in alertness, both of which profoundly affect how a person will react to specific situations. This may be particularly relevant to "nervous arousal", for as Asmussen (1979) hypothesized "nervous excitement" influences mental alertness to such a degree that muscles are able to endure greater than 'normal' strain. This elevation in physiological proficiency is influenced by the endocrine system which increases the flow of epinephrine (Bergstrom, 1970; Hashimoto **et al.,** 1975). However, there is a limit to the amount of elevated arousal that can be tolerated before there is a deleterious effect on performance efficiency. Furthermore, there appears to be an 'ideal' level of arousal, and various forms of human behaviour are best conducted during moderate levels of arousal or physiological activation, with performance deteriorating with either high or low extremes of activation which will result in a deterioration in physical and mental performance (Bergstrom, 1970; Roy and Steptoe, 1991). This topic has been studied by researchers as early as 1908 by Yerkes and Dodson who proposed the Inverted-U Theory of arousal, originally stating that performance is lowest when arousal is very high or low, and highest when arousal is optimal for that specific situation.

PERFORMANCE REQUIREMENTS

Soldiers in action are continually thinking, moving, observing and dodging. The ability to think quickly and clearly is critical to reacting appropriately and therefore, cognitive processing plays a vital role in successful combat performance. Mental workload is often conceptualised by the interaction between task demands and the intellectual capacities of the human worker and it has been stated by Akila (1997) that changes in work content and demands of work in the military and defence professions have made it necessary to develop more reliable methods for measuring cognitive performance of the soldiers, an area that has not received as much attention as the physical ability of the foot soldier.

Associated with this cognitive ability is the speed at which a person can take in information from the immediate environment, select the appropriate response and react as quickly and as effectively as possible. This skill is the foundation of military competence and can be most basically assessed by means of an individual's reaction time.

Once a decision has been made, a physical response is required and in a combat situation strength and endurance, plus precision in aiming and throwing are critical physical requirements. However, continuous intense physical activity as experienced in long term battle conditions will inevitably take its toll on the human body and fatigue will, sooner or later, set in. Factors such as training, experience and practice may possibly delay the debilitating effects of fatigue and it is therefore important to determine what exactly the effects of fatigue are and how to reduce or minimise them in order to improve proficiency of performance.

In order to utilize human power in the most economical way, it is necessary to improve the capacity for physical work of the human being, and good physical condition is a time-honoured and unquestionable axion in the military. Yet, Jette **et al.** (1989) report that there is limited objective knowledge as to what criteria of "fitness" are necessary to maintain combat effectiveness during sustained operations, and how these should be assessed.

Ultimately the physical condition of the combatant will be determined by natural endowment, together with the way this has been adapted to physical demands through specific training programmes. It is evident that anatomical and physiological factors will influence the work capacity of an individual, just as psychological influences such as motivation play an important role in performance output.

STATEMENT OF THE PROBLEM

Infantrymen are required to be in good physical condition in order to be optimally efficient in combat technique when the need arises. However, a high level of physical conditioning may not be sufficient for effective, successful fighting performance as the unavoidable cumulative effects of external and internal environmental demands will inevitably influence the cognitive and physical ability of fighting soldiers. The resultant state of physical and mental fatigue ensuing in sub-optimal physical and mental performance is unacceptable when human life is at stake and financial losses are immense.

As cognitive and motor functions are affected by continuous, exhausting physical activity, this study assessed the effects of an extended period of physical activity on the psycho-motor components of Reaction Time, Cognitive Ability, speed and accuracy of Aiming, accuracy in Throwing, upper body Strength and Power of the lower limbs. A determination of how these factors are altered after strenuous physical conditions may assist in establishing methods of possibly minimising the detrimental effects of fatigue on military efficiency as measured through the execution of physical and mental tasks.

This study assessed heart rate responses and electromyographic activity as tangible assessments of the physiological adaptations to the imposed intensive physical activity. Perceptual factors were considered, with Rating of Perceived Exertion (RPE) and Bodily Discomfort being assessed. Therefore, an holistic approach was taken in investigating the effectiveness of the soldier, as the standard of performance plus the physiological and perceptual responses of an individual are interdependent. This principle is based on Borg's (1978, b) proposition of the "Effort Performance Triad" which considers the physiological and perceptual factors as well as the overall performance responses of the individual.

RESEARCH HYPOTHESIS

It was hypothesised that the fatigue resulting from the strenuous physical demands, including marching under loaded conditions, would have a deleterious effect on the efficiency of post-march combat efficiency.

STATISTICAL HYPOTHESES

1) Fatigue resulting from demanding marching conditions will have no affect on the efficiency of performance.

$$H_o: \mu\ \text{Pre-Physical Activity}_{\text{Performance}} = \mu\ \text{Post-Physical Activity}_{\text{Performance}}$$

$$H_a: \mu\ \text{Pre-Physical Activity}_{\text{Performance}} \neq \mu\ \text{Post-Physical Activity}_{\text{Performance}}$$

Where Performance included the assessment of Magazine Loading, Target Shooting, Grenade Throwing, Grip Strength, Power of the lower limbs, Reaction Time (Finger and Whole Body), and Cognitive Ability.

2) There will be no difference in physiological responses to specifically physically challenging tasks before and after demanding physical activity.

$$H_o: \mu\ \text{Pre-Physical Activity}_{\text{Physiological}} = \mu\ \text{Post-Physical Activity}_{\text{Physiological}}$$

$$H_a: \mu\ \text{Pre-Physical Activity}_{\text{Physiological}} \neq \mu\ \text{Post-Physical Activity}_{\text{Physiological}}$$

Where Physiological assessments included Heart Rate and Electromyographic activity.

3) There will be no difference in perceptual responses to specific physically challenging tasks before and after demanding physical activity.

Ho: μ Pre-Physical Activity$_{\text{Perceptual}}$ = μ Post-Physical Activity$_{\text{Perceptual}}$

Ha: μ Pre-Physical Activity$_{\text{Perceptual}}$ ≠ μ Post-Physical Activity$_{\text{Perceptual}}$

Where Perceptual considers the Ratings of Perceived Exertion (RPE).

DELIMITATIONS

The sample for the present study was confined to 32 male military personnel aged between the ages of 20 to 37 years. All the subjects were chosen from the same military barracks. Data were collected on the subjects at three separate testing sessions. The first of these sessions was in the University laboratory where demographic data of the subjects were recorded. Familiarisation of laboratory testing equipment and testing protocol was thoroughly discussed with the subjects. The other two testing sessions were conducted at the local Military Base and in the laboratory.

The scope of the project was to investigate physiological and perceptual responses to physical performance parameters under 'normal' conditions and immediately after 'physically fatiguing' conditions. The physiological parameters included for assessment were heart rate and electromyographical (EMG) recordings of the right forearm (Palmaris Longus), the right Intermediate Deltoid, the Trapezius on the right side of the body, and the left forearm (Palmaris Longus). The perceptual variables evaluated were Rating of Perceived Exertion (RPE) and Body Discomfort.

The standard of performance was measured by assessing the time taken to load a magazine with thirty rounds, speed and accuracy in aiming in while shooting five rounds from two distances from the target in different positions (ie lying down and standing), and finally accuracy in aiming was evaluated by throwing a dummy grenade into a target 20m away. Further performance responses to various tests that were considered relevant in a military context were assessed in the laboratory. These included Grip Strength using a hand-grip dynamometer and Power output of the lower limbs was measured using the Sargent Jump. Finger and Whole Body Reaction Time was measured, and finally Cognitive Ability, through the use of a computer programme, was assessed.

LIMITATIONS

While every effort was made to ensure rigorous control of as many influential factors as possible, it must be kept in mind that when investigating individual human responses, there is an extremely broad network causality affecting these responses and it is therefore impossible to control all imposing influences. Therefore, when examining the subsequent conclusions and implications of the experimental data, one must be aware of the following limitations:

1) Although the sample for the study was a fairly homogenous group in that they were all members of the same Battalion of military personnel, the age of the subjects did vary substantially, ranging from 20 years to 37 years. This had a concomitant affect on the number of years of military experience, which ranged from 3 to 14 years.

2) It was assumed that the physical condition of the subjects was similar as they were from the same Battalion and therefore participated in the same training routine. Extra-curricular activities were not taken into account.

3) While diurnal influences were controlled for, nutritional and sleeping conditions were not as these factors are specific to the individual and were beyond the control of the experimenter.

4) By virtue of the fact that the Electroymyograph (EMG) equipment used in this experiment had four channels, only four muscles could be measured, resulting in an inability to assess whether other muscle groups were recruited to assist in the execution of the required activities. As there was intermittent activity of the muscle groups assessed, with target shooing requiring ballistic contractions of the upper body, EMG assessment of the primary agonist and antagonist muscles would have proved to be interesting in determining how these specific muscles are affected after

participation in strenuous physical activity. Again, this was not possible due to the limited number of channels.

5) A major limitation of the study was the restriction on the duration of testing time. Ideally, in order to obtain accurate assessments of the effects of intensive physical activity, like that encountered under battle conditions on combat-related skills, testing should be assessed over an extended period of time. While the army approved of the project, they did request limited interruption to army routine and time. Although Condition 1 only took approximately three hours to complete, Condition 2 lasted about six hours. The subjects had to report three times for data collection, and as the project took eight weeks to complete, it was somewhat disruptive to military activities.

6) Despite the intensity of the physical activity programme proposed by the army personnel, the duration of exercise proved to be insufficient in inducing fatigue. This limitation was a result of the great emphasis placed on enhancing the physical condition of the military, and an intensive bout of strenuous activity, similar to that conducted in this study, is possibly typical of normal training procedures.

7) As empirical data collection during combat conditions is not possible, and critical influencing factors such as environmental temperature, fluid intake,

sleep deprivation and the cumulative affect of the emotional tension experienced during live combat being difficult to simulate, a true evaluation of the effect of extended combat fatigue on the effectiveness of performance is impossible to obtain.

CHAPTER II

REVIEW OF LITERATURE

INTRODUCTION

The problems inherent in participating in vigorous physical activity over an extended period of time, like that experienced in challenging, unpredictable combat situations, are of considerable concern to the Army, as cumulative strain will inevitably result in fatigue with consequential adverse effects on fighting performance. Commanders have repeatedly associated success on the battlefield with the high level of physical fitness of their troops, and as a result, good physical condition of the soldier is essential. The importance of physical well-being in the military, particularly for the infantry, has been considered by Jette **et al.** (1989) as crucial and unquestionable.

It has been estimated by Knapik **et al.** (1990) that 40% of the Army's active divisions move to and about the battlefield on their feet, and with the development of new weapons and other equipment, the amount of firepower and protection for each soldier has increased. This, however, is not always advantageous, for as these authors report, the modern day combatant carries almost twice the load of his counterparts in the past consequently increasing the energy expenditure and the risk of both chronic and acute injury.

There is a limited amount of scientific knowledge as to what level of general physical fitness is necessary to maintain combat effectiveness during sustained operations, and which components of conditioning are the most important. Knapik **et al.** (1990) and

Patton **et al.** (1991) suggest that a multifactorial approach needs to be taken in the understanding of the factors that influence overall combat efficiency, as it involves physiological, psychological and other influencing variables. This suggestion follows the same concept as Borg's (1978,b) "Effort Performance Triad" which considers perceptual and physiological factors, as well as performance responses of the individual. An holistic approach is therefore necessary in assessing the various external and internal influences on infantrymen, with the final evaluation focussing on their ability to execute effective combat skills.

REQUIREMENTS OF COMBAT PERFORMANCE

Acknowledging the "human" factor, one must recognise that soldiers are affected physically and psychologically by both external and internal environmental factors. A significant amount of military preparation for battle consists of extensive physical training designed to improve the physical condition of the body. This preparation comprises a number of tasks that simulate actual combat situations, focussing particularly on endurance-building aerobic activity, improvements in strength and power, plus mental tasks requiring concentration and accuracy.

However, the long term effects of this intensive training may result in cumulative fatigue, and if the recruits are suddenly expected to fight, the chances of successful combat performance are reduced (Ramaswamy and Sivaraman, 1956). As the physical tasks that the infantry are required to execute are extremely diverse, for example, running, climbing, crawling and shooting, there is a broad area in which to assess how the inevitable consequences of prolonged physical activity, similar to that of an actual combat situation, may positively or negatively affect the overall combat performance of the fighting soldier.

Cognitive and Emotive Considerations

Physical demands are not the only factors to be appraised, as cognitive alertness also plays a vital role in combat efficiency. Mental workload can be conceived as the quantity of resources needed for information processing that are imposed by a task on a person. According to Culic (1997), this load depends on the amount of resources available within the person and the amount of resources demanded by the task situation. In the military environment during training, the soldier is taught to obey commands unconditionally and tends to 'react without thinking'. However, in an actual fighting situation where there may not be time for communication or consultation with superiors, the soldier has to think quickly and clearly on how to react most appropriately, while surrounded by loud noise, danger and life-threatening situations.

Veltman and Gaillard (1997) assert that there is no consensus about the method used to measure mental workload, and this is especially evident in military situations where the demands made on the soldier are completely unpredictable due to the continuous difficult and challenging events. Changes in work content and demands of task requirements in the military and defence professions have made it necessary to develop more reliable methods for measuring the cognitive performance of soldiers, for as Akila (1997) reported most human errors may be explained by a misalignment between the task demands and the actual performance capacity of the human being. Gobel **et al.** (1997) state that even in the case of very reasonable working conditions, intrinsic human errors occur to a certain degree. This may either be due to autonomous changes in information processing and action preparation, or due to restrictions in the availability of cognitive resources. Such restrictions may be caused by the attempt to minimise strain, by the allocation of the resources for other processes or simply by fluctuations of the resource capacity. Resource allocation is controlled to a certain extent by making a conscious effort (or not), and by primarily autonomous mechanisms, such as activation and arousal (Gobel **et al.,** 1997), all of which are extremely prevalent in a battle situation. Reductions in arousal level are possibly responsible for a decrease in performance for very low task demands, while stressful, highly demanding situations require increased alertness to maintain performance efficiency. The subjective estimation of priorities and consequently of psychological effects and error probability play a significant role in the standard of performance.

Both Dziados **et al.** (1987) and Mello **et al.** (1988) have noted the importance of motivation on maximal physical effort in the army. Mello **et al.** (1988) claim that a well motivated soldier of average strength and endurance would outperform a poorly motivated soldier with high strength and aerobic capacity, while Knapik and colleagues (1990) identified that soldiers with a higher rank tend to set the example on road marches by moving as fast as possible, and are often reluctant in allowing subordinates to out-perform them.

Schwab in 1953, and over forty years later Ntoumanis and Biddle (1998), conducted an investigation into "mental outlook" or an individual's perception of the situation related to physical fatigue. Both researchers concluded that one can ordinarily depend on one's motivational levels to influence or produce changes in muscular performance under different conditions. As individuals are inclined to display extreme changes in these motivational levels from test to test, some kind of subjective assessment of the perception of the task is essential. In actual battle situations the motivation to survive is a priority and is therefore a primary factor in attempting to maintain successful performance in the execution of combat tasks.

However, when one has endured severe weather conditions, combined with arduous physical and mental demands, it is obvious that motivation will fluctuate, predisposing recruits to 'give up'. Recent research conducted by Kroenke **et al.** (1998) revealed that predominant syndromes found in military personnel consisted of chronic fatigue, cognitive dysfunction and mental disorders, including depression, anxiety, and post-traumatic stress disorder, plus deviant behavioural problems such as alcohol abuse. From this evidence, it is apparent that both physical and psychological factors are interdependent and are both affected by the harsh, erratic environmental conditions of military combat.

Physical Factors

One of the main priorities of the military force is to build up the soldiers' physical endurance and strength and to improve motor skills such as accuracy in aiming and throwing. Intensive general and specific strengthening of the body has been shown to be an effective method for increasing muscular resilience (Carpinelli and Otto, 1998) and this, combined with endurance activities designed to enhance stamina, form a large component of combat training. The road march is a critical aspect of military preparation and because of the equipment required in battle, soldiers typically carry very heavy loads consisting of communication gear, weapon systems, site preparation material, subsistence items and protective equipment (Myles and Saunders, 1979; McCraig and Gooderson, 1986; Patton **et al.,** 1991). Knapik **et al.** (1993) claim that in training exercises conducted at the Joint Readiness Training Centre (Fort Chaffee, USA), soldiers bear average loads of 40kg and maximal loads of 69kg, while estimates made on light infantry units suggest loads of 76kg could be carried in a "worst case" situation. This excessive load carried over extended durations of time under extreme environmental conditions goes against the U.S. Army doctrine (Knapik **et al.,** 1993) which recommends maximum combat loads of 22kg and maximum march loads of 33kg. Despite these recommendations, constriction of load carriage is often ignored in battle, and after marching for days or even weeks with minimal rest, nutrition and sleep, soldiers are expected to fight to the best of their ability. One must then question how successful performance will be when soldiers are in such a fatigued state.

Marching

Focussing specifically on particular physical tasks incorporated in everyday military routine, Knapik **et al.** (1990), who have conducted extensive research into army efficiency, noted that higher rank and seniority in the service are associated linked with faster road march time. This has been attributed to the fact that those with higher rank or time in service may be in better condition for road marching as a result of the number of previous road marches performed, and it is possible that they have learned to be more proficient at pacing, load distribution and other factors influencing load carriage ability. Experience in performing various tasks and being aware of the physiological effects of these tasks on the body enables the individual to "pace" oneself more efficiently and increased confidence in one's abilities as a result of past experience will further assist the soldier in pushing himself harder.

Shooting

One of the most critical skills associated with combat is that of target shooting. Of relevance to this study, an example of the effects of intense physical activity on the efficiency of combat performance is provided by Knapik **et al.** (1990) who established that shooting accuracy degrades severely as a result of a 20km road march. The same authors noted an increase in body tremors due to fatigue that was induced by repetitive muscular contractions over an extended period of time and whole body sway while aiming a rifle was discovered to be substantially increased even after a short period of exercise, negatively affecting accuracy in aiming. Other factors affecting shooting efficiency have been observed by the same authors, as well as early researchers such as Ramaswamy and Sivaraman (1956), whose experimental results demonstrated that as the shoulder muscles support much of the rucksack load, subjects reported severe discomfort and pain in this area. This muscular strain has detrimental effects on the outcome of combat performance as the shoulder supports the butt of the rifle while firing the weapon and if pain, discomfort and tremors are present, it is likely that marksmanship ability will be negatively effected. Another possible explanation for the degradation in shooting performance is an elevation in heart rate where slight, uncontrollable movements of the rifle occur even when the heart beats reasonably 'normally'. The effects of this will be exaggerated with greater movement of the rifle during post-exercise conditions where strenuous physical activity combined with elevated arousal levels result in increased heart rate.

Throwing

Post march decrements in grenade throwing have been attributed to a nerve entrapment syndrome, local fatigue and/or pain in the muscle groups used for throwing. A reason for this is the compression of the brachial plexus by the shoulder straps of the rucksack which can result in weakness, pain, paraesthesia and numbness in the upper extremities. Minimal research has been conducted on this skill due to the nature of the task which requires the soldier to throw a grenade in the general direction of the target, with the knowledge that the specific object will be destroyed along with the surrounding area. Therefore, highly accurate aiming is not essential (unlike that of target shooting, for example), and although general aiming in throwing may be improved with practice, this is not considered to be a relevant military skill to be studied.

Strength

Strength and endurance are physical performance variables intimately associated with the functional well-being of the musculo-skeletal system and are fundamental principles in enhancing military training. Research conducted in this area by Pedersen **et al.** (1989), Robertson **et al.** (1996) and De Looze **et al.** (1998) postulate that strength deficiency is linked with those physical risk factors which may precipitate onset of injury. This has relevance to the military as 'less strong' individuals tend to have a higher predisposition to local and general physical fatigue that is associated with the onset of cumulative trauma disorders (CTD's), resulting in consequential decrements in performance.

Delecluse (1997) maintains that in developing training strategies in the army, it must be kept in mind that strength, power and speed are inherently related to one another because they are all the output of the same functional systems. Legg and Duggan (1996) claim that a failure to observe improvements in muscular strength and endurance suggests that there is insufficient emphasis on training in these areas, which may often be the case when soldiers are following strict exercise programmes that neglect important aspects of conditioning. The object of training is to match the requirements of the event and the deficiencies or limitations of the soldier, which often poses to be a problem as training should then be an individualised and event specific process. However, this is not possible in a military context because of the importance of different ranks and training levels, as well and the unpredictable battle situation.

Referring specifically to strength training and matching the requirements of the 'event' to the limitations of the soldier, the majority of the literature focusses on the improvement of strength of the lower limbs and it appears that military personnel consider combat situations to predominate in marching, running and jumping, ie. lower limb activities. However, not to disregard the necessity of these skills, a critical factor that tends to go unnoticed is the strength of the upper body as this is equally as important in the carrying of rifles and shooting, throwing, pulling and climbing. An attempt to determine the strength of the upper body was conducted in this project with the use of static power grip dynamometers, which have traditionally been used to estimate wrist/hand strength. Although strength measures from hand-held dynamometers have been shown to be valid and reliable for physical training and clinical purposes, two different groups of authors (Robertson **et al.,** 1996, and Robertson **et al.,**1997) argue this point, suggesting that the inclusion of hand-held dynamometers in impairment ratings of the upper extremity is limited because they (dynamometers) are influenced by factors such as age, pain, fear of injury, anger, a lack of motivation, fatigue, disuse and malingering, which tend to restrict a maximal effort.

In a review article related to muscle fatigue, Kroll (1973) claimed increased difficulty in identifying the utility of strength data because of the wide variety of test protocols being used and the inadequate instructions which accompanied some of them. Another factor to be taken into consideration is the muscle group being evaluated, as strength testing with smaller muscle groups (hand and wrist) has been found to be less variable than when testing with larger muscle groups (back, arms and legs).

Robertson **et al.** (1996) recognise that individual strength performance in a repetitive power grip protocol may be influenced by several factors including fear, pain, a lack of test comprehension, motivation and boredom, thus including a psychological component to strength and power output. Laboratory testing of grip strength may not necessarily reveal similar results to those taken *in situ*, as the mental state of the soldier is likely to be very different, with the absence of fear and excessively high levels of motivation.

In conclusion, it is evident that a number of influencing factors prevail in the assessment of strength, as well as other military skills. However, the necessity to determine how performance is affected by the extreme external and internal environmental factors compels researchers to continue searching.

PERFORMANCE UNDER PRESSURE

Stress

Due to the threatening, unpredictable nature of combat situations, excessive levels of strain are experienced by the military personnel, with the realities of war involving intolerable physical, mental and emotional distress. Psychologists have emphasised that intense external and internal demands, identified as stress, which are imposed upon the individual will result in the organism experiencing strain, with the person's cognitive interpretation of the situation playing a critical role in inducing strain (Scott, 1994), as this may turn a stimulus into a stressor. The concept that a stressor must be unpleasant or harmful has been challenged and it has been argued that any event that requires adjustment and accommodation can induce potential strain. Increased levels of fear and uncertainty are common stressors among the military, as the situation which they spend long, hard hours in preparation for is completely unpredictable, with no guarantee of success.

Working in the field of aviation, which has similarities in the psychological and physiological demands to that of the military which are therefore applicable to this study, Vaernes **et al.** (1991) identified several causes of stress which become unique when combined with a need for a high level of performance during critical situations. Those easiest to recognise are the physical ones such as noise, vibration, temperature, extremes of humidity and acceleration forces. The psychological stressors like work/rest patterns, circadian rhythm changes and emotional stress associated with family separation may not be as immediately obvious but may be as important (Rudolph and McAuley, 1998). Other affective psychological stressors are also present, such as the feeling of insecurity induced by the annual medical and proficiency checks.

Focussing on the physiological responses to stress being imposed on the body, exercise has been stated as being the most powerful physiological perturbation experienced by healthy humans (Richter, 1989), requiring major metabolic and cardiovascular adjustments. To accomplish this, changes in autonomic nervous activity and hormone secretion occur during exercise and if these factors are highly activated in response to intense physical activity for long durations of time, severe affects of cumulative strain will have detrimental consequences on the individual's physiological and psychological functioning, and physical and cognitive fatigue is an inevitable outcome.

Emotional stress can be met by defensive distortions of the perceived situation instead of direct action (coping). 'Psychological defence' is most likely to occur when the individual is unable to handle the situation and the level of fear is high (Weiss, 1989). In occurrences such as these, the defensive distortion of the danger can reduce efficiency in managing hazardous situations, resulting in critical and life-threatening consequences. Vaernes **et al.** (1991) report that under conditions of stress, empirical evidence reveals that people who use defensive strategies tend to display inadequate performance in tasks requiring high autonomic activation, demanding swift and accurate cognitive efficiency. In extreme cases, such individuals tend not to cope adequately during training, and in the long term develop significant psychosomatic problems. A military soldier has to exercise a high degree of responsibility and extreme concentration under stressful events. An added stressor is the fact that he is also faced with expectations from different groups, for example, his peers, his superiors and family, which may result in a sense of role conflict and role ambiguity. Repetitive exposure to simulated combat situations would benefit the recruit in providing experience and increased awareness of what to expect in battle, reducing the negative overwhelming sensations of fear, thus enabling the soldier to think and act more effectively.

Arousal

It is evident that there are a number of inter-related external and internal environmental factors that play a substantial role in affecting an individual's behaviour and performance efficiency. The effect these have on human beings is unpredictable as man is an extremely complex species and external stimuli that may affect him one day may not necessarily have the same influence on him on another day. Efficient and appropriate performance responses therefore depend on both internal and external environmental factors, taking into account how the individual is thinking and feeling at the time, as well as subjective current perceptions of the specific situation.

When assessing the consequences of an individual's perception of a situation and the emotional effects it has on behaviour, the activation theory of emotion proposed by Grings and Dawson (1978) relates the interdependence between bodily reactions that accompany emotion and the level of internal activation or arousal. The inter-connectedness of these two factors are considered to be responsible for significant changes in a person's behaviour and performance. Another interpretation originated from the notion of energy mobilization, where the concept of the level of energy mobilization is equivalent to what the layman calls "tension level" or "excitement level". These terms typically define arousal by a variety of physiological measures, among which are autonomic responses and muscle tension. These physiological indicants are assumed to reflect the emotional response to a life situation. Their relevance to this study is critical as the nature of a battle situation requires combatants to fight to protect themselves while enduring excessively high arousal levels in response to the threatening situation. A fine line exists between optimal levels of arousal and under- or over-arousal, physiological reactions that have been extensively researched. From a psychological aspect, and continuing along the same lines as Scott (1994), Wilson and Eklund (1998) claim that the perception of a threat is a key antecedent to anxiety.

When applied to military contexts, anxiety is a natural reaction to the stressful combat situation where soldiers are fighting for their lives, increasing the likelihood of undesirable performance.

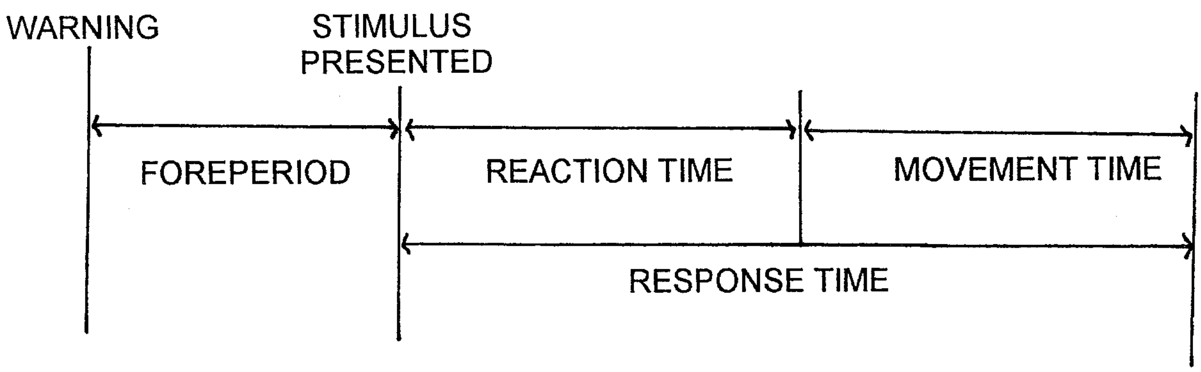
The finding that efficiency in performance improves with elevated arousal to a point where it then becomes worse with further increases indicates an inverted-U relationship between performance and arousal. As performance is optimal at certain levels of arousal and is inferior at higher or lower levels of arousal (Yerkes and Dodson, 1908; Bergstrom, 1970; Grings and Dawson, 1978), it is essential to strike a balance between these points to achieve maximal efficiency in combat tasks.

The identification of emotion associated with physiological arousal and motivation has important implications for predicting relations between emotion and performance on motor tasks. If arousal is synonymous with alertness, as proposed by Cox (1994), then the aroused individual should be in a physiological state of readiness and should theoretically react faster and persevere longer, at least up to a point where excessive levels of activation might inhibit performance or increase error (Yerkes and Dodson, 1908; Malmo, 1959; Duffy, 1962; Grings and Dawson, 1978).

REACTION TIME

The ability to locomote from one point to another rapidly and with goal-orientated direction is a function of the neuromuscular system (Harbin **et al.,**1989) and this integration of activity is commonly called "co-ordination". The co-ordination and speed with which an individual can react is the foundation of military competence and is critical in successful performance output. Definitions of reaction and response times have been explained by Harbin **et al.** (1989), with response time being the speed with which an individual reacts, and is the total time required from the onset of a stimulus to completion of a task. This has been divided into two separate components: reaction time and movement time. Reaction time is the interval from the onset of the stimulus to the initiation of movement (Hoyes Beehler and Kamen, 1986; Crabtree and Antrim, 1988; Harbin **et al.,** 1989) while movement time begins when reaction time ends and is the interval of time from the beginning of movement to the completion of the task, as illustrated in Figure 1.

Studies have measured the ability to react quickly to several types of stimuli including auditory, proprioceptive, tactile and visual. Researchers, for example, Hoyes Beehler and Kamen (1986), have generally concluded that proprioceptive stimuli produce the fastest reaction times, auditory stimuli produce the next fastest, and that visual stimuli produce the slowest reaction times. However, this is dependent upon the physical distance of the individual from the stimulus; in the present study an auditory stimulus within closer proximity of the individual was used.



Reaction Time + Movement Time = Total Response Time

Figure 1: The Decision-Reaction Response Model (adapted from Schmidt, 1988).

The *oculomotor response* consists of sensing a visual stimulus, processing the stimulus, and deciding on a course of action (reaction time), followed by the movement time. The movement time is strongly influenced by coordination or precision of movement, with precision defined as the accuracy of performing a single goal-orientated task with the least number of random moves during the motor performance of that task. Improvement in this skill is highly beneficial in military environments where accuracy in aiming, shooting and throwing is essential and where reductions in unnecessary energy expenditure are favourable.

Practice can decrease the overall response time by reducing the time necessary to make a decision and improving on precision of movement (Harbin **et al.,** 1989). These authors suggest that by allowing an individual to anticipate an oncoming stimulus there will be a decrease in the reaction time, while interfering stimuli, cold and fatigue all significantly increase the reaction time. It is generally accepted by Hoyes Beehler and Kamen (1986) that variation in reaction time is primarily due to factors which can affect central processing time such as aging, practice, a warning period and movement; and Henry (1952) asserted that with the addition of motivation, reaction time and movement time is reduced.

A simple stimulus which requires little cerebral processing will result in a faster reaction time compared to a complex stimulus demanding cognitive discrimination. Here, the difference between simple and choice reaction time are evident. Movement time is also faster with simple movement which requires no precision as compared to the complex movement. Training may improve synchronization of appropriate muscular responses, which may improve movement time, however, the enhancement of reaction time is limited as this skill can only be improved to a certain degree.

From a physiological perspective, Harbin **et al.** (1989) identified two "neurological electrical lags" associated with reaction time. The first is the sensory input travelling to the brain and the second is the motor impulse travelling from the brain to the appropriate muscle group. The actual time interval required in a particular reaction time depends on the complexity required in interpreting the stimulus. Hoyes Beehler and Kamen (1986) state that from a neurological standpoint, the fewer the number of synapses involved in the transmission of a signal, the faster the sensory nerve can send information to the appropriate supraspinal centre. Therefore, it is logical that a proprioceptive stimulus should evoke the fastest reaction time, since the number of synapses from a proprioceptive or tactile stimulus to the somatosensory cortex is less than that required for a stimulus to reach either the auditory or visual cortex.

In the present project, finger and whole body reaction time to an auditory stimulus was assessed. The primary reason for using this test was because it is understood that in the military environment, the appropriate timing of constituent elements of fine skilled and gross motor performance is a prerequisite to the successful execution of combat tasks, for example, target shooting and quick movements of the body as a whole.

Again, an individual's cognitive and perceptual response to the situation are believed to influence performance output, as Wendt and Palmerton (1976) and Etnier and Landers (1998) concluded that various factors, for example motivation, were found to raise one's efficiency of performance on tests of reaction time, strength and endurance.

Reaction Time and Fatigue

In some tasks fatigue is demonstrated as a straightforward decrement in one or more aspects of performance. For instance, speed and accuracy may diminish, or the ceiling of performance may be lowered in the sense that the amount of physical effort which can be exerted, or the complexity of material which can be handled, becomes less. Hayes (1976) supports the notion that reaction time lags attributable to fatigue are thus held to be of great importance when considering the disruption of skilled motor performance, and this is especially critical when applied to military tasks such as magazine loading, shooting and jumping where speed of reaction may determine life or death.

Floyd and Welford (1953) describe a task where the subject was required to move a lever in response to light signals with each correct movement bringing on the signal for the next which was entirely dependent on the preceding movement. Performance at such a task involves a whole chain of processes from the reception of data by sense organs, through central processes organizing the incoming data, giving it meaning and shaping out-going actions, to muscular action itself, which in turn leads to sensory feedback monitoring the action and signalling readiness for the next. These researchers proposed that fatigue attacks only one portion of this chain, leaving the rest little if at all affected. The identification of the affected portion is often of theoretical interest and could be of considerable practical importance in that ways of preventing fatigue would differ according to the portion concerned. The measures of overall achievement, such as the number of responses per minute or the degree of accuracy attained, which are often taken as the only measures in experiments, are not sufficient for such identifications to be made. However, when applied to critically important performance output, this end result is usually considered the only aspect to be focussed on. However, Bartlett (1947) has urged that to improve the overall end result of performance, it would be beneficial to split up the performance into sections in such a way that the timing and accuracy of the different processes making up the total performance can be assessed separately, thereby enabling the researcher to determine where exactly along the chain of physical and cognitive processes the inhibiting problem lies.

Research conducted by Hayes (1976) revealed that hand responses to a stimulus are markedly delayed during prolonged work periods and this elongation of reaction time was attributed primarily to biochemical changes influencing the functionality of the central nervous system. Hayes (1976) concluded that following light intensity exercise, reaction times recorded from the arms and legs were faster than during pre-exercise conditions, but following heavy physical activity, reaction times were slower than those measured during resting conditions. It has therefore been proposed that arousal levels are increased during light exercise enhancing reaction time, with obvious decrements in performance as these levels are exceeded (Crooks and Stein, 1988).

Wendt and Palmerton (1976) noted that the awareness that one's performance is falling short may induce anxiety within the subject about successful completion of the task, further compounding the disruption. Increased tension levels have been associated with improved performance, yet this is so only up to a certain point (Cox, 1994) as prolonged physical or psychological exertion in a highly stressful situation contributes to mistakes and misjudgements following the initial stress. In situations where reaction times are not altered under extremely stressful conditions, it was hypothesised by Hayes (1976) that if any one component in the chain of events occurring prior to the overt response undergoes alteration, one might assume a compensatory or reciprocal change in another component to maintain the consistency of reaction time under fatigued conditions.

Summarizing, there are indications that reaction times may be altered during work, and under some circumstances, following work. In particular, the implication is that prolonged work of either a physical or mental nature may cause some elongation of reaction time and for brief bouts of strenuous exercise, evidence suggests that if any changes are observed, they tend toward shortening of reaction time (Hayes, 1976).

VIENNA TEST SYSTEM (VTS)

The Vienna Test System enables the computer-assisted application of a large number of highly diverse psychodiagnostic tests and measuring procedures. In developing the system much emphasis was placed on transparent structure and largely uniform design. It is therefore simple to operate and easy to understand and does not require any special computer skills.

The VTS supports the administration of both single tests and test batteries. Many of the single tests are available in different test versions. These test versions may differ, for example, in terms of test duration or difficulty. They are characterised by different parameters reflecting specific test requirements. Within the context of the VTS they are therefore called standard parameter blocks (named S1, S2 etc.) and have usually been designed for administration to a specific population (pilots, psychiatric patients, children) or for special measuring purposes.

The Work Performance Series (ALS) Test

This is a test assessing concentration on numerical tasks done under time pressure. The Pauli Test, a procedure developed on the basis of Kraeplin's work test, presents continuous number adding tasks to determine a subject's work performance over time. The subject is required to add up single digit numbers, always two at a time, as quickly and accurately as possible over an extended period of time. The test is broken down into sections (sub-times) allowing identification of the development of performance over time. The Work Performance Series test is a computer-assisted procedure for administration and scoring of the Pauli Test.

The Pauli Test measures what is described in the literature (Bukasa and Wenninger, 1992) as "sustained concentration on mental tasks done under time pressure". This includes personality attributes such as determination in resisting interference, distraction and disturbance as well as motivation and willpower and the ability to sustain attention to a specific task.

FATIGUE

Fatigue is one of the many factors which is known to negatively affect an individual's ability to respond effectively and efficiently to environmental stimuli and it is important to recognise the uniqueness of individuals as different physical and psychological components will result in different responses. One of the most perplexing problems in modern life concerns a lack of understanding and control of what is called 'fatigue'. Physiologists often consider fatigue as being a prime cause of a decrease in physical performance (Hashimoto **et al.,** 1975), while McFarland (1975) stated that psychologists consider it as a negative condition affecting mental functioning, including factors such as a lack of motivation and feelings of exhaustion, with a concomitant deterioration of performance. Ergonomists are particularly interested in the consequences of fatigue in all working situations.

Fatigue refers generally to a group of phenomena associated with the impairment or loss of efficiency and skill, and the development of anxiety, frustration or boredom (Bartlett, 1953; Eagles **et al.,** 1953; Floyd and Welford, 1953; Singleton, 1953; McFarland, 1975; Hayes, 1976; Simonson and Weiser, 1976; Wendt and Palmerton, 1976; Landers, 1980; Maughan and Noakes, 1991). Bartlett (1953) suggested that fatigue is a term used to cover all those determinable changes in the expression of an activity which can be traced to the continuing exercise of that activity under its normal operational conditions, and which can be shown to lead, either immediately or after delay, to a deterioration in the expression of that activity, or more simply, to results within the activity that are not wanted.

Although this principle applies to both cognitive and physical activities, evidence demonstrates the interdependence of the physiological and psychological systems of the human body. In situations requiring motor skills, it is often assumed that the fatigue is localised in the effector organs, while "mental" fatigue being regarded as a consequence only of a long period of strictly cognitive work (Singleton, 1953). However, Hashimoto **et al.** (1975) argued that the sensation of all fatigue has three major components: a feeling of bodily tiredness and drowsiness; weakened motivation or concentration toward the task; and a group of physical complaints pertaining to psychosomatic disorders. If this is the case, it is evident that 'fatigue' tends to affect the individual both physically and mentally.

In everyday experience, fatigue is an accumulation of various internal and external sources. These include the intensity and length of manual and mental work; monotony in the task being performed in situations where an individual is under-aroused; responsibility, worries and conflicts; the environmental surroundings; illness and pain; and one's eating and drinking habits (Hashimoto **et al.,** 1975; Wendt and Palmerton, 1976; Johnson and Knapik, 1995). The temporal factor as well as the capacity of the individual to cope with these situations are important variables in the accumulation of fatigue.

Hashimoto **et al.** (1975) claim that an accumulation of sensations in the form of fatigue, which have a more or less general character, will be reflected in subjective feelings towards the task. These sensations are no doubt a biological sign of the necessity to recover, an indication that the relative inflow of fatigue is exceeding the individual's capacity to cope with the demands and therefore participation in the physical and/or mental demands should be terminated. Two important consequences associated with fatigue are diminishing work output (mentally and physically) and increasing expenditure of effort (Bartlett, 1953; Wendt and Palmerton, 1976). Diminishing output is a consequence of a change in performance, but it does not reveal what change; while increasing effort is an expression of changes in the causal conditions of performance, perhaps of changes in motivation, but it does not disclose what changes. Both are rough indicators only, and both are effects which can be shown to be the consequence of a considerable number of widely varying circumstances and conditions.

It is impossible to obtain a purely objective rating of the amount of fatigue an individual is experiencing, for as Wendt and Palmerton (1976) state, the subjective aspect of fatigue has been defined as a "self-recognizable" state in which the individual feels inadequate for his task, based on bodily experience of discomfort and weakness, and also upon other cognitive criteria such as feelings of futility. However, it is certain that one cannot be confined by reports which only the individual himself makes about his aches and pains, his localised or general mal-ease, and his feeling of tiredness (or freshness) as it is possible that one exaggerates or, when feeling the need to impress peers, may "play down" the reported sensation. Therefore, when taking perceptual aspects into account, it is essential to be aware of possible over- or under-estimations of ratings of fatigue. The unique individuality of human beings is emphasised here as the researcher attempts to obtain tangible results of unpredictable, fluctuating individual responses. The literature demonstrates this challenge, with authors such as Hashimoto **et al.** (1975) who reported that the appearance of objectively observable fatigue by the examiner has components comparable with those of subjective feelings of fatigue, while Wendt and Palmerton (1976) claim that the effects of such subjective states are often delayed in comparison to physiological measurements possibly because the individual is pushing himself to maximal limits, determined not to reveal the actual degree of fatigue for fear of displaying a sign of weakness or failure.

Physical Fatigue

Fatigue comprises of both physical and cognitive components. Individually, or in combination, both can affect the overall performance. However, focussing on physical fatigue, the duration of time that a person can maintain efficient muscular performance depends on a variety of factors. Amongst these are: the type and intensity of the physical exertion; the structure of the muscles involved; and experience in the task performed (Darcus, 1953). Despite the unpredictability of combat situations, these factors are taken into consideration by the military where basic routine training is aimed toward enhancing battle skills such as marching with heavy loads for extended periods of time in order to improve endurance and strength. However, a study conducted by McCraig and Gooderson (1986) revealed that up to 20% of questionnaires listed fatigue, imposed by the length of marches and the load carried, to be a significant problem in combat, with the comments in these interviews suggested to be a conservative estimate. Particular mention was made of occasions when heavily laden men negotiating difficult ground, sprained ankles or otherwise injured themselves, inferring that these soldiers were more susceptible to injury as a result of fatigue.

It has been demonstrated by Dubik and Fullerton (1987) that interviews conducted with soldiers immediately after battle are most beneficial in terms of obtaining first-hand statements of the effects of prolonged military training followed by intense combat action on the individual. Below is an example of the degree of fatigue experienced by a soldier:

> We attacked to secure the airhead. We were like slow-moving turtles. My rucksack weighed 120 pounds. I would get up and rush for 10 yards, throw myself down and couldn't get up. I'd rest for 10 or 15 minutes, struggle to get up, go 10 more yards, and collapse. After a few rushes, I was physically unable to move, although my body is in great shape. Finally, after I got to the assembly area, I shucked my rucksack and was able to fight, but I was totally drained (Dubik and Fullerton, 1987, pp 39).

Even allowing for some exaggeration by the soldier, no one can doubt that they were physically overloaded. The false belief that overloading with ammunition is good for battle morale is a significant factor affecting the load carried and load content and weight ought to be enforced by commanders by reducing soldier's load carriage to a minimum, limiting contingency equipment and eliminating all non-essential items. These commanders may predispose the platoon to greater risks by doing this, but researchers such as Myles and Saunders (1979), Dubik and Fullerton (1987) and Patton **et al.** (1991) strongly believe that overloaded combatants reduce the unit's ability to fight and win.

Wendt and Palmerton (1976) have suggested that the individual's perception of a task is important when assessing fatigue, as a person's expectancy about the task or performance situation usually has a substantial effect upon how that person performs, and also upon the degree of fatigue which one reports. In particular, the perception of the probability of success at a certain task is an essential variable to be taken into consideration when evaluating an individual's performance. This suggests the possibility that fatigue effects are to some extent under voluntary control, in the sense that the individual sets levels of effort he is willing to make and of discomfort he is prepared to bear. Having a definite goal toward which to strive perhaps serves to direct the attention of the individual, channelling one's energies in that direction and in 'ignoring' or over-riding feelings of fatigue. In the military, each individual's life is dependant on the effectiveness of the unit and this should aid in providing the motivation to reduce the likelihood of 'giving up' when one is completely exhausted. However, when performing in combat for months, or even years, reduction in morale and vigour are inevitable as cumulative fatigue effects take their toll on the soldier, with each day becoming more of a challenge to survive, let alone fight effectively.

When taking a closer look at the muscle itself, analysed solely in terms of neuromuscular activity, an inability in the execution of appropriate movements at a required level may be due to a failure of the fibres themselves in developing tension or an inhibition of the neural impulses reaching them. The transmission of nerve impulses, or the development of tension in muscle fibres, entails a release of energy and the subsequent restoration of the system responsible for its release, a process which may depend on local resynthesis or on the use of stored material. In the long-term, continued restoration is likely to require the arrival of fresh material and the removal of waste products of metabolic activity (Hemingway, 1953; Wendt and Palmerton, 1976), therefore, sufficient rest and nutrition is essential in reducing the cumulative negative effects that result in chronic fatigue. This is not always possible in combat because infantry personnel may be required to fight until the enemy is defeated, or the soldier is injured, and the need for regular night-patrol combined with constant anticipation of attack may result in many days without adequate rest. Nutritional supplies may be low or even disregarded because they are considered an unnecessary load.

Mental Fatigue

In general, fatigue cannot be considered a simple physiological condition resulting from sustained activity. Furthermore, if one thinks of the body as a whole, fatigue cannot be defined solely in terms of biochemical changes in the muscles or nerves, or by the exhaustion of energy reserves (McFarland, 1975; Wendt and Palmerton, 1976). When placed under stressful environmental conditions like that of a combat situation, various forms of exhaustion and fatigue will result with emotional strain combined with prolonged physical and mental effort exacerbating the situation, resulting in unfavourable consequences. Under such circumstances a person's psychological and mental performance inevitably deteriorates. It appears vital, therefore, to consider the role of psychological variables on military efficiency.

A number of studies have investigated physical fatigue and its possible causes and effects on performance. However, mental fatigue is a far less tangible concept and is extremely complex to measure. As a result, it is difficult to establish to what extent an individual is mentally fatigued and how long it takes before one becomes so. Due to the uniqueness of human beings, feelings of cognitive fatigue, like those of physical fatigue, will vary greatly from one individual to the next and each will experience it differently, reiterating the difficulty in assessing subjective responses.

On a daily basis, humans are subjected to many hours of continual mental involvement in tasks, especially in the work environment; a situation which has been exacerbated by the advancement of technology. Employees suffer from 'mental' pressures, often feeling threatened and overwhelmed and the strain experienced is perpetuated by feelings of weariness, lethargy and depression, ultimately resulting in a decrement in performance efficiency. Various cognitive processes, such as decision making, are affected by mental fatigue altering the individuals ability to respond efficiently. This is not usually considered in military contexts where cognitive requirements are minimal during training as infantrymen 'automatically' react to demands shouted by superiors. However, the situation is very different while fighting as the soldier has to react to unpredictable circumstances and think about the most effective, appropriate way of responding.

Contemporary research on mental load and fatigue (Marek **et al.,** 1988) distinguishes between two opposite types of mental fatigue corresponding to tasks with high and low stimulation levels. The first type occurs when the person is exposed to a high level of stimulation, including various tasks of high complexity. Such fatigue depends on the degree of hyper-arousal which exists and also on the person's coping processes. The latter tends to act to reduce both levels of arousal and stimulation inflow and is associated with low levels of physiological and psychological excitation, for example, in vigilance and monotonous tasks.

Of relevance to this study is the extent of hyper-arousal imposed by life-threatening battle situations on the recruits, where there appears to be an increase in the strength of the relationship between the intensity of stimulation and the magnitude of the subsequent response. Each stimuli receives additional attention because of the state of hyper-arousal (Cox, 1994), often demonstrating marked increases in performance efficiency. However, Crooks and Stein (1988) support the proposition that too much arousal may leave one overstimulated, overloaded and temporarily incapable of effective action and believe that a certain optimal level of arousal is essential in order to express goal-directed behaviour.

Bartlett (1953), who has done extensive research in cognitive fatigue, identified three psychological criteria associated with decision making and cognitive ability, where the first lies within the task itself and refers to physical and mental fatigue. He proposes that there is a normal reaction lag to the presenting stimulus, followed by a contraction phase and then a brief interval marking the directional change over from the contraction to the relaxation phase. Finally there is a relaxation phase. This process is repeated continuously for as long as the required task must continue. Initially a regular sequence of these phases is established, but irregularities begin to present themselves as the duration of the task extends. Initial reaction lag may lengthen and contractions may become rushed or delayed. In activities requiring a variety of responses, there is a need to time and adjust reactions to the changing stimuli and these timing measurements are far more difficult to achieve in the case of mental fatigue.

The second criterion for fatigue is the splitting up or disintegration of performance effectiveness, resulting in rigid actions at the wrong time while others may be omitted altogether. Movements comprising the execution of skilled acts must be adapted to the dynamic, unpredictable environment that requires action consisting of responses spread out over the field of senses or a combination of the senses. The process of perception ensures cues are picked up from one area of the field of information and used to indicate what is happening in another part. This produces the smoothness of successive responses, but when irregularities set in attention becomes focussed on specific aspects of the task, neglecting critical secondary or 'outlier' elements. These features are most likely to be ignored, forgotten or emphasised at the expense of central features (Bartlett, 1953) with a consequential deterioration in performance. This concept was supported by Schmidtke (1976) who suggested that as fatigue accumulates, there is a greater decrement in the individual's ability to concentrate on important information from the environment, constituting the basic conditions for 'lapses' of behaviour which frequently mark advancing fatigue of body or mind.

Bartlett's (1953) third psychological criterion focusses on acute or advanced fatigue which is accompanied by reports and complaints of discomfort, of aches and pains and unpleasant postures. The preoccupation with internal accompaniments of the deteriorated performance of the activity is significant. Associated with the disintegration of performance effectiveness is the number of elements of the total situation, both external and internal, which earlier required no response suddenly now do. Fatigue subsequently results in a loss of direction due to an inability to selectively choose those patterns of information necessary to perform the desired action. At this stage, the individual's perceptions of how they are experiencing fatigue will in all probability influence their perceptions of the task (Rejeski, 1981; Robertson, 1982) and thus their personal ability to cope.

Thus it is evident that physical and mental fatigue is influenced by the duration of activity as well as the task requirements, whereby the longer and more complex the situation the quicker the onset of fatigue will be. In an attempt to maintain successful execution of performance under physically and/or mentally demanding situations, other critical factors are neglected as the individual directs more energy into the primary aim of the task (ie increased concentration in one specific area), tending to neglect important cues. This results in a reduction in the standard of performance output as the individual can no longer cope with the task demands. This is exacerbated by increased awareness of bodily discomfort, negatively influencing the perception of the task and results in a lack of motivation to continue and a strong desire to terminate activity.

Emotional Fatigue and Arousal

Integrating arousal levels with emotional effects, Landers (1980) is in favour of the theory that when arousal levels are excessively high, the individual may experience unpleasant emotional reactions associated with prolonged activation of the autonomic nervous system, thus identifying the need to acknowledge emotional factors and their effects on fatigue of the human body. 'Emotional fatigue', as defined by Wendt and Palmerton (1976), consists of those subjective feelings of tiredness and lethargy which occur as a result of the expenditure of energy due to psychological conflicts. Chronic subjective fatigue seems to be a manifestation of such fatigue associated with emotional phenomena, including pronounced tiredness throughout the day, irritability, depression and listlessness or apathy. Further symptoms include weakness, feelings of inadequacy, poor concentration and the presence of a variety of other lesser physical, psychologic and emotional features, emphasising the interdependency of physical and psychological effects.

With reference to the military, emotional fatigue may itself have some antecedents in the framework of motivation. A soldier's motive to achieve success is greater than his motive to avoid failure, with temporal factors playing a critical role in determining the extent of motivation to succeed. Hence, recognition must be given to the fact that emotional fatigue, personality dispositions, motivation and individual variation are all inextricably bound up in the study of fatigue effects.

ELECTROMYOGRAPHIC ACTIVITY

As the effects of excessive muscular fatigue become obvious in uncontrollable movements when aiming a rifle, manual tracking and other military tasks, the measurement of muscular activity has been studied in connection with combat efficiency (Eagles **et al.,** 1953). Darcus (1953) stated that following an exhausting muscular task, the maintained or repeated exertion may leave its mark with the working muscles becoming hypersensitive, displaying a tendency to go into contraction much more readily than a well-rested muscle. In some cases, it is not even possible to relax the exercised muscle completely after exertion and this residual activity may reveal itself as a tremor (Binet, 1920; Bousfield, 1932). Despite a good deal of work, much of the fundamental physiology and especially the mechanics of uncontrollable muscular movement remains unelucidated (Eagles **et al.**, 1953), although its association with emotion has long been recognized.

Although many aspects of the structure and mechanics of muscle have been explored, the actual functioning of human muscle has received limited attention and this can be ascribed to the difficulty of directly studying the activity of muscles in the intact person. However, methods developed during recent years have enabled one to gain a better understanding of the co-ordinated activity of human muscles. Perhaps the most notable technical advance is the improvement in the technology of electromyography (EMG).

The EMG signal provides a convenient methodology to study the intricacy of muscle neurophysiology during various types of muscular contractions and has been used to monitor fatigue in a variety of muscles (Chiou, 1999). This was a primary reason for analysing EMG recordings in this project as fatigue factors such as decreased muscular strength and inappropriate movement are a consequence of participation in intensive physical exertion, resulting in decrements in performance.

Electromyographic activity is influenced by the quality and quantity of electrical activity generated within the muscles and this is registered and evaluated by means of computer-aided methods (Strasser and Miller, 1999). In isometric contractions the EMG signal is proportional to the amount of force generated by the muscle (Schultz **et al.,** 1987; McArdle **et al.,** 1991; Chiou **et al.,** 1999), while in dynamic-type contractions, the situation is more complex because of the ever-changing force-torque characteristic during contraction at different angular velocities of movement. During rapid, ballistic-type movements, the EMG is characterised by alternating bursts of electrical activity in both the agonist and antagonistic muscles.

When the output of muscular effort is held constant, either as a result of static contraction or phasic movement at a constant speed or with a constant load, there is a progressive increase in the activity of the muscles (Strasser and Miller, 1999) and more contraction is required to produce the same power output (Bower **et al.,** 1984; Darcus, 1953). This maintenance of power output is due to an increased contraction of individual muscles and to a recruitment of other muscles directly useful to the task. However, time is a limiting factor as prolonged contraction will inevitably result in fatigue, displaying reductions in electrical activity. In phasic contraction, besides the increase in amplitude of the muscular activity there is also an increase in the duration of individual contractions. Eventually the period of each contraction may become so prolonged that one phase runs into the next, so that the muscle is never able to relax completely (Darcus, 1953).

Activity may even be recorded from remote parts of the body and extraneous and purposeless movements develop and increase as the muscular task develops. Continuous exertion may eventually lead to a change in the manner in which a particular task is achieved (Darcus, 1953). For example, if the primary muscles involved in a movement fail and if the output is to be maintained, efforts are made to effect the same result by using different sets of muscles; thus imposing extra strain on other muscles but allowing performance (though usually less proficient) to continue.

The electrical signal from a single muscle unit can be picked up and recorded by the use of surface electrodes where the electrical activity of larger groups of fibres can be recorded by simply measuring the voltage over the muscle. If electrodes are placed over a muscle (for example, the forearm flexor) and the electrical signal is appropriately amplified, each movement of the arm or hand will appear as a burst of activity on the recording. Analysis of an EMG tracing demonstrates that the EMG pattern is triphasic in nature; where the first burst of electrical activity occurs in the agonist, followed by signals from the antagonist (during which time the agonist is electrically silent), and then another burst of activity in the agonist (McArdle **et al.,** 1991). Each phase of the EMG is associated with certain aspects of the contraction. The first burst of the agonist is believed to create the propulsive force to set the limb in motion, the antagonist's burst stops the limb, and the agonist's second burst is involved with the final positioning of the limb. In order to quantify a recording, it is possible to count the number of bursts within a time interval, but measuring the amplitude of the response is difficult and time consuming (Grings and Dawson, 1978). To overcome this inconvenience, it is common practice to integrate or summate the potential, so that a total amount of electrical activity in a given period of time is graphically registered (Grings and Dawson, 1978).

The muscle potential integrator serves as an electrical adding device. There are different ways to achieve such integration. An example is the contour follower that smooths out or averages over time the spikes of muscle potential. The rise and fall of the recording pen is proportional to the ongoing raw potentials (Grings and Dawson, 1978) and the EMG is typically quantified in millivolts (thousandths of a volt) or microvolts (millionths of a volt).

Beside the main contractions required to execute required movements, Grings and Dawson (1978) state that muscle tension is a frequent correlate of emotion and therefore it is desirable to have an objective indicator of skeletal muscle activity to determine how muscles are affected by various emotions. Studies performed by Wood and Hokanson (1965), using muscle tension as a way of increasing physiological arousal and then studying its effect on performance, demonstrated that heart rate is an reliable indicator of arousal and it has been found to increase linearly throughout the range of muscle tension, whereas performance increases up to a moderate level of tension and then declines, affirming the inverted-U relationship between physiological arousal and performance.

The contraction of muscle fibres is accompanied by electrical potentials that can be measured in various forms. Sandercock **et al.** (1985) propose that when a muscle is activated by electrical stimulation at a constant frequency, fatigue is defined as a decrease in tension. Few easily measurable, objective physiological indices of fatigue exist. Changes in the surface electromyogram (EMG) have been used extensively as indices of fatigue, but the relationship between the EMG and fatigue remains unclear as Sandercock **et al.** (1985) propose EMG changes often precede muscle fatigue. Therefore, in spite of extensive use, the exact relationship between the EMG signal and muscle fatigue has not been defined.

Interpretations of the EMG signal as indicators of fatigue are made difficult by the complexity of the EMG signal. The EMG recorded from a muscle during volitional activation is a summation and cancellation of the motor unit action potentials (MUAPs) from all the active motor units. The characteristics of the EMG depend on the firing patterns of the motor units as well as on the configuration of the MUAPs; because of the difficulties encountered in recording single isolated MUAP trains at high contraction levels, the relative importance of the two factors is unknown (Sandercock **et al.,** 1985). Despite these difficulties, an attempt was made in this investigation, to observe any possible fatigue effects within the primary working muscles while shooting.

OTHER FACTORS AFFECTING COMBAT PERFORMANCE

Heat Strain

In the military, the potential for or the presence of nuclear, biological or chemical hazards necessitates the use for protective clothing. However, the high insulation and low permeability of some protective clothing severely restricts the body's ability to dissipate heat, resulting in elevated core temperature consequent to work even at mild temperatures (Patton **et al.,** 1995). This can significantly increase the risk of heat casualties by reducing the effectiveness of convective and evaporative heat loss to the environment. As the degree of task mobility increases, the effect of protective clothing on oxygen consumption also increases. Metabolic rate contributes significantly to the degree of heat strain experienced (Patton **et al.,** 1995), and researchers such as Hancock and Vasmatzidis (1998) have found that efficient performance on a task commonly fails before these physiological limitations are reached.

In addition to the heat strain problems, the physical performance limitations imposed while wearing protective clothing include decrements in task performance, increased time for task completion, and decreased work tolerance time. Psychological reactions are also a consideration especially in life-threatening circumstances where the resultant deterioration of performance due to the restriction of movement by protective clothing results in increased anxiety, frustration and panic.

One of the major factors affecting physiological and psychological performance of physical tasks in protective clothing is the weight and bulkiness of the clothing and the carrying of weapons and equipment (Patton **et al.,** 1995), which may be assumed to enhance military morale, but actually increases the energy cost of exercise performance due to the added weight and restricted movement. Endurance training and heat acclimation are both tactics commonly used by military forces to improve subjective heat tolerance (Aoyagi **et al.,** 1998), with the implication that improvement of physical fitness and acclimation to heat are beneficial for operations in hot climates. However, it has yet to be established whether the normal responses to training and acclimation are helpful during hot conditions where personnel must wear protective garments. McLellan

(1993) suggested that when an individual is wearing protective clothing, differences in environmental conditions (temperature and humidity) have more of an influence on exercise tolerance at low metabolic rates, compared to moderate or high. Therefore, the effects of endurance training and heat acclimation on heat tolerance while wearing protective clothing may depend on the intensity of work. In combat situations the duration of battle is generally unknown and it is therefore difficult to assess the long term effects of heat tolerance and protective clothing on the soldiers. Aoyagi **et al.** (1998) have concluded that if individuals are to wear protective clothing with limited vapour permeability, the benefits of either acclimation or an increase of training are relatively small and do little to improve heat tolerance if a task requires high intensities of effort.

Dehydration

Research in sports science has shown that the use of a regular fluid intake regime is one method of reducing workload and delaying the onset of physical and mental fatigue (Paterson **et al.**,1998) and it is generally accepted that loss of body water or fluid adversely affects exercise performance (Derave **et al.**, 1998). The detrimental effect is most evident in endurance exercise where sweating is the most effective cooling mechanism, and this has the potential to cause dehydration if fluid intake does not fully replace fluid loss. The harder one works and the heavier one is, the greater the fluid loss and if the environmental temperature is hot and humid, the body will find it difficult to dissipate this heat, especially when wearing bulky, protective clothing. Burke (1995) and Paterson **et al.** (1998) stated that a fluid loss of as little as 1% body mass can increase body temperature significantly, while for each litre of fluid lost, heart rate increases approximately 8 $bt.min^{-1}$ and cardiac output decreases by 1 $litre.min^{-1}$. When fluid losses move into the range of 5-10% of body weight, Burke (1995) stated that heat exhaustion may become a threat, although heat-related problems also present separately without dehydration.

Ideally fluid intake should match fluid loss. This is possibly not the case in the military given the high physical workloads and harsh, hazardous environmental conditions. Even where planned fluid intake has been carried out before and during training, it is likely the soldier will finish the session with some degree of dehydration. This is particularly true for prolonged and intense physical activity in a hot environment where sweat losses exceed the usual intake of fluid.

A recent study conducted by Burke (1995) has established that there is no 'critical' point or level of dehydration that may be reached causing significant impairment on performance, but rather a gradual 'erosion' of performance as the degree of dehydration increases. Physiologically, heart rates are higher, body temperature regulation becomes more difficult with every percentage of sweat loss and perception of exertion is increased. While dehydrated, cognitive performance is also adversely affected and this is supported by Knapik **et al.** (1990), Burke (1995) and Derave **et al.** (1998) who demonstrated that dehydration affects a number of important factors that are applicable to combat effectiveness; for example, mental functioning, decision making, and concentration. One cannot learn to adapt to chronic dehydration by repeated exposure and strategies should be developed by the military to reduce the soldiers work stress (particularly thermal), promoting work performance and minimising injury risk.

Sleep Deprivation

The requirement to remain awake and function for periods of time beyond the typical daily wake-sleep ratio of 2:1 (16:8h) is an increasingly common aspect of some work settings, and is especially prevalent in sustained military operations (Dinges **et al.,**1988). In such situations, the prolonged fighting or anticipation of a fight not only results in a loss of sleep, but co-exists with a continuous, or intermittent, demand for very high levels of accurate performance and sustained motivation and morale.

Physical exertion and sleep deficit obviously predispose one to fatigue, and in addition, Wendt and Palmerton (1976) have quoted that an important factor to be considered is the individual's emotional state. Given the need for optimal functioning in military situations, there is considerable interest in discovering effective countermeasures to the decline in performance and mood that result from prolonged wakefulness. Dinges **et al.** (1988) suggest that, although notions of mental and physical 'toughness' as well as prior experience with sleep loss continue to be popular countermeasure concepts, there is no concrete evidence that these factors prevent sleepiness and its behavioural consequences, although they may motivate the person to try harder to overcome these effects. There appears to be no substitute for sleep itself. If this is the case, then the question of countermeasures focusses on obtaining sleep in small amounts, whenever there is an opportunity during a quasi-continuous work scenario. Somatic symptoms related to combat stress are common after previous military conflicts (Kroenke **et al.,** 1998) where months of prolonged anticipation, anxiety and fear while living in harsh environments, with threats of massive casualties are high. These factors accumulate, imposing detrimental effects on the soldiers' peace of mind. Sleep-related disorders are therefore not uncommon and result in increased involuntary muscular tremor, double vision, and reduced pain thresholds. However, a positive finding by Crooks and Stein (1998), has revealed that reflexes are largely unimpaired by sleep deprivation.

Sleep is perhaps the most pervasive behavioural control in nature (Dinges **et al.,**1988), and there is every reason to believe that the basic process of sleepiness and its effects on functioning are among the most potent variables in situations that require sustained periods of optimal performance. This emphasises the fact that regular sleep of sufficient duration is necessary during military training and battle, although this is extremely difficult to control.

PERCEPTUAL RESPONSES

Rating of Perceived Exertion (RPE)

Borg (1970) is renowned for his statement "man reacts to the world as he perceives it and not as it really is". It is therefore of interest and importance to know more about the relation between an individual's objective and subjective measurements of physical stress in an attempt to obtain a tangible assessment of the strain one is actually feeling in response to the physiological demands of the task. Awareness of individual, subjective perceptions of various physical tasks performed by the infantry enable military commanders to focus on specific areas of training that may be lacking; or identifying unnecessary negative factors that result in detrimental consequences on the soldier.

Analysis of the psychology responses to hard physical work, and the effects of this on the individual, include the study of subjective aspects of physical working ability, problems concerning muscular performance, exertion and fatigue, various aspects related to the physical condition and training of the individual, the level of motivation, as well as psychophysiological relations (for example, heart rate and breathing frequency). It must be remembered that no matter how physically well conditioned the infantryman is, physical exertion will still be experienced when worked to maximal capabilities under stressful conditions. One of the primary aims of the military, therefore, is to enhance the physical condition of the soldiers in an attempt to prolong the inevitable onset of fatigue during long duration intensive physical activity.

Gamberale (1985) reinforces the fact that being a "privately experienced" event, perceived exertion, or any other subjective reaction to physical work, can only be measured indirectly through the use of self-report techniques. By far the most frequently used scale for rating the degree of perceived exertion during physical work is the Rating of Perceived Exertion (RPE) scale developed by Borg in 1970 (Mihevic, 1981; Borg, 1982; Gamberale, 1985; Baumgartner and Jackson, 1991; Lamb **et al.,** 1999). Borg (1982) proposed that the overall perceived exertion rating integrates various information, including the many signals elicited from the peripheral working muscles and joints, from the cardiovascular and respiratory functions, and from the central nervous system.

This scale consists of 15 grades from 6 (minimal exertion) to 20 (maximal exertion), where every second number has a verbal anchor. The scale, which is presented in quarto format, is shown to the subject and the test procedure is explained. In a physical work test, the subject is shown the scale during the last half minute of each work load and asked to verbally say, or point to, a number that accurately corresponds to the degree of exertion experienced (see Figure 14). The values of the RPE scale grow fairly linear with the work load and correlations with ratings and Heart Rate is reported to be high (r about 0.80) (Borg, 1982; Gamberale, 1985; Goslin and Rorke, 1986; Garcin **et al.,** 1998). The RPE scale is currently constructed so that the heart rate for middle-aged people should, for work loads of medium intensity levels, be fairly close to 10 times the RPE values (Hayes, 1976). According to this basis, a rating of 7 on the RPE scale (very, very light) would correspond approximately to a heart rate of 70 beats.min^{-1}. Borg cautions, however, that this equation should not be taken too literally since derivations from the equation are evident when the subject experiences "difficulties in rating, a lack of motivation, or disease" (Hayes, 1976). Other factors resulting in inaccurate responses are the age of the subject, the type of exercise, environment and level of anxiety (Borg, 1982). However, it has been suggested by Gamberale (1985) and Goslin and Rorke (1986), that individuals have both the capacity to attend to psychological and physiological cues and to report, on a psychological continuum, their judgements of increasing difficulty of the task, or their diminishing capacity to perform.

Interestingly, heat load has been found by Gamberale (1985) to have no impact upon perceived exertion comparable to the physiological strain it produces. He thus cautions that exercising maximally in excessively hot environments will create conditions in which a person will overestimate his physical endurance. This could be a determinant component in the occurrence of cases of exhaustion and collapse, an important factor to be considered in combat situations involving intense physical activity in hot, humid conditions with recruits wearing protective military uniforms and equipment that drastically inhibits heat loss.

Borg acknowledged that perception of effort was dependent upon input from one peripheral class of factors referring to the working muscles and joints involved in the work task and one central class of factors referring to the strain on the cardiovascular system (Ekblom and Goldbarg, 1971; Borg, 1978; Mihevic, 1981). The use of the term "central" in the broader physiological and psychological literature refers to the central cardiovascular system, while classification of a physiological or muscular response as a "local" factor is based on the mediation of feelings of strain in the exercising muscles (Mihevic, 1981). Both central and local recordings are of importance in this project, for as Pandolf (1979) suggests that the use of differentiated ratings of local and central sensations represents a close linkage with specific physiological events. The perception of exertion during physical work therefore not only has a psychological validity, but it also reflects real conditions such as the interplay between the requirements of the task and the capacity of the individual.

There has been sufficient research to demonstrate the validity, reliability and replicability of the findings related to Borg's RPE scales. Evidence suggests (Hayes, 1976) that the RPE scale may be more useful than physiological indices of working capacity in real-life situations since it may merge both motivational factors and physiological cues in a single index. To better understand individuals at work, the ordinary ergonomic criteria, for example, speed and error of performance, should be complemented not only by physiological measurements of strain and work load, but also by measurements and indicators of the perceptual (Borg, 1978).

The Body Discomfort Scale

In 1976, Cortlett and Bishop devised a regional discomfort scale as a means of providing a quantitative measure of the effects of posture which could be useful to identify physiological limits and rest requirements. The literature is limited on the use and validity of this scale, however, it has been widely used in clinical and research settings.

With this technique, the term "discomfort" is used, and it makes use of a 10-point perceived discomfort scale in conjunction with a body map diagram. In order to identify the sites or areas of bodily discomfort, a body map dividing the body into 27 segments

With this technique, the term "discomfort" is used, and it makes use of a 10-point perceived discomfort scale in conjunction with a body map diagram. In order to identify the sites or areas of bodily discomfort, a body map dividing the body into 27 segments is used. Once subjects have identified the most prominent sites of discomfort, they are able to rate the intensity of the discomfort at each identified site.

CONCLUSION

An understanding of the interdependence between mental and somatic responses is mandatory in assessing how various internal and external factors affect an individual's perception of and response to a specific situation. The military recognise the importance of evaluating how one is affected by environmental demands, as successful performance is determined by surviving threatening, violent operations while attempting to defeat the enemy; and as combatants are human, their physiological and psychological capabilities will be pushed to maximal efforts in response to these stressful situations. High levels of physical conditioning will only partially alleviate the fatigue of sustained intensive activity, with the diversity of combat skills requiring both physical and mental alertness. While there are no tasks that are exclusively either physically or cognitively demanding, one may tend to be more prominent than the other depending on the given situation. Therefore, it is evident that an in-depth investigation should be conducted into the differentiation of mental and physical fatigue arising from stressful combat related conditions and the individual's physiological and perceptual responses to the required task, in order to discover how these may influence the proficiency in performance. Unfortunately the main factors such as environmental heat, dehydration, sleep and stress of any live combat situation are not easily simulated under laboratory experimental conditions.

CHAPTER III

METHODOLOGY

INTRODUCTION

It is never possible to predict exactly how long a combat situation may last, or precisely what physical and cognitive demands are made on the combatants. These unpredictable external factors, combined with the physiological and psychological limitations of human beings, make tangible assessments of behaviour and performance output extremely difficult. However, as the primary purpose of an armed military force is to protect, defend and fight for the safety of a country, it is necessary to obtain as accurate an appraisal as possible of the military efficiency of individual soldiers.

It is evident that the success or failure of a military operation is determined by the actual performance output of the combat forces, and it was therefore deemed imperative that an holistic approach be taken in investigating the effectiveness of the soldier, as the standard of performance plus the physiological and perceptual responses of an individual are interdependent. This principle is based on Borg's (1978, b) proposition of the "Effort Performance Triad" which considers the physiological and perceptual factors as well as the overall performance responses of the individual.

The primary objective of this study was to assess the various physical and cognitive requirements of infantrymen and to establish how the individual soldier is mentally and physically affected as a result of fatiguing military exercise. Performance, physiological and perceptual responses were evaluated under two conditions: a 'normal' situation without prior physical exertion; and a condition which entailed that responses be assessed immediately after the completion of three and a half hours of continuous physical activity.

SUBJECT CHARACTERISTICS

Forty foot soldiers from the local Infantry Battalion voluntarily agreed to participate in the study. All subjects were members of the Battalion 6 SAI. Out of the total group of subjects, 10 were selected for Electromyographical (EMG) assessment. These subjects were chosen according to the Captain's discretion in terms of level of responsibility and commitment to the project, and were required to be right hand dominant for convenience of controlling the EMG and standardisation of testing purposes. Due to various reasons, including injury and deployment, a total of 32 subjects completed the requirements of the project.

Basic demographic data were collected from each subject, namely: age; the number of years of military experience; stature, which was measured using the Harpinden stadiometer; and body mass (minimally dressed and full uniform), using the Toledo scale.

Although attempts were made to use male subjects spanning a 10 year range this was not possible and the final age span was from 20 to 37 years. The mean stature was 1706mm with little variability. In contrast, the mass of the subjects, when minimally dressed, ranged from 52.92kg to 84.04kg. When clothed in full military uniform, there was a mass increase of 4kg.

Table I: Basic demographic data of the sample.

	AGE (yrs)	STATURE (mm)	RPI	MASS (kg)	MEXP (yrs)
$\bar{X}$	28	1706	420.34	67.63	6.21
SD	3.88	0.058	16.21	7.30	2.28
CV(%)	13.68	3.41	3.85	10.79	36.69

Where:

RPI = Reciprocal Ponderal Index $\frac{\text{Stature(mm)}}{\sqrt[3]{\text{Mass (kg)}}}$

MEXP = Years of military experience

The Reciprocal Ponderal Index (RPI) was calculated using the equation above to provide a general impression of body robustness. With low values indicating a robust build and higher values indicating a linear, more gracile build, the sample mean of 420.34 indicated that the subjects tended to be relatively linear in physique.

The number of years of military experience was recorded, displaying a range from 3 to 14 years, with a sample mean of 6 years. All subjects were currently in the same military unit where the physical activity, dietary intake and duration of sleep were similar for all. Clothing of the subjects plus the time of data collection was standardised.

PERFORMANCE EVALUATIONS: Equipment and Basic Protocol

Physical performance was examined using a selection of motor activities of relatively short duration that were based on tasks considered fundamental to successful military operations.

Field Testing

Magazine Loading

Three field tests were conducted *in situ*, commencing with the Loading of a Magazine with thirty rounds of ammunition, as fast as possible. The army supplied bullets and magazines, while the experimenters recorded the speed of performance time with stopwatches. Testing protocol required the subject to indicate when ready to begin, then the stopwatch was started. As the last bullet was inserted into the magazine, timing was terminated.

Figure 2: Subjects loading thirty rounds of ammunition into a magazine.

Target Shooting

The second field test was employed to assess Shooting accuracy and speed of firing, the testing being conducted at the shooting range on the Military Base.

Targets, rifles and ammunition were provided by the military personnel. For security and safety reasons all shooting was under the direct control of the Captain of the platoon. Research assistants simply recorded the time taken to complete the firing of five rounds in each of the four selected positions; the four positions were: Lying at a distance of 50m from the target, then Standing at 50m;Lying at 100m from the target and Standing at the same distance.

Figure 3: Subject shooting in a Lying and Standing position.

Military personnel calculated the number of points scored, following the Army's standardized scoring method. A maximum of five points per round was scored if the subject hit the centre area marked on the target, four points were assigned if the slightly bigger box surrounding the centre was hit, three points for the greater area marked around this, two points for firing on the trunk area, and one point for hitting the target in any other area (ie helmet or legs), (See Figure 4). A total of twenty-five points was the maximum possible score that could have been recorded for five rounds of ammunition. The marksmanship results were later submitted to the experimenter.

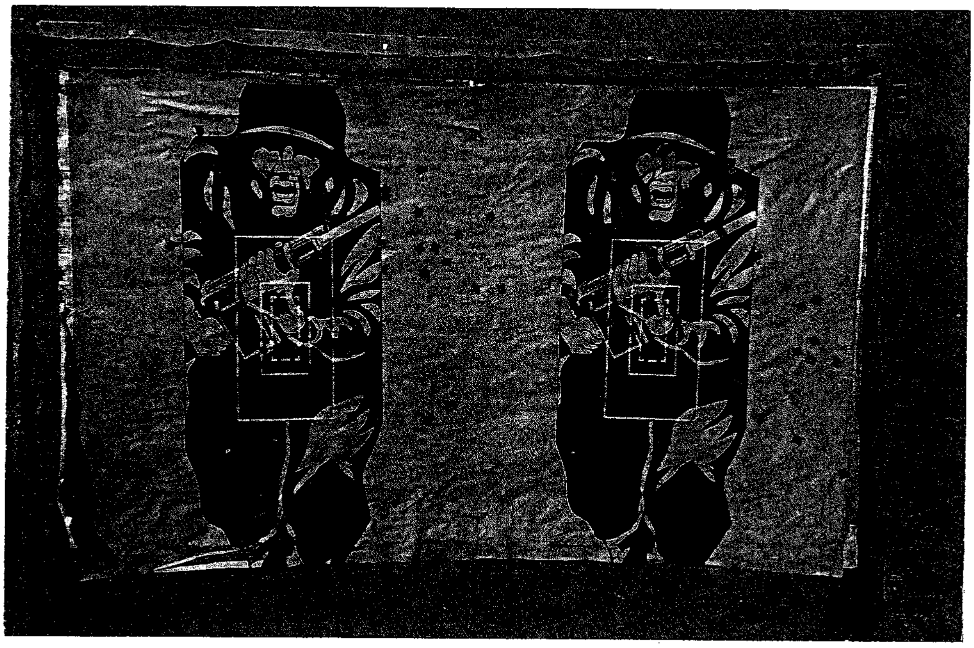


Figure 4: Shooting Targets.

Grenade Throwing

Grenade Throwing accuracy was the final field test. Each subject was required to throw a de-activated hand-grenade, from a stationary position, at a target area (a tractor tyre) 20m distant. One trial per subject was allowed and the distance the grenade landed from the target area was measured.

Figure 5: Subjects lined up to throw de-activated grenades into the targets.

Laboratory Testing

Grip Strength

A measure of upper body Strength was determined by the use of hand-grip dynamometers. This appraisal constituted the first of four laboratory tests. The dominant hand was used, the effort beginning with the arm raised above the head. The subject compressed the dynamometer has hard as possible while fully extending the arm. The Grip Strength, in kilograms, was read off the scale on the dynamometer. Three trials were conducted, the average of the scores being recorded.

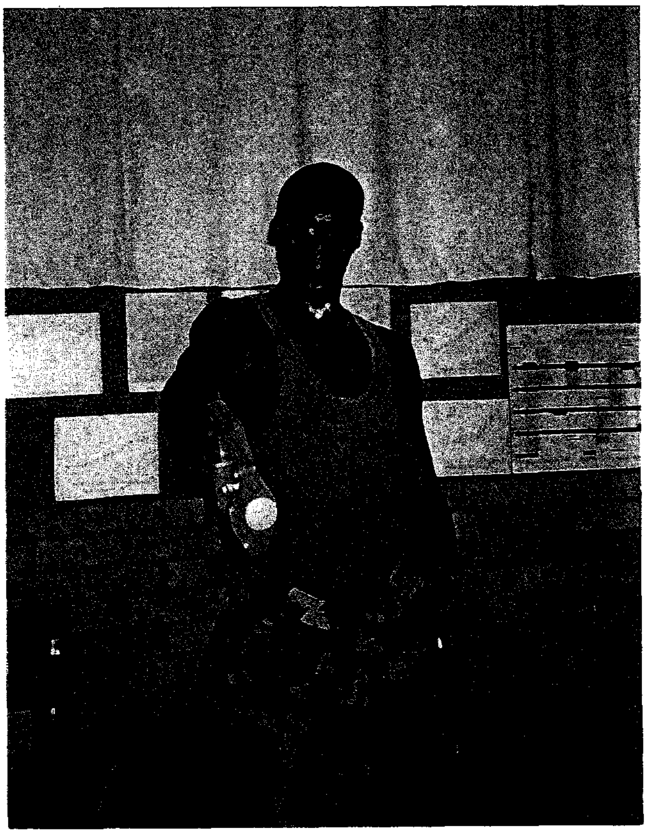


Figure 6: Grip Strength assessed with hand-grip dynamometers.

The Sargent Jump

The TKK Sargent Jump unit was used to evaluate the Power of the lower limbs. The subject was required to stand on a tapeswitch signal mat situated alongside the wall-mounted timing board. Both pieces of equipment were connected to a "stop clock" which automatically displayed the time taken from leaving the mat to touching the board. Standardisation of the task compelled the subject to stand erect with the right arm stretched above the head to just touch the bottom panel of the electrical board with the distal end of the middle finger. The board was vertically adjustable via a pulley system.

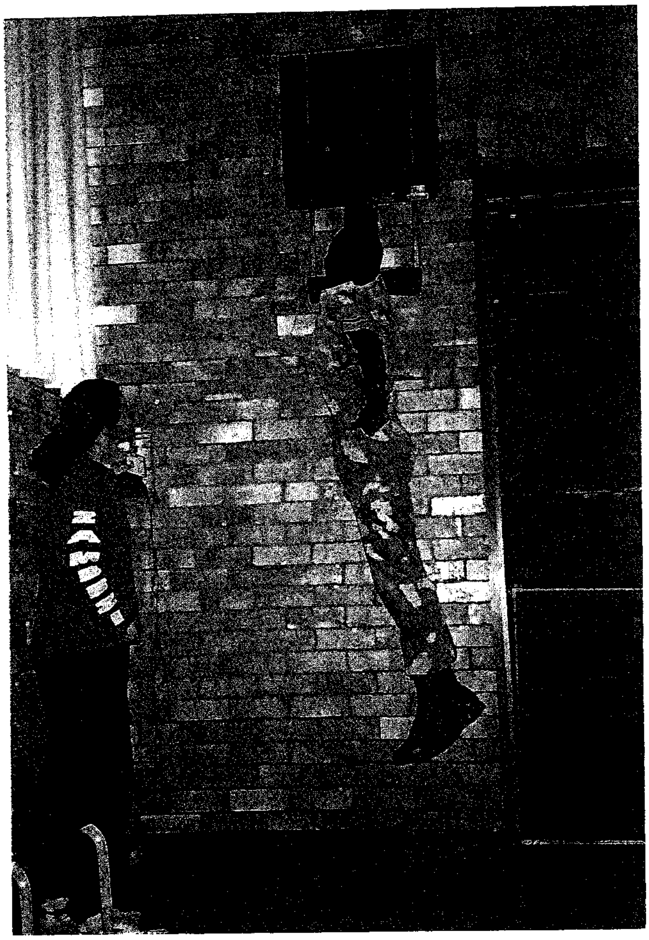


Figure 7: A subject jumping to touch the electrical board.

The subject jumped as high as possible and touched the board with his right hand. The TKK Jump Metre digitally recorded the height jumped from the ground in centimetres. Three trials were performed with an average value calculated. The following formula was used to assess power output:

$$\text{Power (W)} = \frac{(\text{Body mass kg} \times \text{Gravity m.s}^{-2}) \times \text{Distance (m)}}{\text{Time (s)}}$$

Reaction Time: Finger and Whole Body

Whole Body and Finger Reaction Time in response to an auditory stimulus was the third laboratory assessment. The TKK reaction unit consisted of a control board connected to either the floor mat or the finger response panel. Whole Body Reaction Time was evaluated with the subject standing on the floor mat with his back to the control board. After the command "ready", the experimenter pressed the 'auditory' button and the tone was activated. The subject was required to jump off the mat as quickly as possible, with the digital clock on the control board displaying the time taken between the activation of the stimulus and the subject breaking contact with the mat. The digital clock was reset and the subject performed a total of three trials, with an average Whole Body Reaction Time measured in seconds.

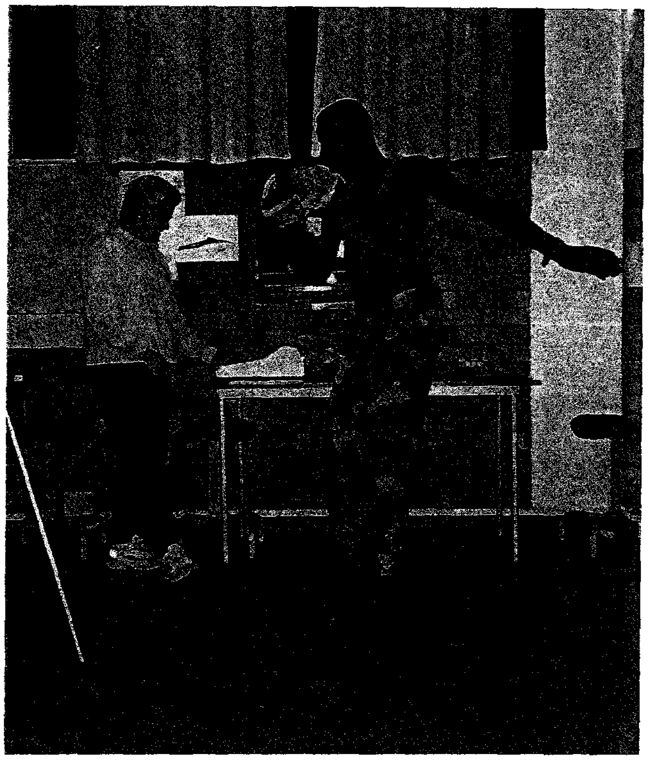


Figure 8: A subject jumping off the tapeswitch floor mat during the Whole Body Reaction Time assessment.

The finger reaction panel consisted of three buttons in a row. The subject was required to push the middle button in response to an audio cue. As the TKK control panel was concealed from the subject, he was not aware when the stimulus would be presented. However, the command "ready" was given and a tone was activated shortly thereafter. Finger Reaction Time was displayed on the control board. Three trials were administered, with an average Reaction Time calculated.

Figure 9: The Finger Reaction Time Test.

Cognitive Ability

The Vienna Test System (VTS), a computer-assisted device enabling the application of a variety of highly diverse psychodiagnostic tests and measuring procedures (Bukasa and Wenninger, 1992) was used in determining Cognitive Ability. The ALS Work Performance Series test uses basic arithmetic as a general performance assessment of concentration and mental alertness over time, indicating the individual's ability to perceive relevant information, make quick decisions and respond appropriately; a task requiring mental agility.

The procedure comprises a standardised instruction and practice phase followed by a 10-minute test phase, during which time the subject is required to complete as many additions of two numbers as fast as possible. The numbers are displayed on the computer screen, one above the other, and the subject is required to type sum of the numbers on the keypad positioned in front of the panel.

Figure 10: The ALS Work Performance Series Test.

The following variables were scored:

a) the total number of responses completed as a measure of working speed

b) the number of correct responses

c) the mean response time.

VTS Protocol

When the required test has been selected the testee information is entered and the test programme started. Every test commences with instructions displayed on the screen and any queries are addressed verbally by the test administrator. This was a common occurrence in the present study as English was the second language of all subjects who also had a limited education level, plus a complete lack of laboratory experience.

The next stage is the programme is the practice phase which ensures that the subject has understood the instructions. If a subject is not able to solve the task, he will be offered help. If he fails several times, he will be asked to contact the test administrator. Following this is the test phase which continues automatically until the end of the test.

When the test has been completed it may be scored immediately. The computer summarizes the raw scores obtained and performs a comparison against norms. The testee's results are compared against an overall sample or a selected sub-sample based on age, sex and level of education. A printout of the results was collected for data analysis of the following: total number of responses, correct responses and mean response time (See Appendix C).

PHYSIOLOGICAL MEASURES

Heart Rate

Heart rate responses are known to be a useful indicator of the intensity of physical activity because of their predictable and reproducible relationship to energy expenditure and cardiac load or strain (Gleeson and Lambert, 1998). The Polar Heart Rate monitor was used in this study to record heart rate values throughout Condition 1 and 2. A transmitter was placed around each subject's chest in direct contact with the skin. The centre of the transmitter was situated between the pectoral muscles with the electrodes positioned directly under the nipples. Signals from the transmitter are received by the wrist watch which displayed the subject's heart rate.

Figure 11: Heart rate monitor and strap.

A general 'Reference' heart rate was evaluated during the initial briefing session of data collection at the laboratory. Subjects had been seated for half an hour before heart rate was measured. 'Pre-data collection' values were recorded at the beginning of Condition 1 and 2. Just prior to participation in each test, an 'Anticipatory' heart rate was recorded; and on completion a 'Post-test' heart rate was assessed. This was conducted after each of the seven field and laboratory tests. Under Condition 2, heart rate was recorded immediately after each physical exercise. Refer to Appendix B (Data Sheet).

Electromyographic (EMG)Activity

Electroymyographic (EMG) activity was assessed using the Muscle Tester ME 3000 Professional System which is a compact and light Electromyograph equipped with four EMG channels per unit. The amplification of the biological signal is done at the grounding electrode site, which effectively minimises, if not eliminates, signal artifacts caused by movement and external noise. The raw myoelectrical activity was sampled at a frequency of 1000Hz, and the sensitivity of the unit is reported by the manufacturer to be 1 microvolt. The ME 3000 unit was connected to the communications port of a Laptop computer via an optic cable for downloading of data. Using the software made available with the EMG data collection system, these signals were examined for any artifact and were then full wave rectified and an average value was computed for each period (ie shooting from 50m while Lying and repeated for 50m in a Standing position, the same procedure repeated at 100m).

Bipolar Ag/AgCl surface electrodes, with a recording surface of $10mm^2$, were applied to the appropriate muscle sites, delimiting the sampling to the right side of the subject's body.

Ten right-hand dominant subjects were selected for neuromuscular activity assessment during the Target Shooting test. Pilot studies, conducted in corroboration with the Military Commanders, revealed high levels of strain and discomfort experienced in the forearms, the shoulders and the upper back, while shooting. Evaluations of right-handed subjects demonstrate that isometric muscular contraction in the left forearm is necessary for supporting and steadying the rifle while firing, the same muscle group in the right forearm is activated while pulling the trigger; the Intermediate Deltoid is contracted as the rifle is positioned for firing, with the butt of the rifle being supported by the shoulder, and finally the Trapezius muscle is contracted when holding the arm in the elevated position required for the shooting action. These specific muscle sites were selected for EMG assessment because of the reported muscular strain while performing this critical military task.

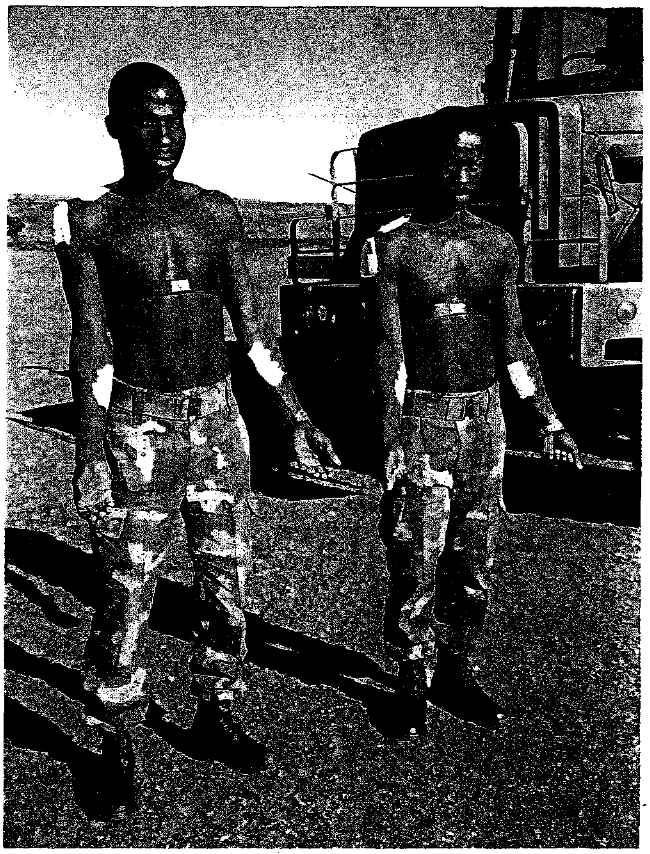


Figure 12: EMG electrodes placed on the right and left Palmaris Longus, the right Intermediate Deltoid and the right side of the Trapezius muscle.

During data collection, one assistant was appointed to mark each EMG subject with an ink pen on all of the relevant muscle sites to ensure an accurate, precise assessment of the appropriate muscle. These included: the right and left Palmaris Longus, the right Intermediate Deltoid, and the right side of the Trapezius. Another assistant then shaved and cleaned the marked area. The original assistant then placed two Ag/AgCl surface electrodes longitudinally with respect to the underlying muscle, on each marked muscle site, and one grounding electrode attached approximately 100mm away from the recording site, ensuring that it was off the muscle body. The electrodes were taped down to ensure that a good contact was maintained throughout the exercise and to minimise the movement-related artifacts.

In order to identify what percentage of a maximal effort was required to execute the task of holding the rifle steady for shooting and for the action of squeezing the trigger, a Maximal Voluntary Contraction (MVC) was assessed for each of the selected muscles. Rigorous instructions were given to the three EMG subjects per group regarding the MVC test. All EMG subjects were required to perform this evaluation before each testing session in order to obtain a baseline recording of the specific muscle site. The first MVC assessment of the forearms compelled the subject to hold a tennis ball in each hand, and as the instruction "ready" was given, the subject had to squeeze the tennis balls as hard a possible for five seconds. The subject then had to kneel with the right arm positioned by his side, with the thumb facing forward. The command "ready" was given and resistance was applied to the forearm by the experimenter as the subject abducted his arm as far as possible, fully contracting the Intermediate Deltoid. This position was held for five seconds. The final MVC of the Trapezius muscle required the subject to remain kneeling while holding a wooden bar horizontally across his chest. The experimenter knelt facing the subject and again, after the command "ready", the subject maximally pushed the bar up, while the experimenter pulled the bar down. This position was held for five seconds. The MVC tests were administered individually to the subjects.

The Target Shooting exercise was the second test to be completed. Before this test began, the subject of the sub-group upon which the EMG data were collected was connected to the four electrode channels. EMG activity was recorded as the subjects were given the command to begin firing firstly from the 50m distance while Lying and Standing, and then from 100m. These four Target Shooting sessions took approximately 15 minutes. The subject was disconnected after the final firing from 100m while Standing. EMG data was immediately downloaded onto a laptop computer before the next EMG subject was to be assessed, and EMG data collection was then completed until the next sub-group performed this test.

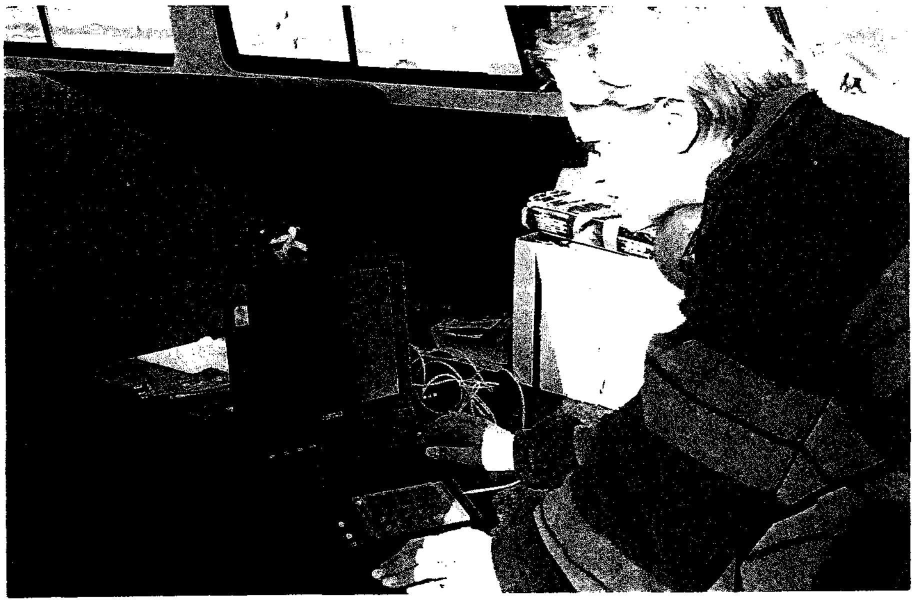


Figure 13: Downloading of EMG data onto the laptop.

PERCEPTUAL RESPONSES

Rating of Perceived Exertion (RPE)

Perceptual responses using Borg's (1970) RPE scale allow the experimenter to assess how a person is 'feeling' while performing a task. Differentiated ratings of Central and Local responses can be used in order to obtain a tangible meaning of how the individual perceives the demands of the load on the cardiovascular system as well as the local group of muscles being used.

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.	

Figure 14: The Rating of Perceived Exertion Scale (Borg, 1970).

The RPE consists of a 15 point numerical scale ranging from 6 (minimal exertion) to 20 (maximal exertion), where every second number has a verbal anchor; however as these are in English there may be some difficulty in using the scale with subjects for whom English is a second language. As the reliability of the scale is highly dependent on a good understanding of the concepts of using such a scale, it was essential that the subjects were provided with specific instructions about the use of the scale. These instructions were explained to the subjects during the initial

'Familiarisation' session, and were repeated before each data collection assessment commenced (Refer to Appendix B for RPE instructions to subjects).

The Body Discomfort Scale

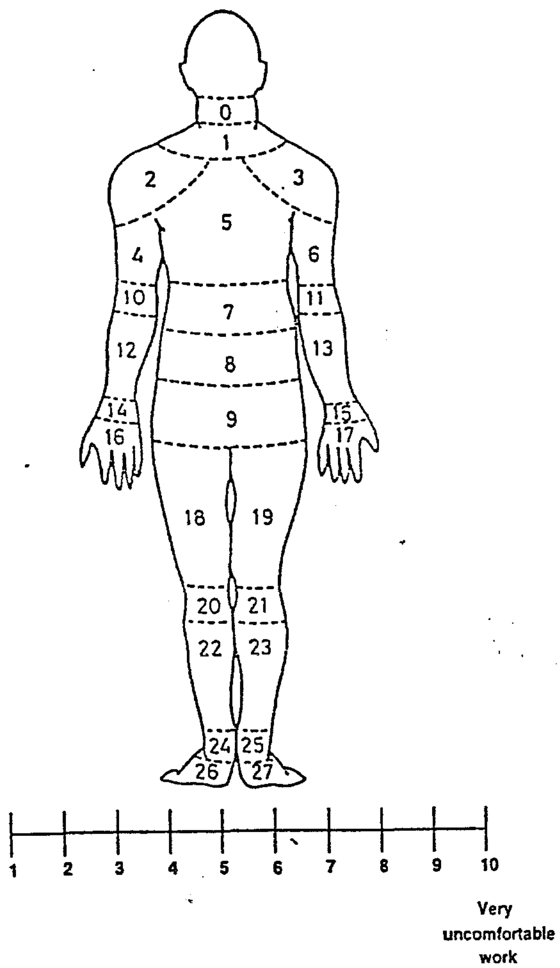


Figure 15: The Body Discomfort Scale (adapted from Cortlett and Bishop, 1976).

The Body Discomfort map, adapted from Cortlett and Bishop (1976), which divides the body into 27 segments (refer to Figure 15), was used to evaluate the discomfort experienced in specific bodily area(s) after completing the tests conducted under Condition 1 and 2, as well as during the physical activity period. Once subjects had identified the sites of discomfort on the body map, they were required to rate the intensity of discomfort at each identified site on the 10 point Scale.

TESTING CONDITIONS

Condition 1: 'Normal'

Performance testing conducted under Condition 1 required the subjects to have participated in minimal physical exertion prior to testing. This condition was termed 'normal', and the performance responses regarded as the base line to which comparisons could be made.

Condition 2: 'Post-Working'

A number of simulated occupational related tasks typical of combat conditions were selected in an attempt to physically fatigue the subjects before repeating the tests conducted under Condition 1. Intense anaerobic and aerobic physically demanding activities were performed over a three and a half hour duration. Firstly, high intensity Set Exercises comprising of the army's standard shuffle kicks, press-ups and sit-ups were performed, with fifty repetitions of each exercise. This lasted approximately six minutes. The subjects then completed a moderate to high activity consisting of a 3.4km run over rough terrain, wearing a battle jacket and carrying a rifle. This task generally took the subjects twenty minutes to complete, before they marched for 15km march with a loaded backpack weighing 26kg, while carrying a rifle. This final military task lasted approximately two and a half hours.

EXPERIMENTAL PROTOCOL

The subjects were required to participate in three separate testing sessions. The first assessment was conducted in the laboratory at the University with all subjects involved. The second and third data collection sessions accommodated a maximum of 10 subjects per session. In order to limit the effect of diurnal influences data collection commenced at the same time of day for both conditions.

The subjects were randomly assigned to four groups (A-D) of nine individuals plus an extra subject available in the event of injury or a subject not completing data collection, and were numbered from 1 to 10, for example A1, A2... A10. These were then further sub-divided into three subgroups, with three of the nine subjects per group, numbered 1,4 and 7 selected for EMG testing.

Session 1: Familiarisation

This was an initial briefing session where detailed instructions of the testing protocol was conducted, informing the subjects of what was required of them during the testing procedures. Letters of information were given to each subject, and consent forms were signed by the Captain of the Battalion on behalf of the subjects.

The use of the Polar Heart monitors and the EMG, as well as the RPE and Body Discomfort Scales, were explained to the subjects, expressing the experimenters interest in not only performance output, but perceptual and physiological responses to the tests.

Familiarisation with laboratory equipment allowed the subjects to become accustomed to the use of the Hand-Grip dynamometer, the Sargent Jump, the Whole Body and Finger Reaction Time unit as well as the Cognitive Ability arithmetic test. Practice was permitted until the subjects indicated an understanding of the correct use of the equipment.

Testing Session 1: 'Normal' Conditions

Data collection commenced for Condition 1 at 10.00 hours at the local Military Base. Polar heart rate monitors were positioned on each of the 10 subjects and 'Pre-data collection' heart rate values were recorded.

The three EMG subjects were marked, shaved and cleaned on the four muscle sites before the electrodes were placed in the appropriate areas. MVC for each of the muscle sites was then assessed.

The group of 10 subjects was divided into the three sub-groups and were reminded of the instructions for the use of the Rating of Perceived Exertion and Body Discomfort Scales before testing began. These assessments, including 'Anticipatory' and 'Post-test' heart rates, were recorded after each field and laboratory test.

Field testing commenced with the assessment of the time taken to load a magazine. This was followed by Target Shooting, with one subject in each group undergoing an EMG assessment. Subjects fired firstly from the Lying position at 50m, then Stood up for the second shooting position from 50m. Both subjects and testers then moved back to the 100m mark where the whole exercise was repeated. One assistant was responsible for EMG measurement, while three other assistants assessed the performance, physiological and perceptual responses of the remaining subjects throughout testing. The final field exercise investigated accuracy in throwing a de-activated hand-grenade at a target 20m away.

On completion of the field tests, subjects were driven down to the laboratory for the remaining four tests, the first of these was the Grip Strength followed by assessment of Power in the lower limbs. Subjects then moved across to the next laboratory where Finger and Whole Body Reaction Time was recorded and the final assessment of Mental Agility, using the VTS arithmetic test.

Testing Session 2: Intense Physical Activity and 'Post-Activity' Responses

Data collection for Condition 2 commenced at 07.30 hours at the local Military Base. It was necessary to begin Condition 2 earlier in the day (compared to Condition 1) to ensure that 'post-physical activity' responses commenced at the same time for both testing conditions, controlling for possible diurnal influences. Polar heart monitors were worn by the group of 10 subjects and 'Pre-data collection' heart rate values were recorded.

The exact protocol administered under Condition 1 was repeated for EMG preparation, with MVC's assessed before data collection commenced.

The first sub-group of 3 subjects began the physical activity tasks with the Set Exercises (shuffle kicks, press-ups and sit-ups). Perceptual and heart rate responses were assessed after each test. The 3 subjects then immediately put on battle jackets and carried their rifles on a 3.4km run over rough terrain. This activity took, on average, 20 minutes. While this test was being completed by the first sub-group of 3 subjects, the next sub-group began the Set Exercises. This procedure was necessary to allow for approximately 20 minute intervals between each sub-group to prevent the possibility of the subjects resting and physiologically recovering after completing the field tests while waiting for the other subjects to complete the laboratory tests. It was the experimenter's intent to assess each subject's response immediately after completing intense physical activity and this would not have been the case had all the subjects participated in the physical activity tasks simultaneously.

As the first sub-group returned from the 3.4km run and heart rate and perceptual responses were recorded, the battle jacket was removed and replaced by a 26kg loaded back pack. The subjects began the 15km march, carrying their rifles. This march took approximately two and a half hours during which time the assistants worked with the next sub-group on the same testing protocol until all three sub-groups had completed the physical activity tasks. As each group completed the full physical activity programme it performed exactly the same field tests as those carried out under Condition 1.

The subjects were immediately driven from the rifle range to the entrance of the Military Base, where they ran 2.5km to the laboratory. This run was necessary to reduce the possibility of recovery from the physical demands placed on the soldiers before completing the Grip Strength test, the Sargent Jump, the Finger and Whole Body Reaction Time test and finally the Cognitive Ability arithmetic assessment.

With the final test, namely the mental agility test, it was difficult to control the delay of time between sub-groups. Despite the attempt to start the sub-groups at set intervals to prevent waiting periods, some subjects from the next sub-group did catch up to the sub-group ahead. This resulted in a backlog of subjects waiting to complete the final test, and physiological recovery was inevitable. Data collection was then completed after each subject had performed all the exercises required of Condition 1 and 2.

STATISTICAL ANALYSIS

The Statgraphics (Version 7.0) package was used to statistically analyse the data. Basic descriptive statistics relative to the variables assessed were gathered, providing general information concerning the sample.

Experimental Design

This study involved the investigation of the performance, physiological and perceptual responses after participation in three and a half hours of intensive physical activity. These measures were assessed on the same subjects under 'normal' and 'post-working' conditions.

Tests of normality of data and homogeneity of variance revealed that parametric statistics were appropriate. Accordingly, parametric related t-Tests (One-sample analysis) was used to determine whether Condition 1 and 2 were significantly different.

Confidence Level

The 0.05 level of probability was employed throughout the statistical treatment of the data for testing the significance of differences within the data. Therefore, any conclusions based on the results of these analyses must bear in mind that there were still five chances our of a hundred that a Type I Error could have been committed (rejecting a true hypothesis). The chances of committing a Type II Error (failing to reject a false hypothesis) are dependent on subject numbers, where the probability of committing a Type II Error is lower at the 0.05 level than at a higher level of probability. Thus, the larger the sample population, the lower the chance of failing to reject a false hypothesis. However, the logistics of organising appropriate subjects, and the temporal demands of data collection kept the subjects numbers relatively low.

Hence, in relation to Type I and II Errors, considering the inherent variability of parameters under investigation, and the limitations related to subject variability, the choice of 0.05 level of confidence was considered a reasonable and acceptable level.

CHAPTER IV

RESULTS AND DISCUSSION

INTRODUCTION

In a combat environment one will experience both elevated arousal levels, due to the threat of an explosive situation, as well as extreme fatigue as a result of the excessive physical demands placed on the soldier. Depending on the severity and duration of the situation, these two responses will have an affect on the ultimate fighting efficiency of the troops. On the one hand, when subjected to intense physical demands over an extended period of time, humans inevitably display marked decreases in performance output. On the other hand, elevated arousal levels in response to the threatening external environment will produce physiological and psychological changes within the individual, and these adaptations play a critical role in facilitating heightened levels of performance. However, the ability to make "life-or-death" determining decisions and to perform strenuous physical actions (both activities being very much part of a combat army platoon) will be negatively affected if one is in an extreme state of fatigue.

The general acceptance that performance improves with increased arousal to a point and thereafter it becomes worse with further increases, was stated, initially by Yerkes and Dodson (1908), and later by other researchers such as Grings and Dawson (1978) and Roy and Steptoe (1991). Thus, there appears to be an 'ideal' level of arousal, with a limit to the amount of increased (or decreased) arousal that can be tolerated before there is a deleterious effect on performance efficiency.

In a military context, the infantryman is often pushed to his physical and psychological limits and the will to survive plays a vital role in delaying the debilitating effects of fatigue on performance. As previously mentioned, in combat situations, arousal levels are undoubtedly elevated, and if these excessive external demands continue over a long duration, the cumulative effects of extreme mental, physical and emotional stress will take their toll on the soldier, negatively affecting performance output.

CONDITIONS

The main objective of the present project was to determine the extent to which cognitive and physical functioning is affected by strenuous physical activity. It was therefore necessary to make a comparison of the standard of performance under a physically 'normal' condition with that of a physically 'fatigued' condition.

Condition 1 consisted of testing a number of military tasks, similar to those required in a battle context, with no physical exercise prior to data collection. Three field tests were conducted at the Military Base, namely: Magazine Loading, Target Shooting and Grenade Throwing. The subjects were then transported to the laboratory at the University to complete assessments of upper body Strength, Power of the lower limbs, Reaction Time and Cognitive Ability.

In contrast, Condition 2 required that these tasks be performed after an intense bout of physical activity which lasted approximately three and a half hours. The physical exercise consisted of Set Exercises (shuffle kicks, press-ups and sit-ups), followed by a 3.4km run while wearing a battle jacket and carrying a rifle, and a 15km march with a loaded backpack weighing 26kg.

The results of the post-physical activity performance were then compared with that of Condition 1 to determine the effects of the strenuous exercise on performance efficiency.

Testing conditions were randomly assigned to four groups of nine soldiers in order to eliminate any learning effect and all data were collected between 10.00 hours and 13.00 hours to reduce the effect of possible diurnal influences.

Results of specific tests are discussed separately initially and then integrated in order to establish an holistic profile of the responses of the combat soldier after participation in physically demanding activity.

PERFORMANCE RESPONSES

Field Tests: 'Normal' vs 'Post-Working' Conditions

Table II: Results of accuracy in hand Grenade Throwing and speed of Magazine Loading.

	Grenade Throw (m)		Magazine Load (s)	
	Normal	Post-Work	Normal	Post-Work
$\bar{X}$	3.52	3.91	62.19	63.2
SD	2.89	2.63	9.69	15.25
CV(%)	82.06	67.25	15.58	24.12

Grenade Throw

Subjects were required to throw a grenade into a tyre positioned 20m away. This test was not physically demanding and the majority of subjects approached this task in a relaxed manner. No subject managed to hit the tyre with the distance from the target ranging from 0.45m to 10.40m during Condition 1, and 0.10m to 8.10m under Condition 2. Unlike Target Shooting, the pinpoint accuracy of Grenade Throwing is not deemed critical and from the high variation in the responses (as high as 82% coefficient of variance) it is evident that subjects simply threw the grenade in the general direction of the target. There was no significant difference in the accuracy of the throw under the two conditions. Minimal research has been conducted on this skill, and this has been attributed to the fact that analysis in the accuracy of Grenade Throwing is not considered to be of critical importance (unlike Target Shooting), as the soldier aims in the general direction of the target when throwing, with the knowledge that direct contact between the target and the grenade is not essential due to the explosive nature of the grenade, and therefore the consequential destruction of the target.

Magazine Loading

Subjects made a determined effort to load the thirty rounds of ammunition with as much speed as possible with superiors and experimenters observing. There was no marked time difference between 'normal' and 'post-working' conditions (62s and 63s, respectively), however, the variance was noticeably greater under Condition 2 where the subjects were evidently hot and tired after performing the physical activity tasks, and were anxious to complete this task quickly. During the 'post-activity' testing, many of the subjects opted for speed of performance rather than precision in inserting the ammunition, resulting in 'jamming' the magazine and having to unload and start again. Although this condition was not stressful as such, it is believed that physically and emotionally stressful situations (typical of that of combat) plus the cumulative affects of fatigue, will increase the likelihood of reduced efficiency in performance, for example, increased problems and time in loading the magazine.

Target Shooting

Table III: Target Shooting time recorded for the four positions under both conditions.

		Time (s)			
		50m		100m	
		Lie	Stand	Lie	Stand
Normal Condition	**$\bar{X}$(SD)**	29.85(8.27)	25.77(7.77)	32.19(11.79)	33.98(13.79)
	CV(%)	27.70	30.73	36.60	40.50
Post-Work Condition	**$\bar{X}$ (SD)**	21.79(9.99)	19.92(9.52)	22.52(9.81)	20.50(9.44)
	CV (%)	45.85	48.78	43.57	46.07

Bar indicates statistically significant differences ($p<0.05$).

The Target Shooting results revealed in this study contradict the findings mentioned by Knapik **et al.** (1990), who claim that even a short period of exercise will increase physiological factors which will negatively affect somatic control (for example, lead to a whole body sway), with consequential detrimental influences on the accuracy in aiming a rifle. The data recorded in the present investigation revealed that arousal and activation of the physiological system as a result of the imposed physical activity, appeared to nominally enhance performance, rather than induce physiological fatigue resulting in subsequent deleterious responses.

Shooting time was significantly faster at both distances and positions after participation in physical activity where the subjects where evidently physiologically aroused and they approached the task with greater urgency and determination to complete testing unlike Condition 1 in which the subjects appeared to be under less pressure.

Comparisons of the time taken to shoot from the two distances reveals nominally faster shooting time from 50m particularly under 'normal' conditions (29.85s vs 32.10s and 25.77s vs 33.98s, 50m vs 100m respectively), demonstrating that a greater concentration is required while shooting at the further distance from the target. Analysis of the various positions showed that a longer time was taken to fire in the Lying position. This was evident at both 50m and 100m during Condition 1 and 2 with one exception, that of shooting at 100m during 'normal' conditions where Lying and Standing times were the same. In summary the quickest firing responses occurred while shooting from the closer distance to the target in the Standing position after physical exercise.

Target Shooting Points

In both the Lying and Standing positions at 50m from the target, there was no difference in accuracy of shooting between the two testing conditions, although subjects tended to score nominally less points while Standing compared to Lying in both the 50m and 100m shooting positions. While shooting in a prone position, the left and right elbows remain in contact with the ground while supporting the rifle, thus increasing the stability while aiming and this is possibly the reason for the moderately higher scores recorded while Lying. High variability within the sample was evident as the number of points scored ranged from 0 to 24.

Comparing the distances and points scored, it can be seen that while Lying and Standing there was greater accuracy from the closer distance, with the most points being scored from 50m while Lying down (average of 18 out of a possible25 points). Accuracy was nominally reduced at 50m Standing, followed by 100m Lying, and finally the least accurate position and distance was Standing at 100m.

Table IV: Points scored during Condition 1 and Condition 2 in the four positions.

		50m		100m	
		Lie	**Stand**	**Lie**	**Stand**
Normal Condition	**$\bar{X}$ (SD)**	17.96(4.39)	15.09(5.13)	14.59(4.35)	11.53(5.19)
	CV(%)	24.46	34.00	29.83	45.03
Post Work Condition	**$\bar{X}$ (SD)**	17.50(3.46)	15.80(3.59)	14.06(4.67)	11.28(2.92)
	CV(%)	19.79	22.74	33.25	25.89

It is of interest to note that while there was no difference in the accuracy of the Target Shooting, the soldiers were in fact significantly faster in completing the shooting exercise after they had participated in the physically demanding activities.

Laboratory Tests: 'Normal' vs 'Post-Working' Conditions

Grip Strength

Although the subjects had completed three and a half hours of physical activity when they ran to the laboratory for final testing, there was no difference between Conditions 1 and 2 in the results of Grip Strength, indicating that the physical activities selected by the army personnel clearly had no debilitating effect on the strength of the upper limbs. Robertson **et al.** (1996) recognised that individual strength performance in a repetitive power grip protocol may be influenced by several factors such as fear, pain, a lack of test comprehension, motivation and boredom, thus acknowledging the psychological component of strength and power output. Excluding motivation these elements were not evident in this study; however, fear and pain are highly common factors associated with combat situations and although it was not possible in this project, strength testing under actual simulated battle conditions would subsequently reveal more informative results.

Table V: Results of 'normal' and 'post-working' Grip Strength and the Sargent Jump.

	Grip Strength (kg)		Sargent Jump (W)	
	Normal	Post-Work	Normal	Post-Work
$\bar{X}$	45.37	45.35	2730.69	2790.06
S.D.	5.70	6.45	328.09	303.42
CV(%)	12.56	14.22	12.01	10.87

Sargent Jump

Although most of the imposed physical activity placed great emphasis on the lower limbs of the subject, this did not negatively affect the subjects' power output of the legs as can be seen by the results in Table V. Power output was actually nominally greater during Condition 2 and this minimal improvement in performance was attributed to the physical activity producing a "warming up" effect on the muscular system as elevated arousal (which is influenced by increased levels of epinephrine) has such a significant effect on an individual's musculo-skeletal system that one is able to endure greater than 'normal' strain, resulting in physiological proficiency (Bergstrom, 1970; Hashimoto **et al.,** 1975; Asmussen, 1979; Roy and Steptoe, 1991). Psychological factors also played a role in performance output as three trials were permitted in this test, with each individual's jumping score being visible to the subject and peers, consequently increasing motivation to improve the registered height with each jump. Although this test was not perceived to be extremely physically taxing, the recruits found it to be challenging and as Scott and Charteris (1996) point out, perceptual factors play a critical role in dictating motivation and the willingness to perform, and thereby affecting task efficiency.

Table VI: Results of the Finger and Whole Body Reaction Time test during 'normal' and 'post-working' conditions.

	Finger Reaction Time (s)		**Whole Body Reaction Time (s)**	
	Normal	**Post-Work**	**Normal**	**Post-Work**
$\bar{X}$	0.1695	0.1696	0.500	0.489
S.D.	0.031	0.025	0.066	0.084
CV(%)	18.32	15.19	13.29	17.18

Finger and Whole Body Reaction Time

The ability to react quickly under combat situations is critical. Often the soldier is required to move from one point to another as fast as possible, and another prompt response is that of squeezing the trigger on the rifle. The results of both Whole Body and Finger Reaction Time displayed no significant differences under the two conditions, although overall group responses demonstrate that reactions were nominally faster when carried out after strenuous physical activity. The results of the task involving Finger Reaction Time revealed that similar Reaction Times were recorded during both Condition 1 and 2, with marginally greater variance noted during 'normal' conditions (refer to Table VI). The lack of a significant increase in Whole Body Reaction Time under Condition 2 was unexpected, as it was the experimenter's intent to physically fatigue the subjects, which would in turn presumably slow down the soldiers' reactions. This concept was based on findings by Harbin **et al.** (1989) who suggested that fatigue affects will significantly increase reaction time. It is questionable as to whether or not the subjects were physically fatigued. Subjective indications of physical strain, combined with increased heart rates indicate that the subjects were physically taxed, however performance output was not affected. It was concluded that cumulative fatigue was not induced by the physical activity in this investigation, and in an attempt to offer a possible explanation for these minimal yet apparent improvements in task scores, differences were attributed to increased adrenalin levels that had been activated by the physical activities, thereby physiologically arousing the subjects. The present Reaction Time results support the findings of Hayes (1976) who claimed that for brief bouts of strenuous exercise, evidence suggests that if any changes are observed, they tend toward shortening of reaction time. On the other hand, research conducted by

Crooks and Stein (1988) indicate that increases in work intensity will overstimulate, overload and reduce the efficiency of performance due to excessive fatigue, although these authors believe it is possible that arousal levels are increased during light exercise resulting in improved reaction time.

Cognitive Ability

The subjects were inclined to complete more mathematical problems after the 'physically active' condition in comparison to 'normal' conditions (273 and 264, respectively). It would appear that the subjects were more mentally alert under Condition 2, resulting in an increase in the total number of responses. However, nominally more errors were made after participation in physical activity, indicating that subjects focus may have been more on the speed of response rather than accuracy, although relatively, the percentage of correct responses was the same during 'normal' and 'post-working' conditions (being 94% correct answers).

Table VII: Results of the mental arithmetic test under both conditions.

	Total Responses		Correct Responses		Mean Response Time(s)	
	Normal	Post-Work	Normal	Post-Work	Normal	Post-Work
$\bar{X}$	264.5	273.4	248.0	255.7	3.89	2.30
S.D.	64.07	67.51	62.12	75.71	0.65	0.69
CV(%)	24.22	24.68	25.04	29.60	28.47	30.00

Speed of response was faster during Condition 2, with a decrease in Response Time and a greater number of sums being completed. However, the standard of performance remained relatively the same as there was a subsequent increase in the number of errors. This reduced response time follows the same pattern as the improved speed in shooting and the quicker Whole Body Reaction Times, supporting the proposition that increased physiological arousal increased the speed of reaction. However, as noted during the Target Shooting and the Cognitive Ability tests, the level of accuracy and mental agility was not improved by this increased alertness.

In the author's opinion, the waiting period experienced by some of the subjects during Condition 2 was too long and the subjects displayed signs of boredom and reduced concentration when finally performing. The inclusion of this test in the protocol was justified by the fact that an assessment of cognitive ability or mental functioning after participating in long, intensive physically demanding situations was necessary in determining how quickly and efficiently military personnel can react under fatigued conditions, an ability considered to be essential in combat (Akila, 1997).

PHYSIOLOGICAL RESPONSES

Heart Rate Responses to Fatiguing Exercises

Heart rate responses were assessed immediately after each physical activity, the Set Exercises, followed by the 3.4km run and finally the 15km march. Reference to Figure 16 reveals that during the Set Exercises (high intensity and short duration), the subjects were working at approximately 87% of age-predicted maximal heart rate for approximately 6 minutes. The duration of involvement in the activity was increased during the 3.4km run which lasted for 20 minutes, and as noted by the subjects' cardiac responses (which were approximately 94% of maximal heart rate), the subjects' were working at a high intensity.

The final physical task consisted of predominantly aerobic demands, and although the duration of physical activity increased significantly the intensity was reduced with subjects marching at an average speed of 6km.h^{-1}. There was a substantial decrease in the mean heart rate responses (from an average of 180 bt.min^{-1} to approximately 140 bt.min^{-1}), which were recorded as approximately 70% of maximal heart rate.

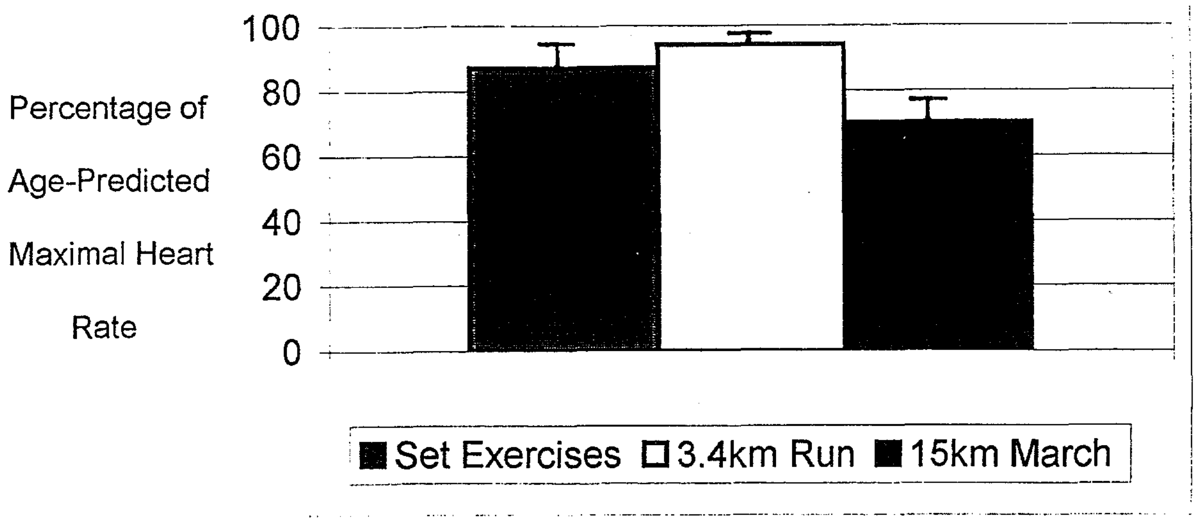


Figure 16: Percentage of age-predicted maximal heart rate during the physical activity exercises.

Heart Rate Responses During Testing Conditions

Base-line measures of 'Reference' heart rates were assessed during the first session of testing where the subjects were introduced to the testing protocol and demographic data were collected. This 'Reference' heart rate was used to compare heart rate responses collected under the two conditions. As would be expected, heart rate recorded for all of the tests after participation in the three and a half hours of physical activity were significantly higher than those recorded under the 'normal' condition. Changes in heart rate are known to be associated with physiological arousal levels and factors such as anticipation of testing (Gleeson and Lambert, 1998), subject wariness of the equipment used plus the physical movement in general led to elevated heart rates. It was thus concluded that these factors were responsible for the elevated ‘Pre-data collection’ measures.

‘Normal’ vs ‘Post-Working’ Heart Rate

The results of the ‘post-working’ heart rates revealed statistically significant differences for each test when compared to the ‘normal’ values. A summary of these results are presented in Table VIII.

Table VIII: Heart rate for the field and laboratory tests under Condition 1 and 2.

		Heart Rate (bt.min^{-1})	
		Normal	Post-Work
Reference	**X̄ (SD)**	73.06 (11.82)	
Magazine Load	**X̄ (SD)**	101.22 (19.93)	124.62 (23.16)
	CV (%)	19.69	18.58
Target Shoot 50m Lie	**X̄ (SD)**	99.64 (16.11)	119.81 (22.26)
	CV (%)	16.17	18.58
50m Stand	**X̄ (SD)**	104.09 (20.67)	132.27 (24.33)
	CV (%)	19.86	18.39
100m Lie	**X̄ (SD)**	98.6 (15.41)	119.44 (19.80)
	CV (%)	15.63	16.57
100m Stand	**X̄ (SD)**	106.19 (22.23)	133.00 (21.46)
	CV (%)	20.94	16.13
Grenade Throw	**X̄ (SD)**	97.85 (17.05)	119.29 (16.48)
	CV (%)	17.43	13.81
Hand-Grip	**X̄ (SD)**	93.31 (14.74)	121.93 (19.41)
	CV (%)	15.80	15.91
Sargent Jump	**X̄ (SD)**	114.22 (16.16)	135.71 (16.66)
	CV (%)	14.15	12.27
Reaction Time Finger	**X̄ (SD)**	79.96 (10.96)	103.89 (19.76)
	CV (%)	13.71	19.02
Reaction Time Whole Body	**X̄ (SD)**	91.74 (12.48)	114.34 (16.77)
	CV (%)	13.60	14.66
Cognitive Ability	**X̄ (SD)**	81.00 (10.81)	96.96 (17.80)
	CV (%)	13.34	18.35

Bar denotes statistically significant differences ($p<0.05$)

Pattern of Field and Laboratory Test Heart Rate Responses

Where:

1 = Magazine Loading
2 = Target Shooting 50m Lying Position
3 = Target Shooting 50m Standing Position
4 = Target Shooting 100m Lying Position
5 = Target Shooting 100m Standing Position
6 = Grenade Throwing
7 = Grip Strength
8 = Sargent Jump
9 = Finger Reaction Time
10 = Whole Body Reaction
11 = Cognitive Ability

Figure 17: Schematic pattern of mean heart rates for the field and laboratory assessments during Condition 1 and Condition 2.

Comparisons of heart rate during Condition 1 and 2 reveal similar trends (see Figure 17), with values rising and falling according to the nature of the task being performed. The highest mean heart rate responses under both conditions were recorded during the Sargent Jump which emphasized maximal Power output of the lower limbs as the subjects were required to jump as high as possible.

The trend differs, however, between the Grenade Throw (6) and the Grip-Strength (7) assessment. Under Condition 1, heart rate decreased after the Grenade Throwing as the subjects were driven to the laboratory where they then performed the Grip Strength test. During Condition 2, the subjects performed this test immediately after running 2.5km to the laboratory, hence the elevated heart rates.

An analysis of the Target Shooting responses during both conditions revealed that the subjects' cardiac responses were lower while Lying down (2 and 4) compared to the Standing values (98 $bt.min^{-1}$ vs 106 $bt.min^{-1}$ during 'normal' conditions and 119 $bt.min^{-1}$ vs 133 $bt.min^{-1}$ after participation in the physical activity, from 100m). It is known that heart rate responses are elevated when one is in a Standing position, and the 'relaxed' position of Lying prone was believed to be the reason for the significant decrease in Lying heart rate.

The increased heart rate responses during the assessment of Finger Reaction Time (9) was noticeably less than the Whole Body Reaction Time (10) values.

Subjects were required to sit, and only respond to the auditory stimulus by pressing a previously identified button, a task requiring a quick and easy response with no physical exertion. On the other hand Whole Body Reaction Time required a rapid movement by the subjects who had to jump off the mat as quicky as possible, resulting in instant physiological adaptations as is evident from the elevated heart rates.

The Cognitive Ability test was the final exercise to be completed. This assessment was time consuming as it lasted ten minutes per subject, and the soldier could physically relax. A comparison between 'normal' and 'post-working' values revealed a difference in heart rate responses of 16 $bt.min^{-1}$ for this test, with 'normal' mean ratings of 81$bt.min^{-1}$ and 97 $bt.min^{-1}$ for 'post-working' conditions. Figure 17 displays the reduced cardiac responses, with values dropping lower than the other laboratory and field tests, particularly during Condition 2. During the physically active testing session, the subjects had completed all of the field tests after the intensive physical exercises, and three of the four laboratory tests. For some subjects, a waiting period of approximately an hour was endured before commencing the computer-assisted test. Heart rate values were reduced during this recovery period as the subjects remained seated waiting for their turn, with the greatest decrease from 154 $bt.min^{-1}$ to 75 $bt.min^{-1}$.

Electromyographic Activity

Myoelectrical data were assessed during the Target Shooting test. With a two week period between the two testing conditions it was necessary to remove the electrodes after the final data collection. While every effort was made to place the electrodes on the same site for both conditions, in order for valid comparisons to be made between 'normal' and 'post-activity' conditions individual EMG data for each muscle were calculated as a percentage of the subject's Maximal Voluntary Contraction (% MVC) for each specific site.

The results demonstrate that there was no statistical significance in electromyographic activity when comparing the two testing conditions. The primary function of the right Palmaris Longus muscle was to squeeze the trigger for five rounds at each distance, the action required being firm brief regular flexions of the trigger finger, requiring contractions of little strength. During the 'normal' condition, there was normally greater electrical activity noted while firing from the Lying position, compared to Standing. 'Post-activity' %MVC was similar at both distances and throughout Condition 1 and 2, hovering at approximately 25% of MVC.

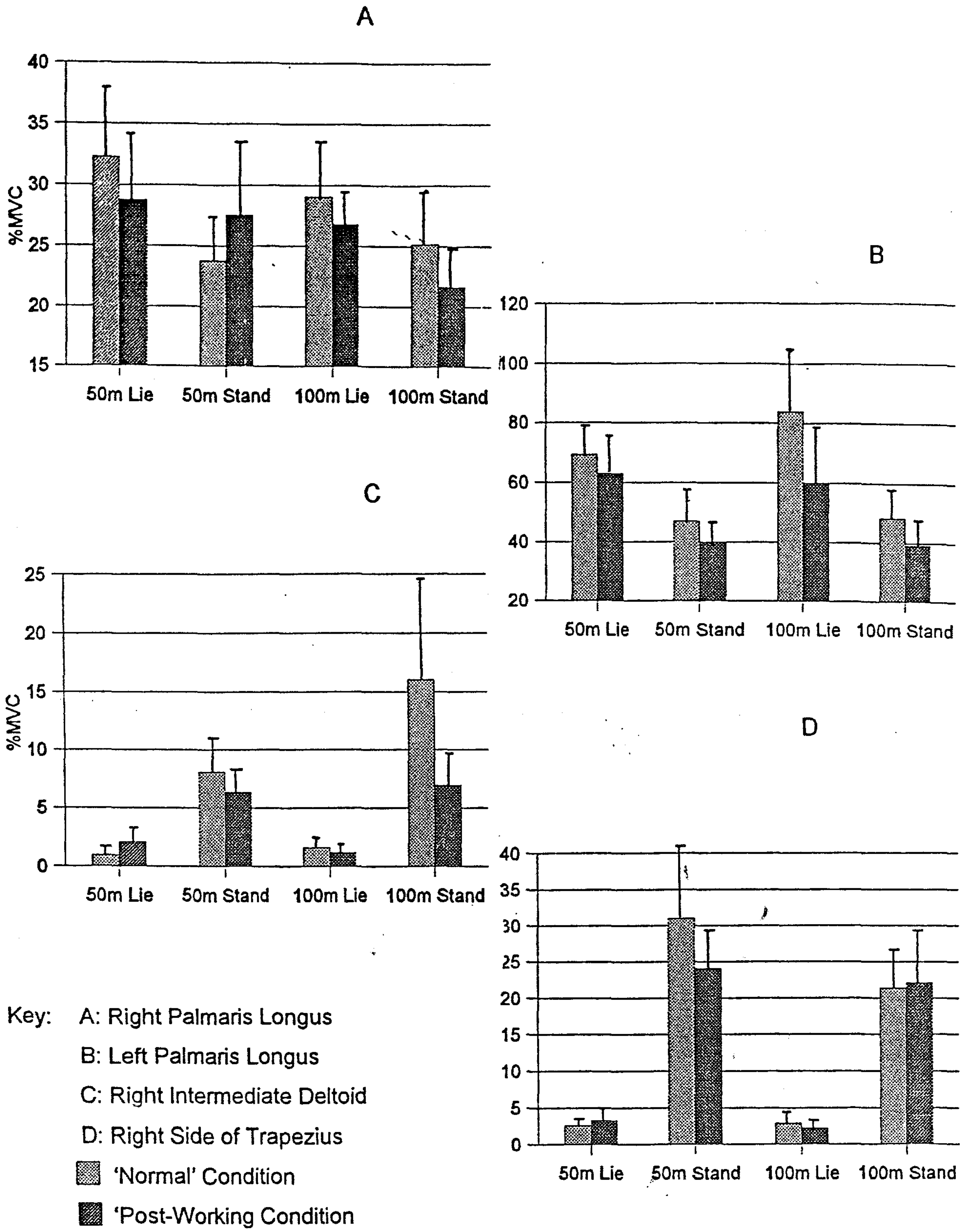


Figure 18: Percent of MVC of the four muscle groups comparing 'normal' and 'post-working' conditions in the selected positions.

During both conditions, the left forearm, which is responsible for supporting the shaft of the rifle, worked at a higher %MVC, compared to the other muscles. Stability of the rifle is essential for accurate aiming. The trends illustrate that more muscular contraction was apparent during Condition 1 for all four positions, with the highest recording being approximately 84% MVC while shooting from 100m in a Lying position (see Figure 18, B).

Minimal contraction of the right Intermediate Deltoid muscle was evident while shooting (less than 8% MVC), with the greatest electrical activity observed while shooting from a Standing position at 100m from the target (16% MVC). These generally low values were unexpected as it was speculated that this muscle plays an important role in maintaining the raised position of the right arm while assuming a shooting position, particularly while Standing.

Assuming the subject is right-hand dominant, the recoil after a bullet has been fired imposes a significant impact on the right shoulder and upper thoracic region, and these factors combined it was believed that an assessment of the performance of the right Deltoid would demonstrate greater levels of contraction. However, when shooting from a prone position, it was noted that the right elbow is rested on the ground while supporting the rifle and therefore minimal contraction of the right Intermediate Deltoid is required, hence the significantly lower %MVC for this muscle.

When observing the data for the other three muscles tested, it was noticed that the right Palmaris Longus endure minimal strain and was merely positioned to effectively pull the trigger, while the left Palmaris Longus was evidently bearing the most weight while supporting and stabilising the rifle. The trends of contraction of the right Trapezius muscle were interesting, with considerably greater %MVC values assessed during shooting in the Standing position (approximately 30% MVC) compared to shooting from the ground. This muscle clearly contracts more while Standing in the established firing position, with the right arm abducted at 90° and, as mentioned, the impact of the recoil being taken in the dominant shoulder and upper back. This increased contraction while stabilising the rifle was more significant while firing from the closer distance in the 'normal' condition, as illustrated in Figure 18(D).

PERCEPTUAL RESPONSES

The "human factor" is gaining greater recognition in the army and therefore the individual's perceptions of what he is required to do should prove useful in any assessment of the efficiency of a soldier's performance. The RPE and the Body Discomfort Scales were used to obtain a tangible measure of the rating of exertion and the area and amount of discomfort experienced by the subjects during the physical activity as well as both testing conditions.

Perceptual Responses for the Fatiguing Exercises

Set Exercises (approximately 6-7 minutes):

The Discomfort Scale was used to infer how an individual is physically affected by imposed strenuous physical demands. Data were recorded while the subjects performed the physical activity exercises included during the second condition of testing. These responses are described below, with a summary of the data presented in Tables IX, X and XI.

Condition 2 commenced with subjects performing shuffle kicks, press-ups and sit-ups where competition against other subjects was high as there were three subjects per group participating in each test simultaneously. With peers, army personnel and experimenters observing the activities it was evident that the subjects made every effort to complete the exercises as quickly as possible. Discomfort was experienced in the following areas: the quadriceps (53.12%), the shoulders (25% of subjects), the chest (25%) and abdominals (25%), with the upper chest/lower neck, biceps, lower abdominals/groin, the wrists and hands and the knees being identified very rarely. The three tests required the involvement of most of the major muscle groups of the body, namely the abdominals, the back, the quadriceps and the upper body, yet the most discomfort was noted in the quadriceps despite the fact that these muscles were only one of three major muscle groups being used. Average ratings of 6 were recorded for the majority of the areas mentioned after completing the Set Exercises, with an individual highest rating of 9 for the waist area. This was reported by one subject who was injured and pain was intensified by the anaerobic tasks.

Table IX: Body discomfort ratings recorded after performing the Set Exercises, displaying the predominant areas, the percentage of subjects and the mean rating out of a score of 10.

Area of Discomfort	**% of Subjects**	**$\bar{X}$ Rating**
Knees	3.12	7.00
Biceps, Hands, Wrists	6.25	6.50
Lower Abnals/Groin	12.5	7.00
Shoulders and Chest	25	6.00
Upper Abdominals	25	5.33
Quadriceps	53.12	6.50

The RPE scores for the Set Exercises were fairly low ratings considering the speed and effort put into the exercise, with a sample mean for the Central rating being 12.8 ('somewhat hard') while Local strain was higher at 14.12 ('hard').

However, from individual scores, the highest individual ratings recorded were 18 for Central RPE and 19 for Local RPE, and it is evident that some of the soldiers took considerable strain during the execution of these exercises.

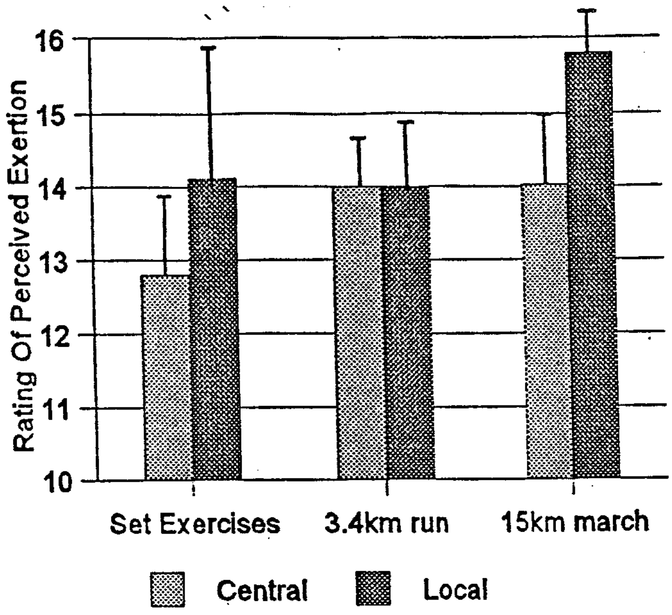


Figure 19: Central and Local Ratings of Perceived Exertion (RPE) for the physical activity.

A minimal value of 7 was recorded for Central RPE; such a low score suggests that the subject either did not fully understand how to use the scale, or was underestimating his level of exertion due to the presence of peers, superiors and experimenters. A summary of these data is presented in Figure 19. In reference to the literature, Bartlett (1953) stated that consideration must be given to the fact that subjects may not fully understand the instructions on how to use the perceptual rating scales, resulting in inaccurate responses; this fact together with the effect of peer pressure, where subjects either under- or overestimate the rating of exertion and/or discomfort, is likely to have a substantial effect on the reliability of responses. Nevertheless, subjective responses are critical in obtaining an overall response of the individual to the imposed physical demands.

3.4km Run (approximately 20 minutes)

This exercise took place over rough terrain with subjects wearing battle jackets and carrying rifles, while running at approximately 10 $km.h^{-1}$. On completion of this activity there were a greater number of areas of discomfort reported compared to the Set Exercises and a presentation of these results can be reviewed in Table X. The most discomfort experienced was predominantly in the lower limbs, specifically the quadriceps (31.25%) and the ankles (22%); plus the chest (18.75%), with high ratings of severity of discomfort being experienced in the quadriceps (a mean value of 7.4 out of a maximal rating of 10). When referring to the heart rate values, it appears that the intensity endured during this run was greater than that of the Set Exercises, and this may be misleading because the duration of the run was more demanding, hence the elevated heart rates.

The sample means for Central and Local RPEs were very similar (14.87 and 14.25 respectively) indicating that the same amount of exertion ('hard') was experienced in the cardiovascular system as well as the local muscles, in this case, the lower limbs. Maximal RPEs reported were 19 for both Central and Local, indicating that some subjects were working at their maximum, while the minimal values were 9 and 8 respectively. When comparisons are made between RPE for the previous physical task and this test, the results indicate that there was a greater perception of exertion being experienced Centrally (compared to the Set Exercises), and more areas of discomfort, despite the same mean Local rating.

Table X: Body discomfort scale ratings recorded after the 3.4km run.

Area of Discomfort	% of Subjects	$\bar{X}$ Rating
Biceps, Hand, Calves	3.12	5.00
Upper Chest/Neck	6.25	7.00
Left Elbow	6.25	7.50
Abdominals, Knees	12.50	6.25
Shoulders, Feet	16.60	5.66
Chest	18.75	7.00
Ankles	22.00	6.80
Quadriceps	31.25	7.40

15km March (approximately 2 hours 40min)

There was a wide range of areas of discomfort reported after the 15km march as this clearly took its toll on the body as a whole. The two main regions reported were the feet and the shoulders. It was evident that the most discomfort experienced was in the lower limbs, especially the feet with 71.87% of subjects reporting pain from blisters and a lack of shock absorption and support from their boots.

As a result of the weight of the backpack, the soldiers reported the shoulders as being another primary area of discomfort (43.75% of subjects), with a moderate intensity rating of 6. Of interest, only two subjects reported feeling discomfort in their upper backs and there were no reports of lower back pain despite the load carried. The quadriceps were the third highest reported area of discomfort (28% of subjects, with a fairly high rank of 7). Extreme degrees of discomfort were observed in the chest area by 13% of the subjects, with a mean rating of 9, identifying another area of the body that is affected by the heavy backpack. These data reveal that stress was imposed on both the upper and the lower body while marching with a load over a number of hours.

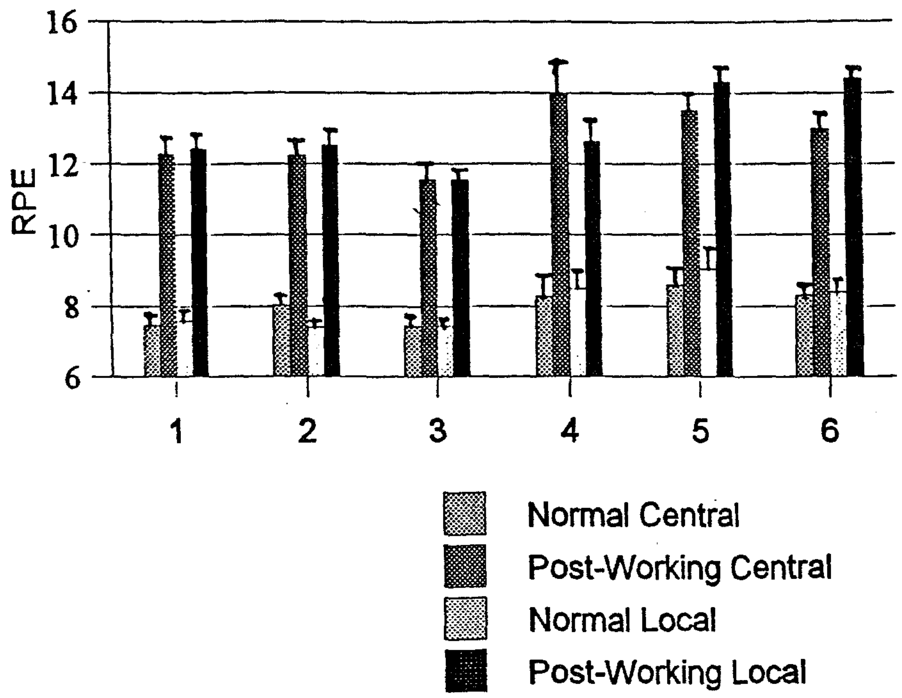
Table XI : Body discomfort recorded after completing the 15km march.

Area of Discomfort	% of Subjects	$\bar{X}$ Rating
Upper Chest/Neck	3.12	8.00
Abdominals, Waist	6.25	9.00
Biceps	6.25	6.00
Ankles	9.37	7.50
Chest	12.50	9.00
Lower Abdominals	12.50	5.00
Calves	19.00	9.00
Quadriceps	28.00	7.35
Shoulders	43.75	6.14
Feet	71.87	7.00

Central and Local RPE values were similar, with sample means of 14.03 and 15.81, respectively. The highest value reported for both Local and Central ratings was 19 compared to a minimal value of 8. Heart rate responses revealed that the subjects were marching at approximately 65% of maximal heart rate, and were therefore working at a moderate intensity. When RPE responses were analysed in conjunction with bodily discomfort, it was noted that Local RPE and discomfort were dominant compared to Central RPE, indicating that there was a greater awareness of the working muscles of the lower limbs rather than cardiovascular exertion. These results display an inverse trend to those recorded for the Set Exercises and the 3.4km run where the Central factor dominated. The reason for this is the nature of the task which was of a long duration, but moderate intensity; unlike the short duration and high intensity imposed by the Set Exercises and the 3.4km run.

Perceptual Responses: Testing Conditions

Perceptual responses under 'physically active' conditions, compared to 'normal' conditions, demonstrate statistical significance in all of the Ratings of Perceived Exertion. This follows a similar trend to that of the subjects' heart rate results.



Where:

1 = Magazine Loading
2= Target Shooting
3 = Grenade Throwing
4 = Grip Strength
5 = Sargent Jump
6 = Whole Body Reaction Time

Figure 20: Rating of Perceived Exertion (Central and Local) for the field and laboratory tests.

Magazine Loading:

Rating of Perceived Exertion

General comments and attitudes of the subjects suggest that this test was perceived to be physically effortless under both testing conditions, yet concentration and precision was required. As indicated by the subject's RPEs, it was evident that the test was not physically taxing as the sample means for Condition 1 display similar Central and Local scores of 7.46 and 7.59, respectively (see Figure 20). A minimum value of 6 was recorded for both Central and Local regions, and 15 and 14 were the maximal Central and Local ratings, respectively. Analysing the data recorded under Condition 2, Central and Local ratings mirror those recorded under 'normal' conditions with significantly higher ratings of 12.28 and 12.43, respectively, revealing the greater perception of exertion of the same task after strenuous exercise.

Body Discomfort

As a result of the 15km March that had just been completed under Condition 2, the subjects reported a great deal of discomfort in the knees and feet during the Magazine Loading. High levels of discomfort were reported in the thumbs, and this was extremely prevalent among 43% of the subjects during Condition 2, compared to 20% during 'normal' conditions, again revealing the physical affects of intense activity. Despite greater discomfort being reported by more subjects, performance was not affected, although the co-efficient of variance was higher when 'fatigued'.

Target Shooting:

Rating of Perceived Exertion

The Central rating of exertion for this task under 'normal' conditions recorded a sample mean of 8.03, indicating that the subjects perceived minimal cardiovascular exertion while shooting. This value was marginally higher than that recorded for Local RPE, where the sample mean was 7.40. Individual ratings reveal a maximum Central value of 13, and a rating of 10 Locally. Under Condition 2, Local ratings were nominally higher than Central (an opposite trend to that found under 'normal' conditions), and a possible explanation for this is the increased awareness of the post-working muscles rather than the immediate cardiovascular demands of this task. This heightened consciousness of the local muscles after exercising was observed in the RPE and bodily discomfort ratings for the majority of the tests conducted.

Body Discomfort

During Condition 1 and 2, a great deal more areas of bodily discomfort were identified during the Target Shooting exercise, compared to the other tests, with predominant areas of discomfort being experienced in the shoulders, elbows, biceps, forearms and chest. Ten percent of the subjects reported discomfort in the shoulders during Condition 1, this figure being increased to 28% after physical activity. This was largely due to the weight of the backpack on the shoulders, and when firing a rifle, the dominant shoulder supports the butt of the rifle which is then subjected to the recoiling impact after the bullet has been fired. Other areas of discomfort mentioned during either Condition 1 or 2 were the back, the abdominals, the wrists, knees and feet.

Grenade Throw:

Rating of Perceived Exertion

During Condition 1, both the Central and Local RPEs recorded were the same, with a mean rating of 7.43 (see Figure 20). The score 7 correlates with a 'very, very light' rating of exertion on Borg's (1970) RPE scale and this value is typically chosen when one is standing still with no physical exertion. These data indicate that the task was not perceived to be physically taxing as this test was a 'once off' action. RPE results for this task under Condition 2 showed the same sample mean for Central and Local ratings, with the rating of 11 being greater than the same activity under 'normal' conditions.

Body Discomfort

Common areas reported during Condition 1 and Condition 2 for the Grenade Throw reveal that bodily discomfort was experienced in the shoulders, the elbows and the biceps. Other areas of discomfort that were mentioned during either Condition were: the hands, thumbs, forearms, upper chest, the back, abdominals, quadriceps and the feet. It has been stated by the Knapik **et al.** (1990) that post-road march decrements in Grenade Throw may be attributed to a nerve entrapment syndrome, local fatigue, and/or pain in the muscle groups used for this task; and compression of the brachial plexus by the shoulder straps of the backpack can result in weakness, pain, and numbness in the upper extremities, limiting throwing ability. However, despite the discomfort in the upper chest and shoulders, as indicated by 44% of the subjects after the 15km road march, there was no significant difference in performance between 'normal' and 'physically active' conditions in this study, although accuracy in throwing was nominally greater during Condition 1. The results mentioned by Knapik **et al.** (1990) were inferred after soldiers had marched for excessively long durations of time with heavy backpacks. Despite the intensity of the physical activity performed in the present investigation, the duration was relatively short (three and a half hours) and there was no emotional stress such as has to be endured under battle situations.

Table XII: The most prevalent areas of discomfort reported for the various tests during both conditions.

	AREA	$\bar{X}$ RATING		% OF SUBJECTS	
		Normal	**Post-Work**	**Normal**	**Post-Work**
Magazine Loading	Thumbs	2	5	20	43
Target Shooting	Forearms	6	7	7	20
	Shoulders	4	6	10	28
Grenade Throw	Shoulders	2	5	7	10
Hand-Grip	Hand	4	5	3	40
	Wrist	5	6	3	15
	Feet	3	7	3	45
Sargent Jump	Feet	2	8	2	40
Whole Body RT	Feet	0	8	0	30

Grip Strength:

Rating of Perceived Exertion

Central and Local RPE values for the Grip Strength test demonstrate sample means of 8.09 and 8.5 respectively, indicating that this task required minimal physical exertion during Condition 1. Greater Central ratings were recorded, compared to Local (14.00 vs 12.64, respectively) after performing physical activity, a response that deviates from the other field and laboratory tests which displayed nominally higher Local ratings after the strenuous exercise. These results were unexpected as this task does not require endurance or cardiovascular exertion. However, the greater Central value has been attributed to the increased physiological demands of the run from the Military Base to the laboratory, which was conducted immediately prior to the Grip Strength assessment.

Body Discomfort

As mentioned in the RPE for this test, during Condition 2, the Grip Strength assessment was completed immediately after the subjects had run 2.5km from the Military Base to the laboratory, and as a result, the main area of discomfort mentioned by 45% of the subjects was the feet, compared to 3% reported under 'normal' conditions. Other primary areas mentioned during 'normal' and 'post-working' conditions were: the wrist, the dominant hand (the hand used for this test) and the quadriceps, with less significant reports of discomfort in the shoulders, the biceps, the elbows, the forearm, the back, abdominals and the knees.

Sargent Jump:

Rating of Perceived Exertion

Marginally greater mean ratings for Local areas were recorded (9.06) compared to Central ratings (8.59) during Condition 1, which on the Borg Scale are identified as 'very light.' However, maximum values of 15 were recorded indicating that some subjects found this task to be fairly taxing Centrally and Locally; on the other hand there was a minimal rating of 6 recorded for both Central and Local areas.

The Sargent Jump test displayed nominally higher Local RPE values compared to Central (14.31 vs 13.52, respectively) during Condition 2, supporting the possibility that the high Central RPE value recorded for the Grip Strength test was a physiological consequence of the 2.5km run from the Military Base to the laboratory. It is evident that the individual responses vary considerably as a result of subject characteristics, making it difficult to assess the exact affects each task is imposing on the sample.

Body Discomfort

Forty percent of the subjects reported discomfort in the feet during the Sargent Jump during Condition 2, in comparison to 5% during 'normal' conditions. Minimal discomfort was identified in the shoulders and knees under both conditions; with the biceps, the forearms, the back, abdominals and the quadriceps also being mentioned during either Condition 1 or 2.

INTEGRATED DISCUSSION

A main objective of this project was to establish whether intensive physical activity, similar to that encountered under combat conditions, has any affect on the physiological and perceptual responses of the individual and in turn how this would affect the soldiers performance in carrying out combat-related skills. In order to obtain accurate assessments of these factors, testing should be evaluated under actual combat situations over an extended period of time. Clearly this is not possible. While Army headquarters requested the project and the local Army unit approved of it, they did request limited interruption of the army time in order to conduct the project. Although Condition 1 only took approximately three and a half hours for one group to complete the battery of tests, Condition 2 lasted approximately six hours. As all 32 subjects had to report three times for data collection, the project took eight weeks to complete and was somewhat disruptive to army routine.

The pre-testing physical activity conducted during Condition 2 comprised of three types of activities with which the subjects were familiar as these are performed by the infantrymen on a daily basis under military training. The nature of these tasks was determined by the Captain of the Battalion, who was requested to compile a battery of training activities that would ensure that the subjects would experience physical fatigue. However, when analysing the 'post-activity' performance responses, it was evident that although the soldiers where physically taxed while actually carrying out the activities (with an individual heart rate as high as 207 bt.min^{-1} being recorded), these were all part of their normal training routine and it would appear that recovery was rapid and that debilitating fatigue was not induced.

The interdependence between physiological and perceptual responses is clearly evident as the study reveals significant physiological adaptations with concomitant perceptual ratings in response to the intensive physical demands; however performance output was not affected. The adaptability of the human to short-term external stressors is exceptional, demonstrating the "compensatory function" of increased arousal and activation in order to maintain the required standard of performance. However, it is speculated that when assessing performance responses over an extended duration of combat activity, the outcome would be different due to the cumulative effects of prolonged involvement in physically demanding and emotionally draining combat conditions.

An holistic analysis of the various physiological and psychological responses, plus performance efficiency under both 'normal' and 'physically active' conditions revealed that the pattern of performance responses displayed during Condition 2 did indicate that task efficiency was nominally reduced for the initial tests immediately after participation in physical activity. This then gradually improved as the duration of data collection continued (compared to 'normal' conditions), despite significant elevation in heart rate and increased reports of bodily discomfort. In other words, after participation in physical activity, the subjects displayed marginally improved efficiency with each progressive test. The physiological aspect of the present study confirms the findings of previous research in that there is clear evidence of increases in the activity of the autonomic systems as they adjust their functioning in an attempt to cope with the demands placed on the body. Wilson and Eklund (1988) postulate that high levels of arousal are equated with high levels of physiological responses, such as increased heart rate and muscle tension. While the differences in performance were insignificant, the analysis of heart rate values demonstrated that there was a marked increase in the autonomic responses of the subjects throughout the data collection time for 'post-activity' testing.

Although there were no significant changes in the battery of performance tests when comparing Conditions 1 and 2 due to the small sample size and the substantial variability in the responses of the subject, it was deemed justifiable to discuss possible trends within the data and closer scrutiny does reveal interesting patterns in the various individual tests. While there was no difference in Grip Strength, there was a nominal improvement in the Sargent Jump with the subjects demonstrating greater power when 'fatigued', despite ratings of increased discomfort in their lower limbs and feet. It is argued that the results from both the RPE and Bodily Discomfort Scales be accepted as a tangible means of concluding that Condition 1 and Condition 2, as perceived by the subjects, differed significantly in their demands, despite the maintained efficiency in performance responses.

Whole Body Reaction Time was nominally quicker during Condition 2, and the Cognitive Ability test confirmed the increased speed of responses after exercising, with subjects completing more mental arithmetic problems. However, while the responses increased so too did the number of errors, but the overall efficiency of responses was relatively the same as for Condition 1. Continuing with the increased speed of response, during the Magazine Loading no improvements in performance were evident during the second condition, but observation of the subjects revealed their need to work more urgently and with this increased speed of performance loading problems arose with bullets being stuck in the magazine having to be started again. There were no differences in the Grenade Throw, and although accuracy in Target Shooting remained the same, response time was significantly greater after participation in physical activity. A significant increase in RPE responses for both the field and laboratory tests conducted reveal the subjects perceived the tests to be harder during Condition 2, and it may therefore be concluded that immediately after completing the strenuous physical tasks, the subjects were initially 'exhausted' as is evident by their elevated heart rate responses and higher ratings of perceived exertion combined with more areas of discomfort.

The overall trend of results for the field and laboratory tests reveal that performance was found to decrease in the initial tests and then improve gradually throughout Condition 2.

These nominal improvements in performance were attributed to the physical activity producing a "warming up" effect on the muscular system of the body which resulted in increased physiological ability. Combined with this are the affective responses of the individual to the task as well as the psychological influences such as motivation which played a vital role in these assessments where the subjects displayed great determination in maintaining the standard of performance. The importance of motivational factors cannot be ignored as they unquestionably play a major role in the amount of effort an individual will put into the task at hand. Dzaidos **et al.** (1987) and Mello **et al.** (1988) claim that a well motivated soldier of average strength and endurance would outperform a poorly motivated counterpart with high strength and aerobic capacity. The activation theory of emotion, proposed by Grings and Dawson (1978), relates the bodily reactions that accompany emotion to the level of arousal and internal activation. Variations in the degree of arousal are considered to be responsible for significant variations in a person's behaviour and performance, as well as the individual's increased motivational levels. Factors such as training, experience and practice may possibly delay the debilitating effects of fatigue, it is therefore important to determine what the effects of long term fatigue are, and how to reduce or minimise them in order to improve proficiency of performance.

The most substantial differences in heart rate were recorded in the Grip Strength test. This increase in heart rate responses as well as bodily discomfort ratings (with 45% of the subjects reporting discomfort in their feet), may arguably be attributed to the testing protocol which required to the subjects to perform this test immediately after running 2.5km from the Military Base to the laboratory. Greater Central RPE (compared to Local)were reported during Condition 2 for the Grip Strength test, indicating the immediate increased cardiovascular demands imposed by the run, which was later followed by higher Local ratings as the subjects recovered cardiovascularly, and the after-effects of the exercise began to set in. It was evident that the individual responses varied considerably as a result of subject characteristics, making it difficult to assess the exact affects each task imposed.

There has been a rigorous attempt to obtain a discernible measure of the affective state of the individual, due to the diversity of complex factors which interact in various ways to affect the psychological responses of individuals in different situations. Human functioning comprises of an interdependent network of perceptual and physiological factors which change in response to the duration of stressful situations, and these must be considered when assessing performance efficiency.

SUMMARY

It was beyond the scope of this project to assess performance, physiological and perceptual responses to 'real' or simulated battle conditions, specifically the effects of extended durations of intensive physical demands on the soldier, as temporal restrictions on data collection made it impossible for the military personnel to be involved in an empirical study over a long duration of time, such as weeks or months rather than hours. The evaluation of human responses under true combat conditions would be ideal in demonstrating how the individual is affected, physically and mentally, by cumulative physiological and psychological stressors. Thus the project was delimited to assessing performance after the completion of three and a half hours of intensive physical tasks, and despite the fact that the tasks performed during testing were intense and temporarily induced exhaustion, the testing conditions were not emotionally stressful as they were conducted without the additional external and internal influencing factors of violence, noise, destruction, fear and anxiety, nor the less obvious factors such as sleep deprivation and inadequate nutrition, all of which are typical under battle conditions. Therefore, participation in the present project's physical activity induced physiological activation such as increasing arousal levels to a point on the inverted-U where performance was in some cases actually enhanced when compared to 'normal' responses.

CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

INTRODUCTION

It is clear that both physical and cognitive demands are imposed on the soldier in unpredictable combat situations. In order to cope effectively with these demands soldiers undergo rigorous military training which tends to focus primarily on enhancing the physical condition and discipline in order to prepare the individual for the best chance of survival. It is important to acknowledge the human factor when dealing with infantrymen and to accept that they are therefore susceptible to a variety of external and internal environmental factors that may enhance or debilitate performance efficiency, depending on the intensity and duration of exposure to these conditions. Extensive literature over the last two decades (McCraig and Gooderson, 1986; Nordeen, 1986; Dubik and Fullerton, 1987; Knapik **et al.,** 1996) has identified that due to increasing modern technological developments, soldiers are required to carry more equipment for greater protection and firepower, which results in heavier loads to be carried over extended durations, and this consequently reduces military efficiency due to decreased motivation, cumulative fatigue and other physiological and psychological factors. Taking a multi-disciplinary, integrated approach, the present investigation sought to examine the fatigue effects induced by intensive physical exertion on selected performance tests which are related to skills required in combat, plus physiological and psycho-physical responses of the soldier.

It was hypothesised that, as a result of the fatigue induced by the strenuous physical demands of marching under loaded conditions, there would be a deterioration in the efficiency of performance, together with increased physiological and perceptual responses assessed during testing conditions.

SUMMARY OF PROCEDURES

In order to compare any changes in the performance, a base line against which comparisons could be made was required. Two experimental conditions formed the basis of this study, with every effort made to keep testing conditions as similar as possible. The performance tests consisted of three field tests conducted *in situ* at the Military Base, followed by four laboratory assessments administered at the University. Condition 1 required the subjects to have participated in minimal physical exertion prior to testing, and this session was therefore termed 'normal'. Condition 2 consisted of a number of simulated occupational related tasks typical of combat conditions that were selected in an attempt to physically fatigue the subjects before repeating the tests conducted under 'normal' conditions.

Thirty-two male soldiers (mean age 28 years) participated in the study. The subjects were organised into four groups of nine subjects with three soldiers per group selected for electromyographical activity assessment which was evaluated during the Target Shooting field test. Basic demographic data including age, military experience, stature, body mass (minimal and full uniform) were collected on the troops.

During Condition 1, a battery of three field tests was conducted where each group was required to load a magazine with thirty rounds of ammunition as quickly as possible. Speed and accuracy in aiming was evaluated in the Target Shooting test, requiring subjects to fire five rounds of ammunition while in a Lying and Standing position, at 50m and 100m from the target. This test was followed by a Grenade Throw, determining the level of accuracy in throwing a de-activated grenade into a target 20m distant. The four laboratory assessments of upper body Strength, Power of the lower limbs, Finger and Whole Body Reaction Time and finally Cognitive Ability were then examined. These data were compared with that collected while performing the same field and laboratory tests immediately after participation in strenuous physical activity of approximately three and a half hours duration. The physical tasks of Condition 2 consisted of Set Exercises (shuffle kicks, push-ups and sit-ups) lasting 6 minutes, a 3.4km run while wearing a battle jacket and carrying a rifle taking, on average, 20 minutes, and lastly a 15km march while carrying a rifle and a 26kg load, taking approximately two and a half hours to complete.

During the performance tests and the pre-testing physical activity, heart rates, RPE and Body Discomfort ratings (site and intensity) were recorded for all subjects immediately after each test. EMG activity of the right and left Palmaris Longus, the right Intermediate Deltoid and the right side of the Trapezius muscle was assessed during Condition 1 and 2 at both distances and positions of the Target Shooting. MVC profiles were full wave rectified and an average value was calculated. These values for each muscle site were used to normalise subsequent experimental data, and are expressed as a percentage of MVC (%MVC).

SUMMARY OF RESULTS

Performance responses indicate that the subjects were not severely fatigued by the imposed physical activity, as there was only one significant difference in the execution of the seven field and laboratory tests conducted under Condition 1 and 2. Testing *in situ* revealed an initial nominal reduction in combat efficiency immediately after exercising, as the subjects were inclined to take longer in loading a magazine and displayed nominally less accuracy in throwing. An interesting finding was the significantly increased speed responses of shooting during Condition 2, no doubt due to an increase in physiological activities. However, these quicker responses did not affect (positively or negatively) accuracy in aiming, although a faster firing speed is advantageous to the combatant. Tests conducted in the laboratory revealed no changes in performance of upper body Strength, but detectable improvements in the execution of the remaining tests of Condition 2 were evident with a nominal increase in Power output of the lower limbs, a reduction in Whole Body Reaction Time after exercising, and quicker responses to the mathematical problems of the Cognitive Ability test. Reasons for these modest improvements in task efficiency are attributed to the heightened physiological state as well as the psychological components of the individual, for performance is influenced by factors such as motivation, fear and pain, with one's perception of the required task being interdependent on the physiological adaptations to maintain homeostasis. It was evident that the three and a half hours of strenuous exercise activated the functioning of the cardiovascular and muscular systems, rather than imposing excessive physical fatigue.

Stimulation of physiological functioning was evident by the increased heart rate response pattern observed during and after participation in physical activity. The mean heart rates recorded for the fatiguing exercises revealed that the subjects were working between 70% to 94% of age-predicted maximal values. Although these heart rate responses did drop after the completion of the physical activities, they remained elevated throughout Condition 2, rising and falling according to the nature of the task. Heart rates recorded under 'normal' conditions reflected a similar trend but at a lower level. The physiological adaptations to physical exertion were similarly observed during the transition between field and laboratory testing where the subjects were required to run 2.5km from the Military Base to the University, resulting in a deviation from the pattern in heart rate when comparing testing conditions, and this was particularly evident in the Grip Strength assessment heart rate values which was the first test conducted in the laboratory. During the final test, namely Cognitive Ability, it was difficult to control the delay of time between the sub-groups, and therefore physical recovery varied greatly for each subject. This was particularly evident in the heart rate responses that dropped to levels considerably less than pre-testing responses, demonstrating the short-term adaptations of the physiological system in response to an intensive bout of physical activity.

There was no significant difference ($p<0.05$) when comparing EMG responses during the Target Shooting test under both conditions. However, nominal trends were observed with the left Palmaris Longus recording the greatest %MVC (70% to 80% MVC) while shooting from a Lying position during 'normal' conditions, and this value was reduced during 'post-working' testing. Shooting while Standing revealed the same pattern, although the effort required was between 40% to 50% MVC. Minimal effort was exerted by the Deltoid muscle throughout testing, with nominal increases in this muscular activity while Standing. The right side of the Trapezius muscle was highly activated while shooting from a Standing position (compared to Lying down), regardless of the insignificance between testing conditions. Minimal difference in EMG activity was observed in the right Palmaris Longus that is activated when squeezing the trigger repetitively. Data reveal that this muscle worked at approximately 22% to 33% MVC while shooting during Condition 1 and 2. The results reveal that more muscular activity is required in holding and stabilizing the rifle than in actually firing.

With reference to the perceptual responses to the physical activity, it was evident that as the duration of exercise continued, Local and Central ratings increased accordingly. Greater musculo-skeletal (Local) exertion, perceived as 'hard', was experienced while performing the Set Exercises, with the Central perception increasing to equal the Local rating during the 3.4km run, which was again perceived as 'hard'. This activity evoked the highest mean heart rate responses during the strenuous activity as the intensity was fairly high over a 20 minute duration. For the final fatiguing task, Local RPE predominated again after completing the 15km march, with the highest sample mean corresponding to 'very hard' on the Borg Scale. Analysis of individual ratings revealed a great deal of variability within the group, with some subjects rating exceptionally lower values than the visible amount of effort exerted (as noted by the significantly elevated heart rate responses). In contrast, injured subjects reported high ratings, and these were dependent on the area and severity of injury. A wide variation in perception of exertion was also apparent throughout the testing conditions, demonstrating the unique individuality of each subject's effort and perception of the same task.

General comments and attitudes of the soldiers, combined with RPE responses during Condition 1 and 2 revealed that the tests were perceived to be physically undemanding, although mean Local and Central perceptions of exertion were significantly greater during 'post-working' testing. Condition 1 revealed similar ratings throughout testing with average responses of 'very light' for both the cardiovascular and muscular systems. The greatest rating of exertion recorded during 'normal' conditions was for the Sargent Jump. Reference to the 'post-activity' RPEs revealed predominantly greater Local ratings, with values rising in response to the Sargent Jump.

The fatiguing exercises conducted during Condition 2 incorporated all of the major muscle groups of the body, imposing alternate high intensity, short duration and moderate intensity, long duration stress upon the soldiers. Overall trends revealed high intensities of discomfort experienced in the feet by 70% of subjects, with a mean scale rating of 7 out of 10, 44% of the subjects reported a mean intensity of 6 in the shoulders, and 28% indicated a moderately high intensity of discomfort (a rating of 7) in the quadriceps. There was an increase in the areas and intensity of discomfort experienced by the subjects during the 'physically active' testing condition, with an escalation in the number of subjects reporting discomfort in particular areas after participation in exercise. As the duration of the testing procedure under Condition 2 continued, reports of discomfort in the primary areas mentioned immediately after the physical activity abated, focussing mainly on the particular areas being required by the different tests, such as the thumbs in the Magazine Loading which increased from an intensity of 2 to 5 on the discomfort scale, when comparing Condition 1 and 2 respectively, by 20% of the subjects during Condition 1 to 43% of the subjects in Condition 2. This trend was apparent throughout the field and laboratory tests. An immediate conclusion that may be drawn from the RPE and Bodily Discomfort responses is that the battery of tests as an entity was perceived as more demanding when assessed under physically active conditions, a factor not as evident in the analysis of performance responses.

Despite the significant physiological and perceptual responses to three and a half hours of intensive exercise, this increased arousal and activation resulted in only nominal though discernible changes in performance output. It must be noted that testing was conducted under calm, 'normal' conditions with no emotional stress, unlike that encountered during threatening battle situations that continue for months or even years. It is proposed that under true combat conditions performance efficiency is likely to be substantially affected.

HYPOTHESES

Hypothesis 1:The hypothesis that physical exhaustion as a result of demanding exertional conditions would have no affect on the efficiency of performance is tentatively retained. There was no statistical difference in the performance of post-march combat efficiency, although the subjects demonstrated elevated physiological functioning. It was concluded that debilitating fatigue was not induced by the physical activity as intensity and duration of exercise was limited, thus preventing possible cumulative fatigue effects.

Hypothesis 2: Increased physiological arousal in response to the imposed physical activities was observed by elevated cardiac responses. Significant increases in heart rate forced a rejection of the second hypothesis, specifically for heart rate responses. However, evaluation of EMG activity reveals that exposure to strenuous physical activity had no effect on the electrical activity of four primary muscle sites used in Target Shooting, and therefore the second hypothesis, with specific reference to electromyographic activity, is tentatively retained.

Hypothesis 3: Both Local and Central RPE responses revealed statistically significant differences when comparing the ratings between testing conditions, thus the null hypothesis is rejected.

CONCLUSIONS

A comprehensive understanding of the effects of internally and externally stressful demands on human performance has been under analysis for almost one hundred years, originating with researchers such as Yerkes and Dodson (1908). Probably the only consistent findings have been in the substantial variability between individual responses.

The realities of war involve extreme hardship with enormous increases in physical exertion and emotional stress. Fatigue is an inevitable accompaniment of these prolonged demands, but the nature of the fatigue process is influenced by many factors (Maughan and Noakes, 1991). Guided by the concept of Borg's "Effort Performance Triad" (1978, b), the analysis of physiological and perceptual variables was the basis of this study, allowing for a multi-disciplinary, integrated understanding of the diversity in the standard of performance in response to physically demanding conditions. From the results it is reasonable to conclude that although the subjects were clearly performing under physical stress, as noted by the significantly elevated heart rate and RPE responses during Condition 2, the physical demands were not perceived as being excessive as the duration of activity was short in comparison to combat situations, and testing was conducted under controlled and relaxed conditions, eliminating influencing factors such as fear, anxiety, violence, excessive noise and chaos. Hence, there were no deleterious effects on performance.

Contrary to expectation, several nominal improvements in the speed of response were observed, suggesting that in order to execute optimal performance there is indeed a need for the individual to experience some degree of strain as increased physiological arousal in response to a challenging situation is proposed by several researchers (Bergstrom, 1970; Roy and Steptoe, 1991) to enhance performance. However, environmental conditions in combat often provide more than simply a challenging situation, with survival being a fundamental priority. Extreme physical, mental and emotional demands are imposed on infantrymen over an extended duration of time, and as there are limitations to the amount of strain an individual can tolerate, the cumulative effects of physical and psychological fatigue will be evident in a deterioration of fighting performance (Asmussen, 1979; McCraig and Gooderson, 1986; Haisman, 1988; Johnson and Knapik, 1995; Knapik **et al.,** 1996).

Another reason for the trend of the results of this study may be the external environmental influences. Goslin and Rorke (1978) and McCraig and Gooderson

(1986) mentioned that as the loaded soldier commences marching, energy expenditure rises due to a number of factors, namely: the load carried, the terrain, the temperature and/or humidity and the speed and gradient of marching. The subjects in the present project were carrying an absolute load approximately one third of the mean body weight over a rough, though fairly level terrain, in an average ambient temperature of 23°C, for approximately two and a half hours. Therefore, it can be concluded that, despite the load carried, the external environmental influences plus the intensity and duration of the march were not extremely harsh, and certainly did not compare to actual battle situations.

RECOMMENDATIONS

A critical factor of the present project was to determine to what extent cognitive and physical functioning is affected by strenuous physical activity and, based on these results, employ relevant methods to reduce where possible the negative effects, thereby enabling the soldier to fight more efficiently.

A factor which merits consideration for future research is the duration of the imposed demands on the soldier as the restriction on temporal factors in this project prevented any possible cumulative fatigue effects of prolonged physical demands. It is recommended that future research be conducted over an extended period of time, and including a simulation of such influencing factors as diet, training and sleep deprivation.

Akila (1997) pointed out that a critical area that has not received as much attention as the physical ability of the foot soldier is the cognitive demands of work in the military and defence professions. This is a difficult aspect to 'train' for as mental requirements during battle are so unpredictable varying from situation to situation, and are not as apparent as the physical demands, yet they play a significant role in carrying out efficient combat activities. Cognitive Ability as assessed in this project was found to be unaffected by an intensive bout of physical activity, and because of the exceedingly broad spectrum of possible psychological assessment, it is recommended that numerous, multi-faceted tests of cognitive performance be considered.

In order to obtain more accurate comparisons of combat efficiency under 'normal' conditions to that of actual battle situations, it is proposed that future evaluations of military performance be undertaken during 'manoeuver' drills. As these gruelling, threatening combat tasks expose the soldier to similar situations as those encountered while fighting, they would provide a more accurate assessment of the physiological and perceptual responses to battle situations, thereby ensuring greater validity of how fighting performance is truly affected by physically and emotionally stressful situations. Even so it must be kept in mind that simulations may underestimate the real stress of emergency situations.

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APPENDIX A

General Information

Initial Letter to Subjects

Informed Consent Information Sheet

Equipment Checklist

Outline of Testing Protocol

LETTER TO SUBJECT

Dear ________________________________

Thank you for offering to participate as a subject in my Masters research project entitled:

ELECTROMYOGRAPHICAL, PSYCHOPHYSICAL AND OTHER PERFORMANCE DECREMENTS IN COMBAT RELATED TASKS FOLLOWING PROLONGED HEAVY-LOAD MARCHING

A great deal of military-relevant ergonomics has focussed on load carriage and its effect on the marching soldier (Levine **et al.,** 1982; Goslin and Rorke, 1986; Haisman, 1988; Johnson **et al.,** 1995; and Knapik **et al.,** 1996), while the effect of intense physical activity, like that required in training and pre-combat situations has received little attention. It is evident that a combination of the load carried and the distance covered by the marching soldier will increasingly exacerbate fatigue, which will inevitably result in a deterioration on the proficiency of performing the required military tasks such as loading of guns, marksmanship and grenade throwing (Haisman, 1988; Johnson **et al.,** 1995). I will be investigating the effects of intense physical activity over a prolonged period of time on such factors such as cognitive ability, reaction time, strength, accuracy and aiming which are all crucial to the military effectiveness of the soldiers. This will be done in an holistic manner through the assessment of physical, physiological and concomitant perceptual parameters.

Cost effectiveness is naturally a military concern, and therefore improved military efficiency, in terms of the safety and general well-being of personnel in relation to combat readiness, is necessary in reducing costs. These costs are twofold and no modern military operation can afford to disregard them: the relatively less important cost of equipment lost as a result of inefficient military operations and the relatively critical cost of failed engagements with consequent unnecessary loss of lives.

Foremost, you will be medically examined (administered by Army Medical Personnel) to ensure you are suitable subjects for the present study. You will then be requested to sign an informed consent, acknowledging your willingness to participate in the study. Prior to the actual data collection the basic testing protocol will be explained thoroughly to you.

Basic demographic and morphological measurements including age, stature and body mass will be collected. Ten subjects will be randomly selected for EMG data collection. If you are selected, you will be required to wear 3 electrodes on your forearms, shoulder and upper back/neck during testing. All subjects will wear a Polar Heart Watch, and the battery of performance tests will include hand-grip dynamometers, the Sargent Jump, reaction time tests and a mental arithmetic test, for which you will be given time to become familiar with.

Subjects will then be randomly divided into 4 groups of 9 subjects, which will further be sub-divided into 3 groups of 3 subjects. This is merely for ease of data collection purposes. All 4 groups will be required to participate in field testing at the Military Base, consisting of magazine loading, target shooting and grenade throwing. Laboratory testing will then be done in the Human Kinetics and Ergonomics Department, where assessment of reaction time, mental arithmetic, strength and power will be done. You will then be required to have another testing session where a fatigue test will be administered at the Army Base, consisting of shuffle kicks, push ups, sit ups, a 3.4 km run in battle jacket carrying an R4, and a 15 km walk with battle jacket. This will be immediately followed by magazine loading, target shooting and grenade throwing (as tested in the previous session). You will then run to the Human Kinetics and Ergonomics Department for laboratory testing of reaction time, mental arithmetic, strength and power. Perceptual data will be collected at regular intervals throughout the data collection, using psycho-physical rating scales such as the RPE and the Body Discomfort Scale. The physiological responses will be inferred by heart rate monitoring (Polar Heart Watch) and muscle tension will be measured using the EMG on 10 subjects.

Following the completion of the data collection periods, I will gladly discuss your test results with you, should you be interested, as no feedback will be available during the test period. This serves to eliminate competition between subjects and to standardise data collection.

Once again, many thanks for your interest. Please do not hesitate to contact me should you have any further questions.

Yours sincerely,

LISA A CLARK
(Human Kinetics and Ergonomics Masters student)

SUBJECT CONSENT FORM

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

PERFORMANCE DECREMENTS IN COMBAT RELATED TASKS FOLLOWING PROLONGED INTENSE PHYSICAL ACTIVITY

do hereby give my consent to act as a subject in the above named 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 of Rhodes University, from any and all claims resulting from personal injuries sustained. This waiver shall be binding upon my heirs and personal representatives. I realise 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 all 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.

SUBJECT (OR LEGAL REPRESENTATIVE):

______________	______________	______________
(Print name)	(Signed)	(Date)

PERSON ADMINISTERING INFORMED CONSENT:

______________	______________	______________
(Print name)	(Signed)	(Date)

WITNESS:

______________	______________	______________
(Print name)	(Signed)	(Date)

EQUIPMENT CHECKLIST

ADMINISTRATION

Letter to subjects

Consent forms

General Information Data Sheets

Subject Data Sheets

Instructions to subjects for RPE

Instructions to subjects for Body Discomfort Scale

STATIONARY

Exam pads

Calculator

Clipboards

Pens/pencils/eraser/sharpener

DATA COLLECTION EQUIPMENT

Toledo Scale

Harpinder Stadiometer

EMG monitor

- 4 wire channels
- 40 electrodes
- tape
- cotton wool
- surgical spirits/alcohol
- razor
- scissors

Heart Rate Monitors - 10 x Polar heart watches

4 x RPE Scales

4 x Body Discomfort Scales

MEDICAL EQUIPMENT

Milton Disinfectant - buckets and cloths

Elastoplast

Tissues

Cotton wool

MISCELLANEOUS

4 x stop watches

Drinks for assistants

Waste bags

GENERAL TESTING PROTOCOL

- 8 sessions in total (4 x 'normal', 4 x 'post-working')
- 36 subjects, with 9 subjects per group (A - D), divided into 3 x 3 subjects

Session 1 = 'Normal'

Session 2 = 'Post-Working'

TUESDAY		THURSDAY	
Group A	Normal	Group B	Post-Working
Group C	Post-Working	Group D	Normal
Group A	Post-Working	Group B	Normal
Group C	Normal	Group D	Post-Working

Data collection procedure during Session 1 and 2 as follows:

SESSION 1: 'Normal' Conditions

10.00am Army Base. 9 subjects put on heart watches

EMG electrodes on 3 subjects: 2 on forearm, 1 Deltoid, 1 Trapezius

RPE and Body Discomfort Scale Revision

Collect Mean HR, RPE and Body Discomfort after each test.

10.30am Magazine Loading

Connect EMG electrodes to 1 subject (x3)

Target Shooting: 5 rounds at 50m Lie, 50m Stand, 100m Lie, 100m Stand

Disconnect EMG electrodes from subject

Grenade Throw

GO TO LABORATORY:

Grip Strength test

Sargent Jump

TKK Reaction Time - Finger

Whole body

Cognitive Ability Test

SESSION 2: Fatiguing Test and Post-Working Condition

- 9 subjects divided into 3 groups of 3, with 20 minute intervals between each sub-group

07.30am Army Base. 9 subjects put on heart watches.

EMG electrodes put on 3 subjects: 2 x forearm, 1 Deltoid, 1 Trapezius

Revision of RPE and Body Discomfort Scale.

08.00am Begin Fatigue tests: 3 subjects with 12 min intervals between each group.

Shuffle Kicks

Push Ups HR, RPE, Body Discomfort

Sit ups

Subjects put on battle equipment and R4

3.4km run RPE, HR, Body Discomfort

15km march RPE, HR, Body Discomfort

First sub-group begins testing of Magazine Loading, Target Shooting and Grenade Throwing.

Magazine Loading

Connect EMG electrodes to 1 subject (x3)

Target Shooting: 5 rounds at 50m Lie, 50m Stand, 100m Lie, 100m Stand

Disconnect EMG electrodes

Grenade Throw

Run to Laboratory - 2.5km

Grip Strength

Sargent Jump

TKK Reaction Time - Finger

Whole body

Cognitive Ability Test

Stop heart watches, remove electrodes, drinks/water for subjects

Disinfect heart rate watch straps, clean razors (EMG)

APPENDIX B

Data Collection

General Information Data Sheet

Subject Information

Data Sheet for Performance Measures Condition 1

Data Sheet for Performance Measures Condition 2

Instructions for the RPE Scale

Instructions for the Body Discomfort Scale

GENERAL INFORMATION DATA SHEET

Date								
Group								
Norm/ Post								
Temp (°C)								
% Hum								

COMMENTS: ____

____

____

____

____

SUBJECT INFORMATION

GENERAL INFORMATION

Name: ____

Age: ____________

Code: ___________

Group: (Tick appropriate letter) A B C D

Subgroup: 1 2 3

Military Experience: _________years

Stature: _______ mm

Body Mass: Minimal clothing _______ kg

Full clothing ___________kg

RPI: ___________

Resting Heart Rate: ________ $bt.min^{-1}$

COMMENT:____

____

____

____

____

NORMAL CONDITIONS TESTING DATA

Code: ____________ Date: _______________

Group: ____________ Resting HR: ________

MILITARY BASE

		Heart Rate (bt.min^{-1})	RPE C	L	Discomfort A	R
GRENADE THROW (m)						
TARGET SHOOTING 50m Lying Standing 100m Lying Standing	 ________ ________ ________ ________					
GUN LOADING (s)						
		$\bar{X}$:______ High:_____				

LABORATORY

	Trials 1	2	3	Heart Rate (Bt.min^{-1})	RPE L	C	Discomfort A	R
HAND-GRIP (kg)								
SARGENT JUMP								
COGNITIVE ABILITY								
RT (s) Finger: Whole Body:								
				$\bar{X}$: ______ High:______				

ACTIVITY TESTING DATA (Condition 2)

PHYSIOLOGICAL AND PERCEPTUAL DATA

Code: ______________ Date: ______________

Group: ______________ Resting HR: ______________

BODY DISCOMFORT SCALE

RESTING	AREA						
	RATING						
POST-ACTIVITY	AREA						
	RATING						

COMMENTS: ____

____

____

____

RATING OF PERCEIVED EXERTION, HEART RATE AND DISCOMFORT:

ACTIVITY	RPE C	L	HR (bt.min^{-1})	AREA	RATING
Shuffle Kicks					
Push-Ups					
Sit-ups					
3.4km Run					
15km Walk					

FATIGUED CONDITION DATA

Code:____________________ Date:____________________

Group:____________________ Resting HR:______________

MILITARY BASE

	Score	HR ($bt.min^{-1}$)	Body Discomfort Area	Rate	Area	Rate
GRENADE THROW (m)						
TARGET SHOOTING 50m Lying Standing 100m Lying Standing	 ________ ________ ________ ________					
GUN LOADING (s)						
		$\bar{X}$:______ High:_____				

LABORATORY

	Trials 1	2	3	HR ($Bt.min^{-1}$)	RPE L	C	Discomfort A	R
HAND-GRIP (kg)								
SARGENT JUMP								
COGNITIVE ABILITY								
RT (s) Finger: Whole Body:								
				$\bar{X}$: ______ High:______				

INSTRUCTIONS FOR THE RATING OF PERCEIVED EXERTION SCALE

As humans are different, individual people, it is of interest to determine how they respond to various forms of physical activity, as two individuals doing exactly the same exercise will usually have different perceptions of how hard the exercise was on their body. Subjective perceptions of various physical tasks provided by soldiers enables military commanders to focus on specific areas of training that may be lacking and identifying unnecessary negative factors that may have detrimental effects on the soldier, which superiors are not aware of.

In this project, each subject will participate in a number of different exercises of physical activity, and while you are exercising, we will be assessing various physiological functions. At the same time, we want you to try and estimate how hard you feel your body is working; and rate the degree of perceived exertion you are experiencing while exercising.

You will be asked to point to (or call out) a number on the Scale presented, which corresponds to your rating of perceived exertion, how hard you feel you are working. You will be asked to give two specific ratings:

First rating: will be a local muscular rating pertaining to feelings or sensations of strain in the exercising **muscles and joints** (i.e. arms and/or legs).

Second rating: involves sensations or feelings within the cardio-respiratory systems (i.e. **heart rate and breathing**).

Try to assess your ratings as honestly and objectively as possible. Do not underestimate the degree of exertion you feel, but do not overestimate it either. Try to estimate it as accurately as possible. A rating of 6 corresponds with feelings of exertion while standing quietly, and a rating of 20 reflects maximal exertion for you.

INSTRUCTIONS FOR THE BODY DISCOMFORT SCALE

The Body Discomfort Scale was designed in order to obtain an idea of how different physical activities, as well as the duration of exercise, affects specific areas of the body. This is purely subjective because only the person who is actually participating in the exercise is able to say where and how much discomfort is felt.

The Body Map allows the subject to say exactly where the discomfort is felt, and with the use of the Discomfort Scale, ranging from 1 (no discomfort) to 10 (very uncomfortable), one is able to give an accurate rating of the location and extent.

The subject is required to point to the specific area on the Body Map where the most discomfort is felt and then to rate, on the scale, how uncomfortable this area feels. Discomfort may vary throughout the different exercises as different body parts are used, and therefore, ratings will be taken at regular intervals.

It is important that assessments are as accurate as possible. The assistant should be informed of where the most discomfort is experienced first followed by less comfortable areas.

APPENDIX C

Results

Vienna Test System (VTS) Printout

Heart Rate Monitor Printout

EMG Printout

Vienna Test System (VTS) Printout

ALS - S 1

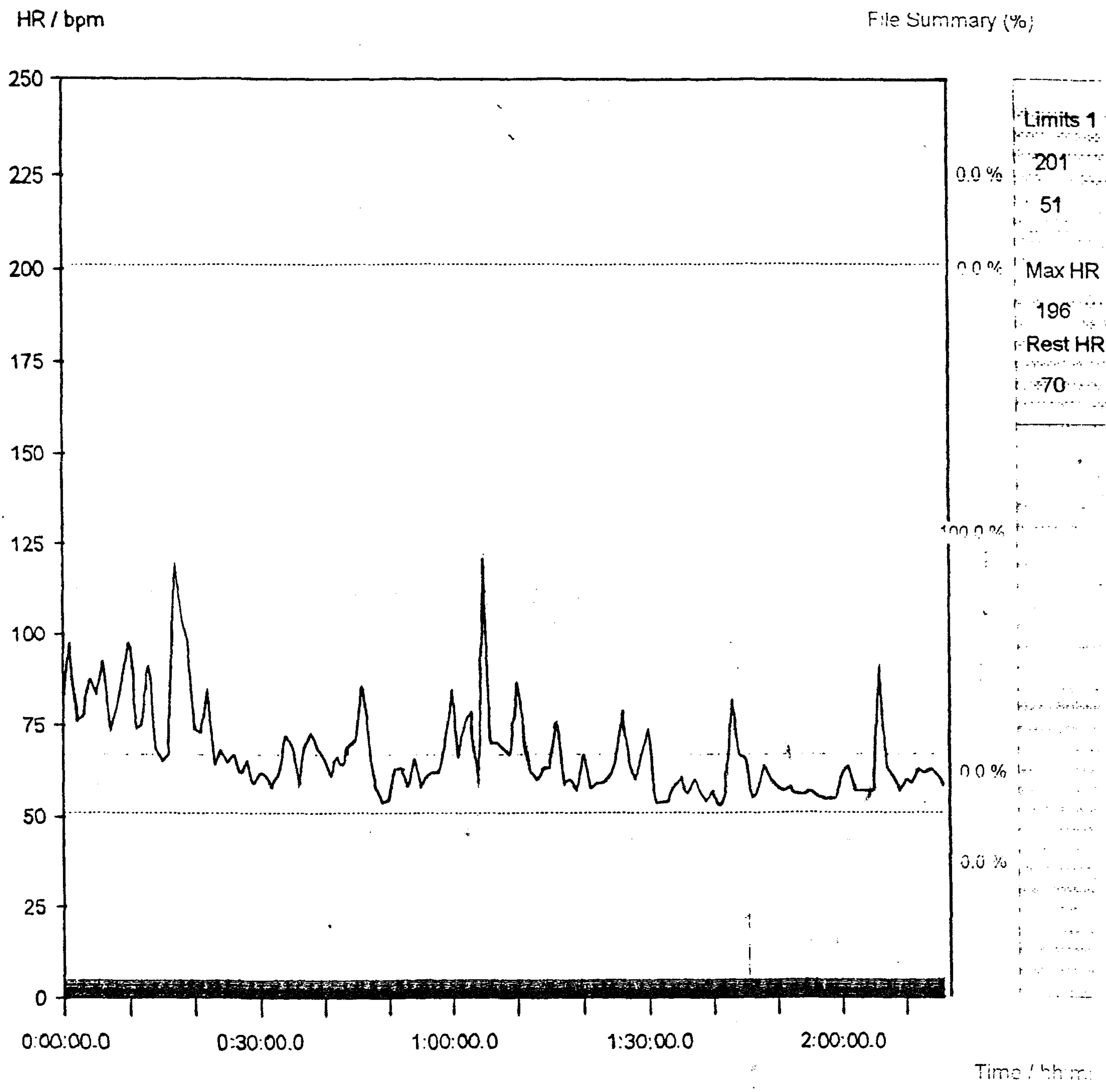
TS: **mfukula(f)** Sc.code: lcmsc
Age/Sex/Education level: 29/m/5 Date: 11-05-1999 - 12:52...13:02 (0:10)

Test variable	Raw score	Comparat.sample	O/S	PR	T:20...80	
Total No. of responses..............	274	Organic disorders	O	14	39	--*----
No. of correct responses............	266	Organic disorders	O	14	39	--*----
No. of incorrect responses...........	8	Organic disorders	O	58	52	---*---
Percent Incorrect..................	2.92%	Organic disorders	O	38	47	---*---
Mean response time (sec.)..........	2.16	Organic disorders	O	69	55	----*--
Std.dev. response time (sec.)......	0.88	Organic disorders	O	62	53	---*---

Additional results:
Corr.
0

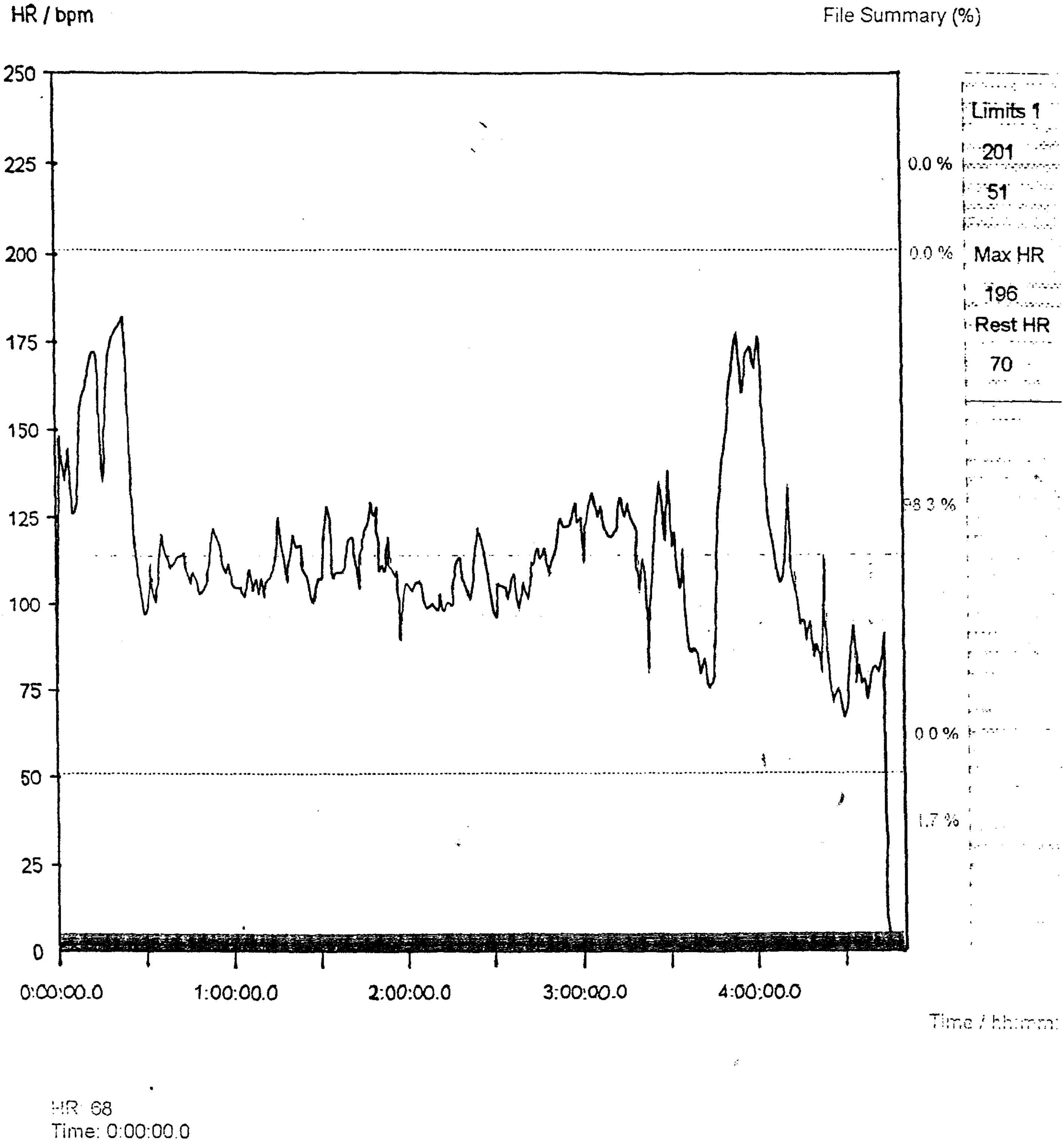
Polar Heart Watch Printout

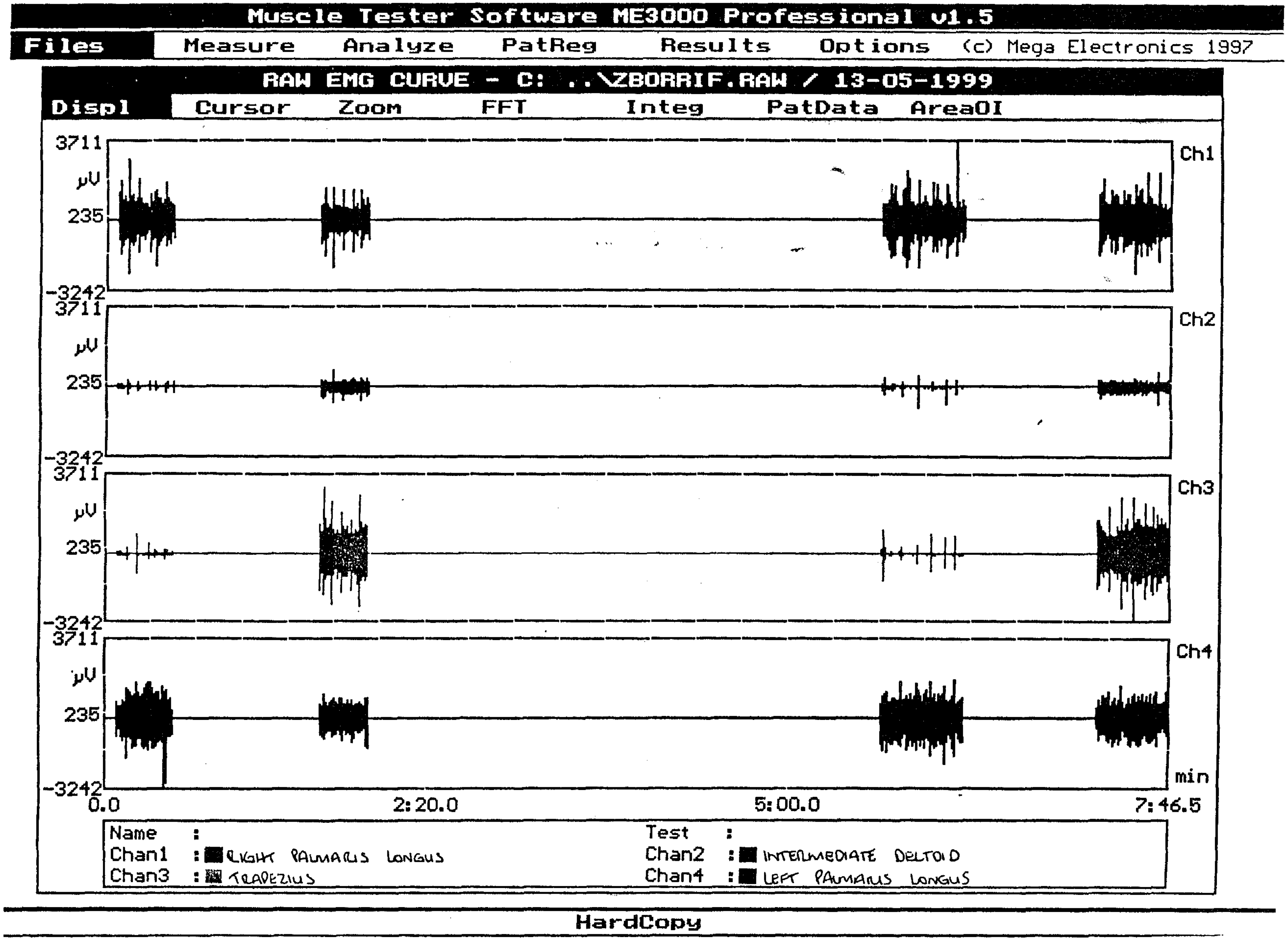
'Normal' Conditions



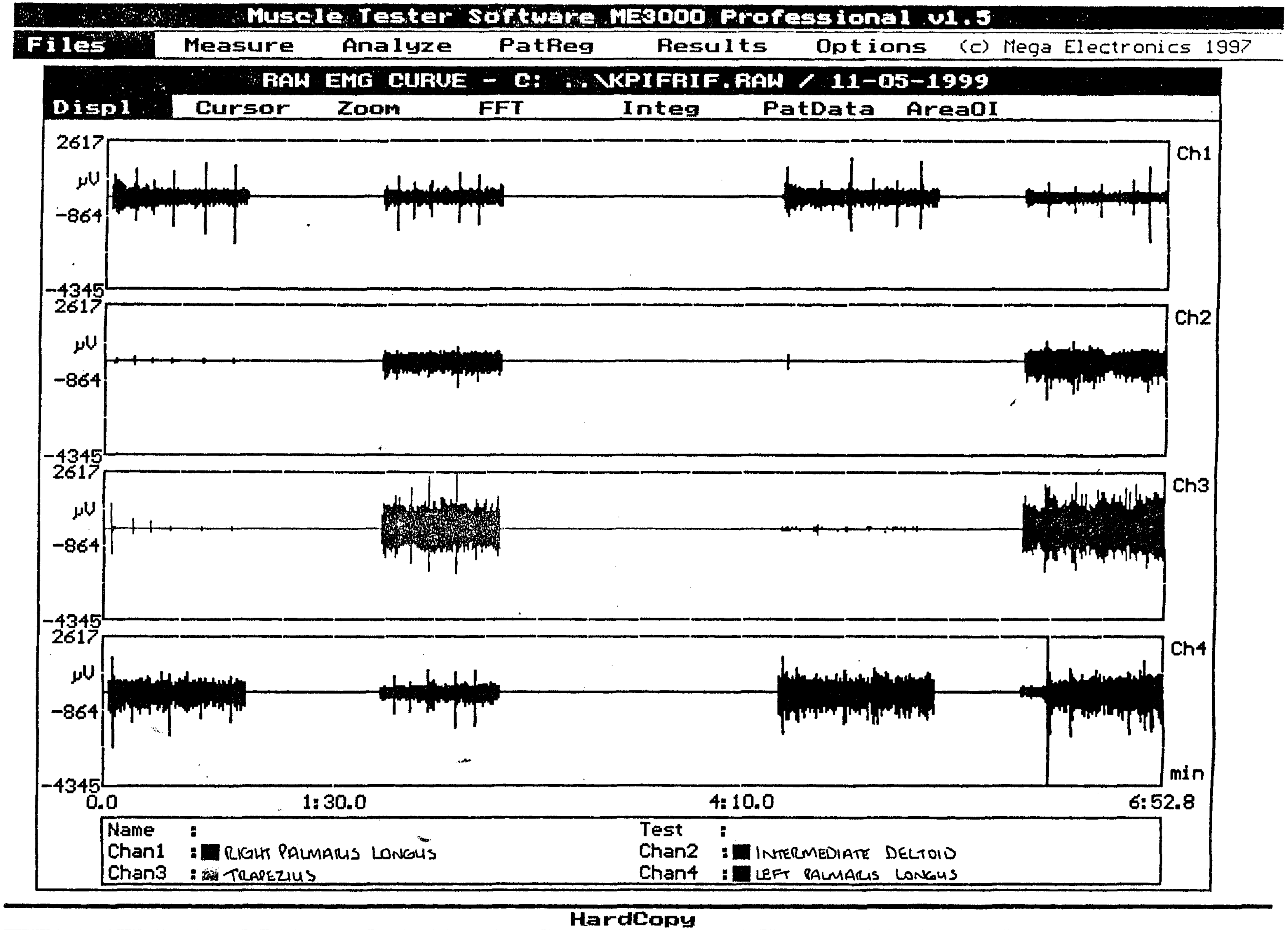
HR: 82
Time: 0:00:00.0

Fatiguing Exercises and 'Post-Working' Conditions





ELECTROMYOGRAPHIC (EMG) ACTIVITY PRINTOUT: 'Normal' Conditions



ELECTROMYOGRAPHIC (EMG) ACTIVITY PRINTOUT: 'Post-Working' Conditions