The development of physical performance in new recruits entering basic military training within the Australian army

Pete John Orchard
University of Wollongong

THE DEVELOPMENT OF PHYSICAL PERFORMANCE IN NEW RECRUITS ENTERING BASIC MILITARY TRAINING WITHIN THE AUSTRALIAN ARMY

A thesis submitted in partial fulfilment of the requirements for the award of the degree

Masters of Science (Research)

from the

UNIVERSITY OF WOLLONGONG

By

Pete John Orchard

Bachelor of Science (Exercise Science)

Centre of Human and Applied Physiology,

School of Health Sciences, University of Wollongong

NSW, 2522 AUSTRALIA

2015

THESIS CERTIFICATION

I, Pete John Orchard declare that this thesis submitted in partial fulfilment of the requirements for the award of Masters of Science (Research), in the School of Health Sciences, University of Wollongong, is wholly my own work unless otherwise referenced or acknowledged. The document has not been submitted for qualifications at any other academic institution.

Pete John Orchard

DATE 30/08/2015

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

It is well known that aerobic capacity, muscle strength and anaerobic endurance are important elements of physical fitness (Shephard., 1997 Aasa *et al*., 2003). Military duties are recognised as being physically demanding, requiring both physical and mental resilience (Rayson., 2000; Kaufman *et al*., 2000). Despite considerable technological advancement and increased mechanization of military operations, loads have increased significantly for the modern soldier (Knapik *et al*., 2014), thus requiring significant physical capacity to perform the allocated military tasks effectively. For that reason, the emphasis of the Australian Army basic military training regimen is for new recruits to develop such attributes. The regimen consists of exercises that target the upper and lower body regions. Exercises include, push ups, sit ups, running, marching with and without load, circuit training, swimming, plus the introduction to lift and carry, functional tasks and battle training.

One hundred and seventy seven recruits commenced the twelve weeks of basic training, with 128 completing the regimen. Of this selected group, forty recruits were assigned to perform physiological testing sessions. Three testing sessions in weeks one, eight and twelve were performed over the twelve week duration. These sessions would last between 40-80 minutes.

Following the twelve weeks of basic training, four key findings were observed; i) a 12-week basic military training regimen was effective in significantly increasing cardiorespiratory endurance. Recruits had a 7.5% increase in estimated peak oxygen consumption as measured by the 20m-shuttle run (Ramsbottom *et al*., 1988)., however, ii) gains in muscle strength and power were considerably smaller than changes observed in cardiorespiratory fitness, iii) the time course of adaptation was not linear; the greatest improvements in physical performance observed in the first eight weeks of training. In contrast, within the final four weeks of basic military training a maintenance of physical performance was generally observed, and, iv) a

poor relationship was observed between existing generic assessment of military performance and task that were functionally relevant to military duties.

It is concluded that basic training in the Australian Army produces some favourable adaptations in recruits, especially in terms of aerobic fitness. However, the poor development of strength and material handling ability during training fails to improve the ability of soldiers to perform simulated military tasks, and it does little to reduce future injury risk while performing these tasks.

ACKNOWLEDGEMENT

"It is not the mountain we conquer but ourselves"

Sir Edmund Hillary.

This journey of the Masters has been a mountain I have never climbed before. I cannot acknowledge that I have accomplished this task on my own, yet the feeling of being at the top and seeing the view is rewarding. This journey has not been my strengths, however it has made my weakness stronger and for that I am grateful. I am truly indebted to all who have helped and supported me. I extend equal gratitude to all of those whom developed me to be better than when I first began, whether large or small.

To Herb Groeller, thank you for being my primary supervisor and sometimes "*domestique*" throughout the masters. I have appreciated your outstanding support, feedback, advice, and expertise throughout the planning stages, data collection and writing phase. I am deeply appreciative of your wisdom, guidance, honesty and tolerance throughout this process. To Nigel Taylor, thank you for your support as well. Almost anytime you were willing to give me a few minutes of your time to offer advice and a laugh. Gentlemen your contribution to the field of science and the development of others is exceptional.

To Denise and the DSTO crew, thank you as well for sharing good times and experiences in this processes and development of better soldiers for the Army.

To the Australian Army I would like to thank you for allowing the privilege to come and complete the study on the recruits that went through basic training. To the ladies and gentlemen PTI's, I am inspired by the work you do and had the best time getting to know you and watch how you conduct your training regime. To Sgt Dan Ferguson, thank you. Mate it was a privilege to meet you and watch you lead, I wish you all the best for your future.

To all my friends, Anna, Lisa, Dan Lee, Jo Odgers, Sean Notley, Petra Olbrechotva, Laura Holland, Broke Collier, Anne van den Peters, Nuri Alrzeghi, this list can go on forever, however to all, thank you for the support and heaps of laughter and cake.

To my family, mum and my brothers thank you for your support.

Finally to Warrant Officer 2nd class Noel Orchard (RAE), Dad I wish you were here to see me finish this journey. I know how much you were an inspiration to those under your leadership in the Army and to me. It was hard to see you go and I always think of you. I dedicate this thesis to you. One day we will meet again.

PUBLICATIONS

i) Groeller, H., Burley, S., Orchard, P., Sampson, J.A., Billing, D.C. and Linnane, D. (2015) How effective is initial military specific training in the development of physical performance of soldiers? Journal of Strength and Conditioning Research: Volume 29, Issue- p-S158-S162.

ii) Burley, S.D, Orchard, P., Linnane, D.M., Sampson, J.A., Carstairs, G.L., Billing, D.C., Drain, J.R. and Groeller, H. (2014). How effective is basic military training in developing the physical performance attributes necessary for military service? Proceedings of the Third International Congress on Soldiers' Physical Performance. Boston, U.S.A. August 18th-21st, 2014. P120.

iii) Groeller, H., Linnane, D.M., Burley, S.D., Orchard, P., Sampson, J.A., Carstairs, G.L., Billing, D.C. and Drain, J.R. (2014). How important is initial employment training in the development of physical performance? Proceedings of the Third International Congress on Soldiers' Physical Performance. Boston, U.S.A. August 18th-21st, 2014. P60.

CHAPTER ONE: INTRODUCTION

.

1.0 INTRODUCTION

It is well known that aerobic capacity, muscle strength and endurance are important elements of physical fitness (Shephard., 1997 Aasa *et al*., 2003). Military and emergency service duties are recognised as being physically demanding, requiring both physical and mental resilience (Rayson., 2000; Kaufman *et al*., 2000) For example, manual material handling is an important characteristic of most duties, where objects can weigh in excess of half of the body mass of the average soldier (Knapik., 1989). Despite considerable technological advancement and increased mechanization of military operations, loads have increased significantly for the modern soldier (Knapik *et al*., 2014), thus requiring significant physical capacity to perform the allocated military tasks effectively.

Understandably the characteristics of the work environment require the soldier to have sufficient levels of muscular strength and endurance to successfully meet task demands (Sharp *et al.*, 2009; Patton *et al*., 1987). For that reason, the emphasis of the Army basic military training regimen is for new recruits to develop these attributes. However, basic military training places considerable physical and psychological demands upon recruits; in part due to constrained total training time (Pope *et al*., 1999). The regimen consists of exercises that target the upper and lower body regions. Exercises include, push ups, sit ups, running, marching with and without load, circuit training, swimming, plus the introduction to lift and carry, functional task and battle training. To ensure the exercise regimen is effective, the Australian Army requires all recruits to attain a minimum standard of fitness prior to entry into military service.

However, despite the increased physical demands of military duties the greater prevalence of sedentary behaviours within society has contributed to declining levels of physical fitness (Kopelman., 2000; Blair *et al*., 2004; Santtila *et al*., 2006). For example, the decline in physical fitness in the Finnish military was compared over a twenty year period. Military service in Finland is compulsory and therefore ninety five percent of the recruits aged 20 y fulfilled their commitment in this time period. After comparing the fitness data over the twenty year period to the level of fitness attained by current recruits it was concluded that there are declining levels of physical fitness among current Finnish adolescents (Kyröläinen *et al*., 2008). It is likely this population based the decline in physical fitness as having significant negative consequences that would include a higher rate of failure to attain minimum physical performance levels and also a greater risk of injury during military training (Santtila *et al*., 2006). Thus, there would appear to be a widening in the gap between the physical demands required for military duties and the physical capacities of those individuals entering for military service (Knapik *et al*., 2006).

Physical capacity is a multidimensional term, incorporating physical attributes such as, muscular strength, muscular endurance, anaerobic endurance; flexibility, occupational lifting and aerobic power that collectively determine one's intrinsic physical capacity to perform work (Sharp *et al.*, 2009; Whaley *et al.*, 2000). For example, a soldier who operates as a field artillery gunner may be required to lift ammunition that can weigh 45 kg (Sharp *et al.,* 1994; Patton *et al*., 1987) from a vehicle which is 1.5 m in height and carry to its designate position (strength). Then proceed to load and re-load the ammunition into the gun as it is being fired (muscular endurance and flexibility), and intermittently move back and forth, carrying the disused shells (aerobic power). Tasks such as these require multiple physical attributes that in combination contribute to the capacity of an individual to perform work.

Development of this physical capacity is important, as the risk of injury increases significantly, when task demand approaches the physical capacity of the individual (McGill, 1997). Rates of injury within militaries in the western armies are high. For example, the U.S. military reported injury rates of 27.4% in male and 44.6% in female recruits in the initial training phase (Jones *et al.*, 1993). Likewise, within the UK Armed Forces, 33.5% of Royal Marines have been shown to sustain some form of injury in training (Riddell, 1990). Similarly within the Australian Army, Rudzki (1997) reported injury rates of approximately 42% for male recruits completing basic military training. Additionally, within the Australian Army injuries to the female population is significantly higher than male peers (Bergman and Miller, 2001; Rudzki and Cunningham, 1999). Importantly, it has been acknowledged that the risk of injury may be reduced if basic military training was modified (Chaffin, 1987; Rudzki and Cunningham, 1999). This suggests that it may be the manner in which physical training is delivered to recruits and not only lowered standards of fitness among the recruit cohort that may be contributing an increased rate of injuries.

However, within a military setting, many physical tasks are critical for mission success and cannot be modified to reduce the physical demand (Harman *et al.*, 2008b; Sharp *et al.*, 2009; Sherrard *et al.*, 2004). Thus, in order to adequately meet these relatively fixed task demands, the military services must ensure sufficient physical capacity is developed and maintained within personnel to meet requirements of the task (Sharp *et al.*, 2009). Therefore the focus of this research will examine the physical characteristics of new recruits entering into basic military training.

1.1 The influence of declining levels of community fitness upon basic military training.

Military organisations use substantial resources to prepare new recruits for their operational service. For example, training new recruits for entry into service, the US Army expends approximately USD$72,000 for each recruit (Green, 2014). For new recruits to acquire the critical knowledge, skill, physical and psychological attributes necessary to be an operational soldier, places substantial stress on military training organisations to deliver appropriate training outcomes with the use of finite resources within a constrained period of time to achieve the necessary levels of adaptation. These constraints are particularly relevant given the declining entry levels of physical fitness observed within new recruits (Santilla *et al.*, 2006), making it increasingly difficult for military organisations to meet the relatively fixed physical performance outcomes required after 12 weeks of basic military training. Therefore within this section, community-based levels of physical fitness are explored particularly in youth, the primary new recruit cohort for the Australian Army.

There is a general awareness that the youth of today are less physically fit and have greater excess body mass than in previous years (Booth *et al*., 2003). Over the last two decades in Australia, there has been a steady shift towards a higher body mass index (BMI) driven primarily by a gain in body mass rather than stature (Australian Bureau of Statistics., 2012). Although it is acknowledge that BMI is a very crude index to make assumptions with respect to body composition; across a broad population base, some basic inferences can be made (Rothman, 2008). The 'healthy' BMI range is considered to be between 20kg.m-^{2} – 25kg.m-^{2}. Evidence strongly supports a relationship between BMI, health and risk of injury during military training (Fogelholm *et al*., 2006;Knapik *et al*., 2013; Kyröläinen *et al*., 2008; McLaughlin and Wittert., 2009; Packnett *et al*., 2011). For example, Knapik *et al*., 2013, investigated combat engineer recruits in the U.S. Army performing their fourteen week

intense course. One thousand six hundred and thirty three male recruits participated in a physical questionnaire, regarding their, date-of-birth, height, weight, tobacco use, and prior physical activity and injury history. It was noted that out of the ninety two percent of graduated recruits, forty seven percent experience some form of injury. It was concluded that those recruits who were at higher risk of injury were older, had low or high BMI, smoked, had a minimal aerobic or muscular strength capacity prior training or had previous lower limb injuries. Defence recognises that individual body build has an impact on the BMI and sets a standard with that in mind. The maximum allowable BMI for entry to the Australian Defence Force is 32.9, with a minimum BMI of 18.5, in both circumstances the soldier may be deemed temporarily unfit by Defence Force Recruitment Centre medical staff.

The occurrence of obesity has increased across all age and demographic groups in the last twenty years, with the rate of obesity in Australia rising from 19% to 24%, with the increase greatest in men (Australian Bureau of Statistics., 2012). In 18 – 24 y Australians, the age range most relevant for entry into military training, the incidence of obesity has increased by 60% in 20 years, from 9.4% to 15.1%. Thus, the Australian Army is faced with a cohort that has had significant changes in body composition over a relatively short period of time (Australian Bureau of Statistics., 2012).

There has also been a significant change in physical activity levels. Tomkinson., *et al* (2003) described a decline in youth physical fitness, particularly aerobic fitness, as measured by running performance. Additionally, Tomkinson and Olds., (2007) noted aerobic fitness has been declining globally at the rate of about 5% each decade. Indeed, the Surgeon General's report on physical activity states that only about fifty percent of youth participate in regular vigorous physical activity and fourteen percent are completely inactive (US Department of

Health, and Human Services, 1996). Furthermore, this level activity appears to be different for young (15-17 year olds) males and females. With males three times more likely to undertake high levels of exercise than women, and women were two fold more likely to be sedentary than their male peers (Australian Bureau of Statistics., 2012). Thus, if the youth today are less active, have a greater percentage of body fat, and have a lower aerobic fitness than those of previous decades, they present a concern not only to national health but to occupations that require high standards of fitness to function successfully (Sharp *et al*., 2002). This opinion is supported by Knapik *et al.*, (2001), who reported run times for basic trainees over a 10-y period (1988 –1997) was five percent slower over 2-miles, indicating a decline in the aerobic fitness of recruits.

The average aerobic capacity of Australian male and females aged 20 -29 years is between 46.4-51.0 $mL.kg^{-1}.min^{-1}$ for males and 35.0-39.9 $mL.kg^{-1}.min^{-1}$, females (Schell., and Leelarthaepin., 1990). It must be acknowledged that recent data on the average aerobic capacity of Australian young adults is not available. The only recent study conducted, were on Australian children, aged 9-17 (Catley., and Tomkinson., 2011). The Australian Defence Force uses a multistage fitness test to predict aerobic capacity of a new recruit. Prior to entry into basic military training all recruits must achieve a minimum cardiorespiratory fitness of Level 7 Shuttle 5 in the multi-stage fitness test which is estimated to be equivalent to a peak oxygen consumption of 42.8 $mL.kg^{-1}.min\text{-}^{1}$. This standard exists because lower levels of physical fitness have been shown to reduce the likelihood for successful completion of basic training and increased risk of training-related musculoskeletal injury (Knapik *et al*., 2001).

Studies have shown that low physical fitness scores on tests of aerobic or muscular endurance fitness are associated with higher injury risk (Jones *et al*., 1993; Jones *et al.,* 1993; Knapik *et al*., 2001). Conversely, the risk of injury during basic military training was significantly reduced in recruits who have higher inherent cardiovascular endurance at the commencement of basic training (Pope *et al.,* 2000). However, the rate at which injury occurred was not evenly distributed throughout basic military training, with the greatest risk of injury observed in the initial weeks of basic military training (Rudzki, 1997). This suggests that the recruits suffered maladaptation, due perhaps to lowered levels of physical fitness prior to entry into basic military training, or alternatively, the training stimulus was in excess of that required for optimal levels of physical adaptation.

Muscular strength and endurance are significant components of health, sport and occupational related tasks (Haskell *et al*., 2007). For developing children, it is important that they engage in some forms of challenging strenuous activities that will provide development of their muscular and skeletal systems (Faigenbaum *et al*., 1999). Similarly, adults need to incorporate strengthening activities in their daily routine in order to ensure that they too can continue to perform successfully their daily activities (Haskell *et al*., 2007). Therefore, engaging in strength programs that are conducted on a regular basis will improve muscular strength over the duration of training (Anderson and Kearney 1982). Having sufficient muscular strength is not only essential in athletic activities but also within occupations where strength is a major pre-requisite requirement for the completion of normal duties (Knapik., 1989; Arvey *et al*., 1992; Rhea *et al*., 2004).

Interestingly, muscular strength is not assessed by the existing battery of assessments within the military. Instead only local muscle endurance of the upper body (push-ups) and trunk musculature (sit-ups) are assessed. With regards to muscular strength and endurance prior entering into basic training recruits must first complete a pre-fitness assessment (PFA). The level of push-ups that must be attained are 15 for males and 8 females with both having to make the sit-up score of 45. According to the fitness categories set by the American College of Sports Medicine (2013) the push ups results are not satisfactory, compare to the normative data (Tremblay *et al*., 2001) and require more improvement in muscular endurance. However, the sit-ups are considered very satisfactory and meet the required normative standard (Tremblay *et al*., 2001). In the first week of basic training, recruits re-tested the same exercises with average scores of 41 push-ups in two minutes and 93 sit-ups in the set cadence. Again according to the fitness categories for push ups and sit ups (American College of Sports Medicine. 2013), recruits are considered to be in the excellent range when compared to age-based normative results.

1.2 Can existing tests of soldier physical fitness be considered valid physical employment standard assessments?

The Australian Army utilises physical fitness assessments to both screen new recruits prior to entry into basic military training and to also monitor adaptation related to the 12-week training regimen. The physical employment standards adopted by the Australian Army should have the following characteristics; i) be utilised to determine if a recruit has the necessary physical attributes to safely and efficiently perform physical demanding tasks relevant to the requirements of the soldering duties, ii) the assessments developed to screen participant suitability should have a clear connection with the performance of the job, iii) the tests and associated standards should be necessary for the successful completion of the position

(Jamnik *et al.,* 2010a; Nindl *et al*., 2013; Jamnik *et al.,* 2010b; Tipton *et al*., 2012; Jamnik *et al.,* 2010c; Jamnik & Gledhill, 1992; Reilly *et al.,* 2006; Sothmann *et al*., 2004; Taylor & Groeller 2003; Rayson, 2000).

The setting of valid employment standards can have a positive impact on both the employee and employer. This is achieved through improvement in worker capability, decreased rates of injury and therefore improved productivity and reduced costs for the employer (Jamnik *et al.,* 2010a; Rayson, 2000). For organisations like the military, that have tasks or duties of a high physical demand, the underlying characteristics of the employee's physical, physiological and psychological capacities are important considerations for the successful completion of critical duties. Therefore, identifying those personnel with the necessary physical capacities through the use of valid screening assessment tools is essential (Tipton *et al*., 2012; Jamnik *et al.,* 2010a).

Through the application of appropriate physical employment assessments, only those individuals who have the necessary physical and physiological capacities would be accepted into basic military training or military duties. These individuals can be defined as true positives. That is the physical assessments correctly identified those recruits or soldiers able to satisfactorily meet the physical demands of the military duties. The physical assessment is defined as being sensitive if it has the ability to successfully select those individuals that are able to perform military duties. In contrast, true negatives, are those recruits or soldiers whom did not pass the test but were also unable to satisfactorily perform the military duties critical for service within the Australia Army. The ability of a test to determine true negatives is defined as the specificity of the assessment. Thus, a physical assessment that is both sensitive and specific is able to successfully differentiate those recruits that are either capable or incapable of performing military duties (Tipton *et al*., 2012).

However, a physical assessment that is characterised by low sensitivity and specificity will have a high rate of false positives, recruits selected on the basis of the physical assessment but are unable to perform military duties, and false negatives, recruits who unable to pass the assessment but actually could perform military duties effectively (Tipton *et al*., 2012; Jamnik *et al.*, 2010a). What then are the characteristics of the physical assessments currently used by the Australia Army?

The Australia Defence Force (ADF) Pre-enlistment Fitness Assessment consists of push-ups, sit-ups and a 20-m shuttle run and for incumbents a similar testing regimen is adopted. The Basic Fitness Assessment consists of a 2.4 km run, push-ups and sit-ups. The minimum performance standards for the assessments vary on the basis of gender and age (Table 1).
This variation in minimum performance scores is significant, with males and females over the age of 51 having to perform approximately 7 times less push up repetitions than their younger peers. However, both age groups and genders are expected to perform the same duties. Thus, there appears to be a significant discrepancy between the minimum physical fitness requirements for military service and actual physical work demands. Furthermore, Australian Army begins conducting physical employment standards in basic training. The aim is to have all personnel at the same level of combat fitness. The physical employment standards test include a 5km loaded march, fire and movement drill (12x 6m intervals), jerry can carry (6 x 25m) and 25kg box lift placement. There are personnel who struggle to pass the test, due to physical height, stature and strength. However, this current study will not focus on these tests.

Table 1: Physical performance standards of the Australian Army Basic Fitness Assessment

Assessment	**Age: < 25 years**		**Age: > 51 years**	
	Male	**Female**	**Male**	**Female**
Push-ups (repetitions)	40	21	6	3
Sit-ups (Repetitions)	70	70	15	15
2.4 km Run (min:sec)	11:15	13:30	14:30*	16:30*

Note: A choice of either a 2.4 km run or 5 km walk is offered for those over the age of 41 years.

Despite this significant discrepancy in physical fitness requirements, the implementation of physical performance standards that differ with chronological age is a traditional mechanism to accommodate older workers. A significant age-related decline in physical performance is the primary rationale offered for the implementation of this approach (Walker *et al*., 2014). Yet, there is an absence of methodology to underpin the setting of these performance standards on the basis of chronological age (Walker *et al*., 2014). Furthermore, developing a legally defensible age-biased physical standard presents numerous challenges such as; i) establishing a valid and universal rate of decline in physical capacity, ii) selecting quintiles, deciles or percentiles for the age-biased categorisation of a physical performance standard, iii) minimising discrimination of younger employees, and iv) ensuring the health and safety of workers is retained.

Given such challenges, the use of age-based physical work standards has met with disapproval for being inadequate to ensure that workers have enough physical capacity to meet occupational demands (Davis *et al*., 1987 and Fullagar *et al*., 2015). Clearly, justifying the use of age-based physical standards as criteria for employment is difficult to sustain. Therefore, the setting of employment standards, which are based on the minimum physical requirement, should be independent of sex and age (Reilly and Tipton, 2005; Epstein *et al*.,

2012) and should take into account constructs such as strength, endurance, range of motion and power necessary for completion of the task (Tipton *et al.,* 2012).

For example in 1999 the Supreme Court of Canada found (the Meiorin Decision) that the test must have a connection with performance of the occupational task and the standard selected for the assessment must be necessary for purpose of performing the work task. Furthermore, employers must be able to show that they are unable to accommodate workers who have levels of physical performance in the assessment lower than stipulated (Jamnik *et al*., 2010a). With respect to the Meiorin Decision a female fire fighter despite performing her duties satisfactorily was stood down from her position due to an inability to meet the minimum performance time for a 2.5 km run test. The running assessment was being used by the fire service as a physical employment standard. The Supreme Court overturned the decision made by the fire department and criticised the process used to determine the basis of performance standards (Payne & Harvey, 2010). It is important to realise that there is no one single, reference assessment most suitable for the evaluation of occupational performance. This lack of a definitive assessment is due to the wide range of employment opportunities and therefore significant variation in physical task demands in the work place. Thus, determining the critical and essential attributes of occupational task performance is necessary for the development of appropriate physical fitness assessments (Tipton *et al*., 2012; Jamnik *et al.*, 2010a; Epstein *et al*., 2012; Chahal *et al*., 1992; Taylor & Groeller 2003; Milligan & Tipton 2013).

However, the physical assessment regimen currently utilised by the Australian Army are known to have a poor association with military task specific demands (Vanderburg *et al*., 2011). For example 2-min push-ups and sit-ups were found to explain only 2% and less than 1% respectively of the performance variation observed during a causality rescue task; a

functional assessment of strength (Harman *et al*., 2008). Others have found a more promising correlation with unloaded 3.2 km running and 14, 27 and 41 kg load carriage performance explaining approximately 73% of the load carriage performance variation (Knapik *et al*., 2000). In contrast, the ability of simple field based tests to predict training induced load carriage ability is poor (Williams and Rayson, 2006). Furthermore, evidence clearly shows that Pre-enlistment Fitness Assessment and Basic Fitness Assessment are significantly biased toward lighter individuals (Bilzon *et al*., 2001, Vanderburg *et al*., 2011), when, on the contrary, many military activities undertaken by soldiers require the lifting or carriage of objects with a fixed mass. Under these load carriage conditions individuals with a lower relative body mass will perform comparatively more poorly (Bilzon *et al*., 2001). Therefore within this investigation we will explore the relationship between existing assessment of military physical fitness (push-ups, sit-ups and 20 m shuttle run) with recently introduced assessments that have a functional link with military performance (single repetition box lift and place, jerry carry and 3.2 km 22-kg load carriage).

While there is some evidence to show simple static strength tests, such as the upright pull, are strongly associated with lift or load carriage performance (Sharp *et al*., 1980, Teves *et al*., 1985 and Nottrodt and Celentano, 1987). More recent investigations suggest that the use of static assessments do not accurately predict dynamic lifting capacity or load carriage performance (Feeler *et al*., 2010, Baker *et al*. 1994, Williams and Rayson, 2006). Thus, the use of dynamic load bearing assessments has been recommended (Williams and Rayson, 2005, Vanderbergh *et al*., 2011, Rayson *et al*., 2000) adopted for investigation within this research project. Therefore the focus of this section of the thesis is to examine the Australian Army's pre-enlistment fitness standards, part of the basic training fitness standards and there correlation with dynamic and functional assessments of military performance.

1.3 How basic military training is conducted within the Australian Army

Australian Army recruits are required to complete two distinct phases of training prior to posting to their operational units; these are basic military training and initial employment training. Basic military training requires recruits to complete a 12-week generic training course that develops knowledge, skills, physical and psychological attributes common in all soldiering duties. Upon completion of this phase, soldiers then complete initial employment training; a regimen that prepares the soldier to meet the specific occupational demands of their allocated employment category, such as infantry, transport or artillery. The focus of this research investigation is upon the first phase of the 12-week basic military training.

Australian Army basic military training requires recruits to complete 39 physical training sessions over an 80-day period (Table 2). Each training session is approximately 60-120 min in duration. The physical training sessions however, are not evenly distributed. Indeed, the frequency and intensity of physical training sessions in the first four weeks of basic military training are higher than final two thirds (8 weeks) of basic training. The first four weeks are likely to increase physical fitness in recruits. Such elevated physical demands at commencement of basic training are associated with an increased risk of musculoskeletal injury (Rudzski, 1997).

The dominant method (nearly one third of all training) used to develop cardiorespiratory fitness, is via continuous running at a moderate intensity and low intensity prolonged duration load carriage. Importantly, there is limited progression in the training sessions, and the sessions are not constructed to individualise the training load for each recruit. Thus, those with the highest levels of fitness or performance have a significantly reduced relative training load and intensity compared to the least fit recruit's. Although manual materials handling is performed daily within the military (Sharp *et al*., 2009), it is not a focus of the current

training regimen, with only 18% of total training time dedicated to the development of muscular strength and endurance (Table 2). While box lifting is replicated within one station of the circuit, the loads are relatively light and the absolute mass to ensure each recruit is able to complete numerous repetitions. However, these constraints mean that there is limited capacity to modify training load relative to the training status of each recruit, and to also apply a training load that may optimally facilitate gains in muscular strength (Kraemer *et al*., 2001). Muscular endurance and strength is developed primarily through a circuit that requires recruits to manipulate a number of objects over a fixed period of time (Fogarty, 2009, Orme, 2005).

Table 2: The distribution of training within the basic military training 80-day program

Training Focus	Method	Sessions	Total training (%)
Strength	Circuit training	7	18%
Endurance	i) Long slow running	6	14%
	ii) Load carriage	8	16%
Swimming	Short intervals, skill	4	10%
Information	Lecture	7	17%
Military simulation	i) Rope climbing	2	5%
	ii) Obstacle course	3	7%
Assessments	BFA, RFA	5	13%

Note: Basic fitness assessment (BFA), includes push-ups, sit-ups and 2.4 km run; Recruit fitness assessment (RFA), includes push-ups, sit-ups and 20-m shuttle run (2013).

Furthermore, there is significant replication of body weight activities that develop local muscle endurance. Generally, these training activities focus upon the performance of push ups, sit ups and unloaded running. Activities that are also used as basic recruit fitness assessments (push-ups, sit-ups and 2.4 km run) to determine the suitability of recruits

entering into military service. Given the wide range of tasks undertaken by military personnel, exposure to frequent heavy manual materials handling and the requirement to perform endurance activities bearing a load, such training regimen are unlikely to be effective in developing the physical attributes necessary for military service. For example, basic fitness assessments are known to correlate poorly with a casualty drag task, which is a critical activity on the battlefield Harman *et al.*, (2008b).

Therefore the current format of basic military training could be best described as non-specific training, where a range of higher volume, lower intensity activities are used to develop non-specific adaptations in cardiovascular endurance and muscular strength and power (Brock and Legg, 1997, Knapik and Sharp, 1998,) Basic training must develop a broad range of physical attributes such as muscular strength, muscular endurance and aerobic power (Harman *et al.*, 1997; Harman *et al.*, 1996; Kraemer *et al.*, 2001; Sharp *et al.*, 2009; Williams *et al.*, 2002). In contrast, basic training has a large focus upon general whole-body conditioning and endurance (Fogarty, 2009; Orme, 2005).

The focus upon developing cardiorespiratory endurance does not necessarily correlate with the occupational demands of military personnel (Hendrickson *et al.*, 2010; Sharp *et al.*, 2009). It suggests a potential disparity between the physical attributes required for military service and those being developed within basic military training (Santtila *et al.*, 2008; Santtilla *et al*., 2010; Williams *et al*., 1999, 2002). Nevertheless, improving general fitness of new recruits is essential; however there should be emphasis on the implementation of specific training methods to improve occupational fitness, especially manual handling and lifting and carry which could reduce future rates of injury. Currently, there appears to be a weak relationship between the physical capacity developed within basic military training and the

fitness required to meet the occupational and military specific tasks engaged in by routinely by soldiers. Improving the overall fitness of the new recruits is important; focus should also be on the implementation of specific training methods to improve occupational fitness, such as strength and strength endurance, which could reduce the incidence of injury.

1.4 Adaptations to basic military training

In military basic training the focus of conditioning has been based on aerobic type endurance training (Santtila *et al*., 2008). This arises partly out of the ease of implementation of such programs and the simplicity of the exercise prescription when training large numbers of recruits during a physical training period. The physical training has often been concentrated toward performance on aerobic components of annual physical fitness tests, rather than on occupational tasks (Knapik *et al*., 2006). For a soldier, the occupational demands is a continual challenge due to the diversity of physical, psychological, and environmental factors faced on duty (Thomas *et al*., 2004; Martinez *et al*., 2001), therefore it may be apparent that a well-designed total conditioning programs are more applicable. It has been noted that basic military training is associated with variable gains in muscular strength, aerobic capacity and endurance, over a six to twenty four week training duration (Brock and Legg, 1997; Knapik and Sharp, 1998; Kraemer *et al.*, 2001). These training-related changes should result in improved physical performance which should have positive effects on job performance as well (Hendrickson *et al*., 2010). Despite a decline in sedentary behaviours within society which has contributed to declining levels of physical fitness (Kopelman., 2000; Blair *et al*., 2004; Santtila *et al*., 2006) the concentration of Army basic training is to improve recruits level of fitness.

Recruits must develop and maintain high levels of physical fitness in preparation for military undertakings. This development can be comparable to the methods used by athlete to prepare for competition (Issurin., 2010). It is for this reason that the demands of military duties involves personnel to routinely engage in vigorous physical and operational training to sustain a high level of readiness (Hendrickson *et al*., 2010; Kraemer and Szivak., 2012). These typical training activities include running, marching, calisthenics, climbing, hurdling, crawling, jumping, digging, lifting and carrying loads while hiking (Jones and Knapik., 1999). Therefore, the beneficial outcome of basic training provides normal personnel opportunities to excel within their physical abilities and to decrease the chances of injury (Knapik *et al*., 2003). Injury is costly (Kaufman *et al*., 2000; Rudzki., 1997) and it is not uncommon in basic training. The highest rates of injured in basic training are people who are deconditioned, especially in the areas of strength and power (Rosendal *et al*., 2003; Rudzki and Cunningham., 1999; Santtila., 2010). However, numerous other studies have shown aerobic fitness to be the most significant independent risk factor for military training injuries (Knapik *et al*., 2001).Within the Australian Army, Rudzki and Cunningham., (1999) described the amount of financial saving the defence force would save if the amount of injuries were reduced. For example, the total amount of recruits that were progressing through basic training in 1995/1996 was 3181. With a reduction in the amount of medical discharges, that is 118 were medically discharged, resulting in a saving cost to Army of $1.7 million. The reduction in injury and medical discharge rates was only possible by introducing modification to the training program (Rudzki and Cunningham., 1999).

As previously mentioned, basic training enhances the aerobic capacity of recruits. Legg and Duggan., (1996) examined 261 British recruits entering into 11 months of basic training. The recruits consisted of 62 adult artillery, 95 junior infantry and 104 junior infantry leaders.

After the 11 months duration of basic training there was significant increases in all of the recruit's aerobic capacity, each group having 2.1%, 2.4% and 3.0% respectively. Even though aerobic capacity improves, in basic training, the enhancement of muscular strength seems minimal, unless the intervention of specific strength training is incorporated (Santtila *et al*., 2008). New recruits that begin training with low levels of physical strength are more susceptible towards injuries in military training (Rosendal *et al*., 2003; Kaufman *et al*., 2000). Research has investigated the possibilities of greater adaptation to basic training using resistance exercises for positive results (Williams *et al.*, 1999; Williams *et al.*, 2002; Kraemer *et al*., 2001; Hendrickson *et al*., 2010). For example, Williams *et al.*, (1999) noted that after ten weeks of basic training in the British Army, recruits exhibited a two percent improvement in box lift performance, a task that requires significant levels of muscular strength (Harman., and Frykman., 1992).

However, with the inclusion of 28 specific resistance training sessions such as; assisted pull-up, bench press, seated row, shoulder press, dead lift, high curl, leg press and upright row performed with a training load of 6RM, twice per week, recruits displayed a significant 8-12 percent increase in single repetition maximum box lift strength and 15-20% increase in box lift repetitive work capacity (Williams *et al.*, 2002). With a 17% improvement also observed in the performance of a loaded march (Williams *et al.*, 2002).

Williams *et al*., (2002) confirmed that significant gains in the performance or capacity to perform occupationally relevant movements can be attained within a military setting (Genaidy *et al.*, 1994; Genaidy *et al.*, 1990; Knapik and Sharp., 1998). These investigations show that applying a resistance program to an existing training program for the duration of six weeks will see significantly improved muscular endurance, muscular strength, and

cardiovascular endurance through the short and intensive training protocols (Genaidy *et al.*, 1990). Asfour *et al*., (1984) identified that box lift training significantly improved box lift performance by 41-99%, in comparison to general training programs where maximum box lift increased by only 2% following a 10-week training intervention (Sharp *et al.*, 2009; Williams *et al.*, 1999). Although occupational performance has been shown to increase significantly, such methods of task specific training have been attributed primarily to neural adaptations (Alexander *et al.*, 2001; Genaidy *et al.*, 1994; Knapik & Sharp, 1998; Sale., 1988).

Military tasks require simultaneously high levels of neuromuscular performance and endurance capacity (Hendrickson *et al*., 2010). For example, Kraemer *et al*., (1995) designated thirty-five US Army male soldiers to one of four training groups. These training groups consisted of high-intensity strength and endurance, upper body only high intensity strength and endurance, high intensity endurance and high-intensity strength training. The training program was performed over twelve week duration. The first two to three weeks of the training were used to familiarize every soldier with each of the experimental tests and respective training protocols. This included upper body exercises such as, bench press / fly, military press, upright row, latissimus pull down, seated row, arm curl, sit-up and oblique twist. The lower body exercises were, single and double knee extension, single leg curl, calf raise, split squat leg press and dead lift. After the twelve weeks of training the results indicated that the high-intensity strength and endurance and high-intensity strength training groups had significantly increased one-repetition maximum strength for all exercises. Furthermore, the high-intensity strength and endurance, high intensity endurance and upper body only and high intensity strength and endurance demonstrated significant increases in

maximal oxygen consumption. Not surprisingly the high-intensity strength training group showed significant increases in power output.

Kraemer *et al*., (2004) also demonstrated that applying strength training in a twelve week period to soldiers had a positive effect on their body composition and lower body power production. These improvements were associated with improved occupational task performance (Kraemer and Szivak., 2012). A group of untrained female recruits in the U.S. military were assigned to resistance training program. The training was considered a long program (six-month duration), however there were improvements in the upper body musculature due to the activation of type II motor units. The specific training programs resulted in significant increases in body mass, 1-RM squat, bench press, high pull, squat jump, bench throw, squat endurance, 1-RM box lift, repetitive box lift, push-ups, sit-ups, and 2-mile run. It was concluded that Strength training improved physical performances of women over six months and adaptations in strength, power, and endurance were specific to the subtle differences in the resistance training programs (Kraemer *et al*., 2001). As a final point, studies by (Legg and Duggan., 1996; Faff, *et al*., 2000; Williams *et al*., 2002) demonstrated significant increases in soldiers muscle strength and material handling ability during a six to twelve week military training period.

However, the marked improvement in this type of training is highly specific to the task trained, and not entirely transferrable to other tasks (Thorstensson *et al.*, 1976). Lastly, the traditional method of military training often involves endurance and resistance training being performed on the same day (Harman *et al.*, 2008a; Williams *et al.*, 1999). For example, recruits in the British Army after a ten weeks of a basic training protocol noted maximal box lift improved by 2% compared to a 6% performance increase in VO2max (Williams *et al.*,

1999). It is therefore apparent that the improvements observed from this investigation are specific to the training regimen employed, where training was focused upon endurance-related improvements in performance. Further research into resistance training is desirable (Williams *et al*., 2002; Kraemer *et al*., 2004; Hendrickson *et al*., 2010).

There is a need for appropriate resistance training equipment and facilities to implement properly designed training programs (Kraemer and Szivak., 2012). Additionally, the need exists for properly educated, trained, and certified professionals within each unit to effectively implement specialized programs needed for the different military occupational skill sets and to identify the differential demands of each individual recruit that must be addressed for optimal progression and physical development (Kraemer and Szivak., 2012).

1.5 Aims of the research

The aims of this investigation were to:

To identify to what extent the 12 weeks of basic military training developed the physical attributes necessary for military service. To determine the relationship between the existing assessment of physical fitness used by the Australian Army and functional assessment known to reflect the physical characteristics required for military service.

1.6 Hypotheses

It is Hypothesised that:

Twelve weeks of basic military training will have a positive effect on recruit fitness

No significant effect will be observed in muscular strength and power following the completion of basic military training. In contrast, a significant improvement in cardiorespiratory endurance will be observed.

The number of repetitions performed in 2 minutes will have a poor relationship with the mass that can be lifted in a single repetition box lift. Similarly, a moderate relationship is expected between load bearing carriage activities and an unloaded 20-m shuttle run.

CHAPTER TWO: METHODS

2.1 SUBJECTS

Volunteers who participated in the investigation comprised of 177 Australian Army recruits from Blamey Barracks, Kapooka, Wagga Wagga, NSW, Australia. Prior to the commencement of twelve weeks of Basic Military Training all recruits were briefed on all the assessments to be conducted within the investigation. Procedures were approved by the Army Defence Research Ethics Committee and Human Research Ethics Committee (645 - 11). All recruits provided voluntary written informed consent prior to participation in the investigation. All recruits were dressed for physical training in clothing consisting of T-shirt, shorts and running shoes. Results from the tests conducted were collected by the PTI's for the push-up, sit-up, shuttle run and 2.4km run. The University of Wollongong research team collected data for all other physical and physiological testing.

2.2 EXPERIMENTAL DESIGN

The investigation was a prospective within group longitudinal design (Figure 1). Four representative platoons (~N = 50 per platoon) from two company's undertook the investigation. All recruits had met the minimum standards of defence force recruits involving push-ups (15 male and 8 female), sit-ups (45 for both genders) and shuttle run (level 7.5 score) prior to entry in the 12-week Basic Military Training regimen. Each recruit was assessed at three time points, the commencement of Basic Military Training (Week 1), midway (Week 8), and at the completion of Basic Military Training (Week 12). At each time point recruits were assessed as according to Basic Fitness Assessment and Recruit Fitness Assessment physical assessment protocols, assessments functional to the physical demands of military requirements. Furthermore, in order to assess the physiological response to military training in more detail, a randomly selected subgroup of 40 recruits also participated in

physiological assessments at each of the three time points. These tests included, strength, power, high intensity work capacity and maximal oxygen consumption levels.

The testing was organised over a three day period, Monday, Tuesday and Wednesday. The recruits would march, post breakfast, and be present at the gym on the Monday and Tuesday and on Wednesday the recruits would march down to the 400 meter running track. On Monday the selected group of recruits would arrive for the physiological testing. Their commanding PTI would give the recruits a brief warm-up session outside the gym facilities. Before assembling inside, the PTI and researcher would check to see if any recruits were injured. In small groups of 3, the recruits would begin their physiological testing. This would be in the order of stature, mass, vertical jump, 1RM bench press, Wingate test and peak oxygen consumption treadmill test. On Tuesday at the same time, post breakfast, all recruits marched and assembled outside the gym facilities. The recruits would then assemble inside the gym hall and do a warm –up session with their commanding PTI. This would follow with clear instructions from the PTI on how they are going to perform their Recruit Fitness Assessment. The order of testing was push-ups, sit-ups and then the recruits would assemble outside the gym in a designated undercover area to do the shuttle run. The shuttle run was performed in two lines as to accommodate for the large number of recruits. After the shuttle run was completed recruits had fifteen minutes recovery before they commenced the two task specific test, box lift and place and Jerry can carry. All recruits would re-assemble in the undercover area and the researcher would give the recruits instructions on how to perform the test. For the Jerry can carry, recruits were instructed and given a demonstration on the expectation of the test. This was then followed with a familiarisation period. For the box lift and placement, recruits were also given instructions on how to perform the task, correctly and incorrectly. The incorrect lift was deemed as a failure. Recruits were then divided into three groups according to body mass, light, (10-40kg), heavy, (20-70kg), and other weight box,

(20-50kg). Again recruits had a familiarisation before commencing the task. On Wednesday the recruits would march down and assemble on the 400 meter oval track. The commanding PTI would take the recruits through a moderate warm-up session. Then the PTI and researcher would check to see if any recruits were injured before commencing the 3.2km 22kg load carriage.

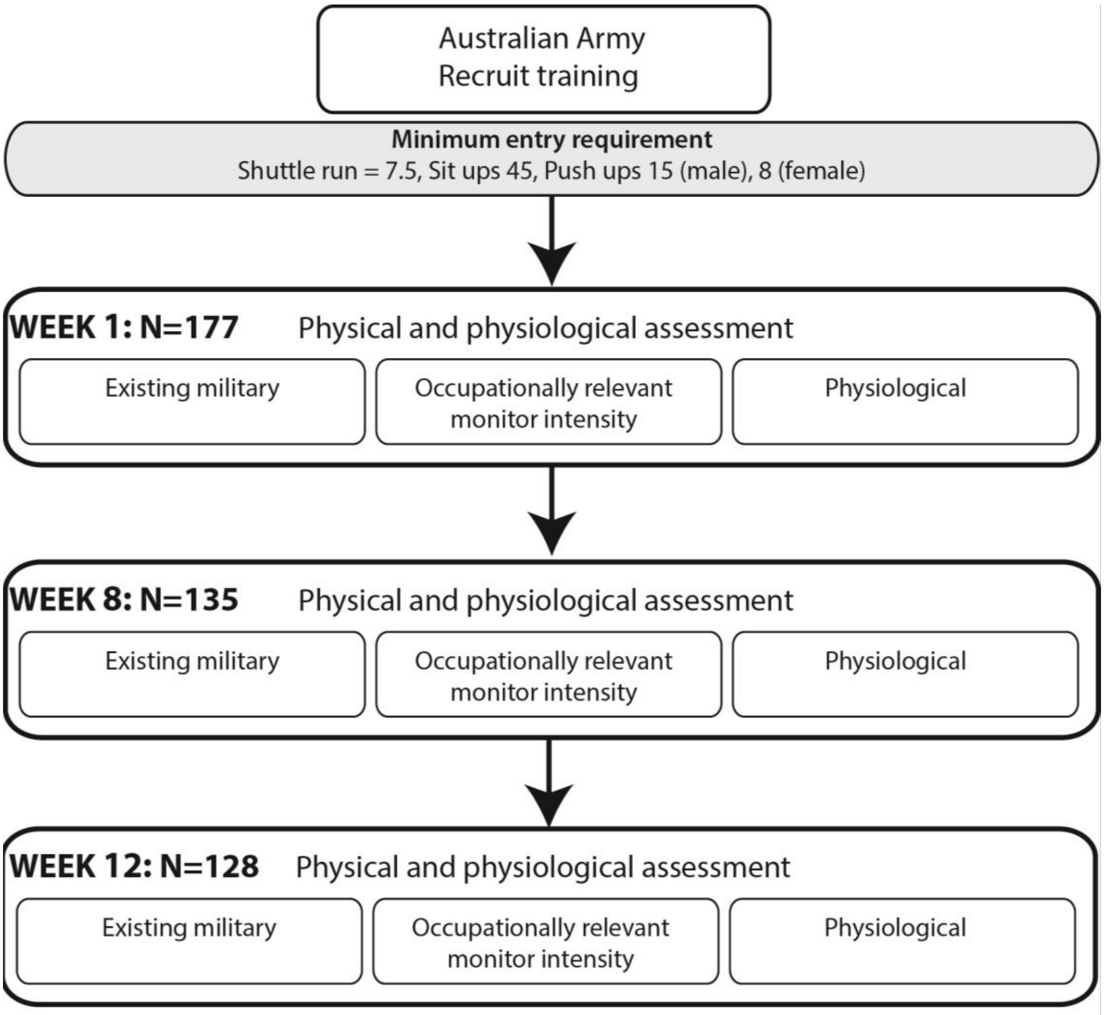

Figure 1: Experimental design

2.3 EXPERIMENTAL PROCEDURES

Within the first week of Basic Military Training all recruits underwent familiarisation and a practice session for each functional assessment to ensure they became accustomed to all testing protocols utilised within the investigation. The cohort of recruits for the physiological test was a random selection from the four platoons to ensure a representative sample was attained.

2.3.1 Existing Military Physical Assessments

The Basic Fitness Assessment, in week one, requires recruits to perform in the following order push ups, sit ups and a 20-m shuttle run. In week eight, a 2.4-km run to volitional exhaustion was added to the Recruit Fitness Assessment regimen.

2.3.1.1 Push up

Prior to each assessment recruits completed a warm-up protocol and were made familiar with all the assessment procedures. The requirement of the push up test for the recruits was to lie flat on the ground with hands positioned at shoulder width. They were instructed for the body to be a straight line from the shoulder to the ankle as they extended their arms, (Figure 2) and then lower their body just prior to touching the ground; this was counted as one repetition. The recruits were instructed to complete as many repetitions as possible in a two minute period, this score was recorded. All recruits were observed by Physical Training Instructors and researchers when performing the tasks. Excessive movement of the trunk and hips, failure to achieve full elbow extension and resting on the ground between repetitions, were regarded as unsuccessful attempts and not recorded within the test period. Recruits were then given a five minute rest period.

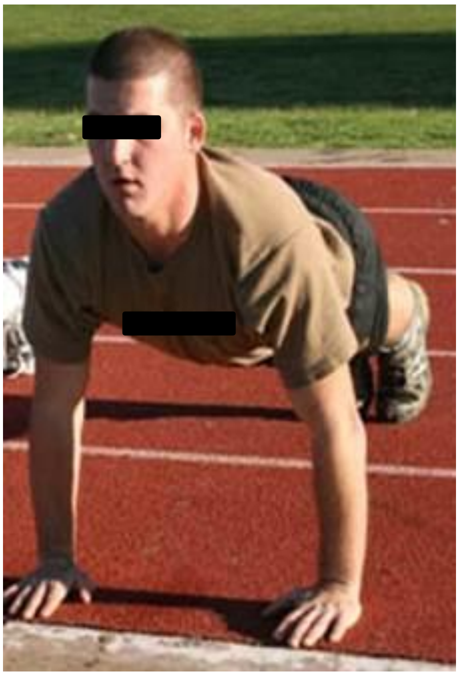

Figure 2: Push-up. (Photo was supplied by the DSTO, Melbourne)

2.3.1.2 Sit up

The sit-up test was performed to a three sec cadence to volitional exhaustion or a maximum of 100 repetitions. Recruits commenced the assessment laying on the ground supine with 90^{o} degree knee flexion and arms fully extended with the palmar surface on the hand resting on the anterior upper thigh. The feet of the recruit were fixed on the floor by the weight of a peer (figure 3). Recruits then commenced sit-ups in time with the three sec cadence. An unsuccessful sit-up was considering if the recruit lifted their hands from the knees or thighs, performed the sit-up with a jerking non-fluid movement, lifting the heels or buttocks off the ground, pausing in the "up" phase or an inability to maintain the cadence on the CD. An unsuccessful sit-up would elicit a warning; three warnings would signal termination of the assessment. The total number of successful sit-ups was recorded. On conclusion of the sit-up task the recruit's then moved to the designated area for the shuttle run test. Recruits rested for a minimum of five minutes prior to commencement of the next assessment. During this time

they were given instructions of the performance of an aerobic multistage fitness test to volitional exhaustion.

Figure 3: Sit-ups. (Photo was supplied by the DSTO, Melbourne)

2.3.1.3 Multistage fitness test

The multistage fitness test was used to predict VO_{2peak} (Léger and Lambert, 1982; Leger and Gadoury 1989. Recruits were required to run between two parallel lines set 20 m apart. The cadence was set at 8.5 $km.hr^{-1}$ for the first minute, increasing by 0.5 $km.hr^{-1}$ every minute thereafter until volitional termination, or not met the 20m line on the beep on two successive occasions (Figure 4). The last successful completed stage and shuttle within each stage was recorded. This completed the first series of assessments.

Figure 4: Shuttle run. (Photo was supplied by the DSTO, Melbourne)

2.3.1.4 2.4-km run

The Australian Army requires all recruits to complete a 2.4-km run to determine cardiovascular endurance. To comply with this requirement, all recruits in this investigation completed a 2.4-km at best pace in Week 8 only of the investigation. The recruits were required to complete six laps of a 400m running, time in seconds was recorded. The 2.4 km run was conducted by the Army PTI's and results were passed onto us.

2.4 Body mass

Stature and body mass was also assessed during this phase of the investigation. An individual's stature and mass have shown to correlate with the ability to perform physically demanding military tasks (Dziados *et al*., 1987; Mello *et al*., 1988). The recruits were asked to remove their shoes, leaving socks on, standing under the stadiometer, (Charder HM-200p

Portstad, Taichung city, Taiwan), with their feet flat on the centre of the base plate, shoulders back and straight as possible, arms are hanging by their side and looking straight ahead. Any adjustments to the recruits head were made by the researcher, i.e. the recruits head in a horizontal position (i.e. parallel to the floor). The horizontal position is an imaginary line passing through the external ear canal and across the top of the lower bone of the eye socket, immediately under the eye. Stature was measured to the nearest millimetre. Calibrated measuring scales, (Charder MS3200, Taichung city, Taiwan), positioned on a hard flat surface were used to record mass to the nearest 10 grams. Mass was recorded with recruits wearing PT turnout (t-shirt, shorts and socks), with the shoes removed.

2.5 Physical employment standards assessments

Three assessments, box lift and place, jerry carry and 3.2-km load carriage were conducted to assess the suitability of recruits to meet the functional physical demands of military training. The box lift and place and jerry carry were conducted on the same day, with the former assessment always preceding assessment of jerry carry. A minimum of 24 hours rest was enforced prior to assessment of the 3.2-km load carriage. The three tests were designed to assess the essential physical demands of military duties. Prior to each assessment day a physical training instructor would take the recruits through a standardised military relevant physical warm-up. Each of the assessments used in this phase are described below.

2.5.1 Single repetition (1RM)box lift

A box lift and place is a common manual handling task and was used to determine recruits single repetition maximal strength for this activity. (Rayson, 1998). The box, a plastic box (dimensions 480mm x 200mm x 190mm) handles on the side was lifted to a 1.5m platform,

thus hand height required to successfully complete the lift was 1.7m. Recruits were instructed on the correct lifting technique which required the spine to remain in a neutral position, placing the hands, palms facing upward under the handles, lift the box from a squat position with straight arms until the box was at the height of the hips, at this stage elbow flexion was to occur so that the arm could raise the box to chest level, recruits took a step forward while extending the arms to place the box onto the platform (Figure 5A-D). A three phase movement pattern was encouraged to complete the lift. Failure to maintain a neutral spine, performing the lift in a continuous or ballistic movement or sliding the box onto the platform was defined as an unsuccessful lift. The box after each lift was returned to a standardised position 500mm away from the lifting platform. Recruits were encouraged to adjust the distance of the box from the platform to suit their own physical constraints and lifting technique. All recruits conducted a standardised familiarisation in which they were required to lift a 10kg box for a maximum of three repetitions or until they showed competency in the lift technique. The mass of the box was then increased by 10kg increment for the first or second increment and their after box mass increased by 5 or 2.5kg until task failure. All boxes were coloured coded to ensure subjects could not calculate the final mass of the box. After each lift attempt recruits had a minimum of 2-min rest prior to the next attempt (Groeller et al., 2015). The highest mass successfully lifted was recorded in kg. Recruits then had a minimum of 10 min rest prior to completing the next assessment. To successfully pass this test, Army requires recruits to lift 25kg as the minimal standard. The test specification was directly linked to the requirements of manual material handling tasks and is designed to assess functional muscular strength (Carstairs, et al. 2016).

A B C D

Figure 5: Box lift and place lifting technique. (Photo was supplied by the DSTO, Melbourne)

2.5.2 Lift and carry assessment

The lift and carry assessment was used to determine local muscular endurance during manual handling tasks such as stretcher team carry (Williams *et al*., 1999). The task required recruits to carry two 22 kg liquid filled containers repeatedly over a 25 metre distance at a speed of 1.25 $m \cdot s^{-1}$, until volitional exhaustion or upon reaching 1000m (Figure 6). Prior to the assessment, all the containers were weighed and adjusted to ensure a mass of 22 ± 0.1kg. All assessments were conducted on a flat concrete surface, with the test performed to an audible electronic cadence. The assessment was demonstrated by a member of the research staff, all recruits were then given the opportunity to lift the water filled containers and walk 25 m to the cadence on one occasion. Recruits were instructed on the command "lift" to carry the containers, with a firm steady grip, without a swinging or rotating movement (Figure 6). At the end of each 25 m recruits were instructed to place the containers on the ground, turn 180^{o} and wait for the tone to pick the containers up again. Recruits were given one warning to show appropriate technique or to keep up with the prescribed cadence prior to termination of the assessment. Distance reached just prior to failure was recorded to the nearest 5 m. A minimum 24 hours rest was given prior to completion of the next assessment. To successfully

pass this test, Army requires recruits to carry the container for a minimal distance of 150 meters.

Figure 6: Jerry carry. (Photo was supplied by the DSTO, Melbourne)

2.5.3 3.2-km 22-kg load carriage

Recruits were required to cover a distance of 3.2km as quickly as possible with a load of 22 kg similar to the load anticipated when prepared with ‘fighting order’ (Knapik *et al.*, 2004). The assessment was performed in physical training clothing and shoes. Prior to commencing the trial, a physical training instructor conducted a standardised military warm up for the recruits. The recruits were then divided into four sections and fitted individually with a 22kg weighted vest that was placed over the shoulder encompassing the trunk of each recruit to ensure a firm fit. The mass of the vest was weighted prior to each assessment and the running track was measured to ensure the distance was 400m. Recruits were instructed to complete the 3.2km distance as quickly as possible (Figure 7). To ensure the recruits were familiar with load, the first lap of the 8-lap assessment was conducted at each individual’s fastest walking pace, there after recruits could complete the course at their fastest pace without constraint. To ensure this was an individual time trial, recruits commenced the assessment in 5 sec intervals

(Figure 8), the number of laps completed and time to complete the assessment minus their commencement time, was recorded in seconds.

Figure 7: Recruits performing the 3.2km 22kg load carriage at their best pace. (Photo was supplied by the DSTO, Melbourne)

Figure 8: Recruits starting with 5 sec intervals. (Photo was supplied by the DSTO, Melbourne)

2.6 Physiological assessments

A sub-sample of 10 subjects from each platoon, total 40, were used in measuring the physiological adaptations. The tests are commonly used to determine maximal oxygen consumption, anaerobic capacity, anaerobic peak power, muscular power and muscular strength (Dziados, *et al.*, 1987., Mello, *et al.*, 1988., Powers, *et al.*, 2009., Ramsbottom, *et al.*, 1988., Swain, *et al*., 2011).

2.6.1 VO_2peak treadmill test

The continuous graded treadmill test consisted of ten subjects, each aiming for their maximal oxygen consumption, (VO_2max). A motorised treadmill was used to perform the test. The running speed of the treadmill was such that the subject became exhausted in 8 to 12 minutes (ACSM Guidelines 2000). Safety mats were used for protection when a subject lost footing and fell backwards. A portable Parvo oxygen gas analyser (Metamax 3B, Cortex Medical LTD, Germany) was fitted for collection of expired gases. Subjects were also fitted with a heart rate monitor (Polar heart rate monitor FT4 Polar, Oulu, Finland). At the beginning of the test, subjects were dressed in their gym clothes, consisting of running shorts, T-shirt and running shoes. Subjects were given a briefing on what was expected in the maximal test. The subjects wore the heart rate monitor, were fitted with the portable gas analyser, chest straps and mouth piece. Gases were analysed by the computer program (Metamax 3B, Cortex Medical LTD, Germany), gas analyser, which was calibrated with known concentrations of O_2 and CO_2 before each test. Subjects began the test with 5 minutes warm-up, speed of 4.8-5.2 km.h^{-1} and 0% grade. Once the subjects had completed the warm-up, the speed of the treadmill was adjusted according to the subjects recorded heart rate. If the heart rate was greater than 160bpm, speed was set at 12 km.h^{-1}, 140-160bpm, 14.5 km.h^{-1}, less than 140bpm, 13.5 km.h^{-1}. On completion of the subjects adjusted running speed the treadmill

gradient increased 2% every 2 minutes until voluntary exhaustion. Verbal encouragement was given for subjects to exercise as long as possible. Measurements of maximal heart rate were defined as the highest recorded heart rate during the test. Maximal oxygen consumption ($V0_2$max) was determined as the highest consumption in the last 30 second period immediately prior to volitional termination. The data collected from the ($V0_2$max) test will be used to correlate with the other running test that is the shuttle run and 3.2km loaded march.

2.6.2 Wingate test

Subjects performed a Wingate test to determine peak anaerobic power (VO_{2peak}) and mean power output over a 30 second period (Inbar *et al*., 1996; Bar-Or., 1987). The subject's height and weight were collected. They were given a heart rate monitor (Polar heart rate monitor) to observe heart rate. The cycle ergometer used for the test was a Monark 894E peak bike, with an external flywheel resistance cradle. Extra weights were applied to the external flywheel for a predetermined load. This predetermine load was estimated, based on mass of the subject (0.075kg per 1kg of subject's body weight). For example a 70 kg subject had an external resistance of 5.25 kg applied to the flywheel. To measure both peak power and mean power out-put, the cycle ergometer was connected to a computer for data analysis. Each bike was calibrated before each test and the seat height for each subject recorded and maintained for each repeat assessment. Seat height was determined by an anatomical position of the hip, greater trochanter, and 5^0 flexion in the knee when the subjects foot strapped into the pedal and down at the bottom of the pedal stroke (Bulbulian, Jeong, & Murphy, 1996). The test began with the subject cycling on the bike at intensity to warm up, followed by 3 –5 minute seated rest (Powers *et al*., 2009). In the rest period the subjects were instructed to cycle as hard as possible but remain seated throughout the 30-sec test. Before the tests starts, the predetermined weights will be placed on the cradle, without placing any external

resistance until the test starts. On instructions, the subject began cycling at full revolutions, within 2-3 seconds, the predetermined load is applied. The subject was encouraged to continued pedalling as rapidly as possible. The peddle rate was recorded every 5 seconds during the test (Figure 9). Within the first five seconds of the applied resistance, maximal power output was considered the highest. Over the full 30-seconds verbal encouragement was given, to facilitate a maximal effort. Measurements of total work over 30-sec (Nm), peak power ($Nm \cdot s^{-1}$), average power ($Nm \cdot s^{-1}$) and time to peak power (ms) were recorded.

Figure 9: Recruit performing the Wingate cycle test. (Photo was supplied by the DSTO, Melbourne)

2.6.3 Vertical jump test

Vertical jumps form an important test to assess the explosive strength of the lower legs (Moir, 2008, Buckthorpe *et al*., 2012). Subjects were dressed in their gym clothing, T-shirt, running

shorts and running shoes. A force plate (Kistler 9281B, Instrumente AG, Winterthur, Switzerland) was the recording instrument for the vertical jump test. Force data were recorded with Bioware software (Kistler Multichannel Charge Amplifier (type 9865A), Kistler, Instrumente AG, Switzerland) at a frequency of 2000Hz for 20 seconds.

The test was performed indoors and the force plate was on a hard even surface. The force plate was zeroed prior to each vertical jump trial. Before performing the vertical jump subjects stood on the force plate body mass was recorded. Subjects warmed in the required position for the vertical jump test. This was for familiarisation and to warm up the body segments. The beginning phase of the jump was to be squatting down so the leg is bent with a 90 degree flexion at the knee. This was measured by using a goniometer, (Baseline) (figure 10). The recruits hands were placed on either side of their hips and were asked to keep them there as to no account for any counter action swing when jumping. This warm up phase would last up for 5 min, which consisting of dynamic exercises. On completion of the warm up phase, the subjects were instructed to stand on the vertical jump platform and squat down into the starting position. On a counting command from three, two, one the subject would jump as high as possible without using a non-countermoveing action, providing maximal effort from the lower body. The instantaneous peak force data was analysed. Acceleration was derived from the vertical ground force reaction and body mass, measured in Newton's second law of motion (force = mass x acceleration) with the adjustment of gravitation ($9.81 m.s^{-2}$). Vertical jump peak force was measured.

Figure 10: Measurement of knee flexion and hands on hips for the starting position of the vertical jump. (Photo was supplied by the DSTO, Melbourne)

2.6.4 Single repetition (1RM) bench press

Equipment for the exercise tests was in a gym environment, based at the Kapooka Army training barracks, Wagga Wagga, N.S.W. The bench press was performed on a Smith rack machine. Two spotters were present to ensure safety and provide encouragement. Protocols for the exercise were at an intensity to perform a single repetition maximally. Intensity of the exercise can be defined as the effort or how difficult the training stimulus was (ACSM, 2000). The starting weight for the exercise was perceived weights at 50-70% of their 1RM.. Subjects were given instruction on correct use and technique for the exercise; this provided a period of familiarisation and warm-up. Once the subject completed one repetition, weights were increase by 5-10 kg until their 1RM was determined. Between each successful lift, subjects were given 3-5 minutes rest.

Subjects began in a supine position on the bench in a five point body contact position, which is feet are flat on the ground, their body is flat on the bench and both hands are fixed to the bar, eyes are below the edge of the supports, hand grip is closed, in pronation and slightly wider than shoulder width. With assistance of the spotter, move bar off supports and place over chest level, elbows fully extended, this was the starting position. It was important that subjects continue to breathe throughout the exercise. Lower the bar to touch the chest at nipple level, maintain firm grip, wrist directly above elbows. Encourage subject to push the bar upwards until elbows are fully extended (Figure 11). Make sure the subject does not arch the back or raise the chest to meet the bar. In completion of the bench press return the bar to the rack. Once the subject had reached their 1RM the weight and perceived exhaustion were recorded.

Figure 11: Recruit performing the Single repetition (1RM) bench press. (Photo was supplied by the DSTO, Melbourne)

2.7 Statistical analysis

Statistical analyses were performed using GraphPad Prism 6. Repeated measure one-way *ANOVA*, linear regression with Tukey's multi-comparisons was used to determine the difference between weeks one, eight and twelve of basic training. Alpha was set at 0.05, with 95% confidence intervals. Pearson product moment correlation coefficients were used for the matrix with 95% confidence interval and R_2 value to determine the strength of the matrix.

CHAPTER THREE: RESULTS

3.0 RESULTS

This investigation commenced with 177 volunteer recruits at the start of basic military training. At the completion of basic military training the physical performance of 127 recruits (6 female) aged 21.5 ± 4.0 y, stature 177.7 ± 6.9 cm and mass 77.8 ± 11.6 kg. Fifty recruits were withdrawn from the investigation primarily due to the inability to meet a minimum standard of performance (Table 3). Also a summary of the point of entry fitness test scores for all recruits 177, and 40 randomly selected recruits for the physiological tests (Table 4).

Although no significant change was observed in body mass, ($p>0.05$), between weeks 1 (77.8 ± 11.6 kg), 8 (77.3 ± 9.9 kg) and 12 (77.3 ± 9.5 kg) a regression toward the mean was observed, with heaviest recruits appearing to lose body mass and lighter individuals gaining body mass during basic military training (Figure 12).

Table 3: Reason for withdrawal from Basic Military Training

Reason for withdrawal	**N**	**%**
Failure of RFA	16	32
Discharged	11	22
Medical, illness, injury	9	18
Re-assigned (back squad)	8	16
Failure of shooting standard	3	6
Failure of PFA	2	4
Other	1	2

Table 4: Summary table of the point of entry fitness scores of all recruits (177) and (40) recruits for the physiological testing of strength, power, high intensity work capacity and maximal oxygen consumption

Number of participants	177	40
Push-ups	41	40
Sit-ups	93	90
Shuttle run: levels	9.3 ± 1.5	8.8 ± 1.4
Vo2max ($ml.kg^{-1}.min^{-1}$)	46.8 ± 4.6	44.2 ± 1.4

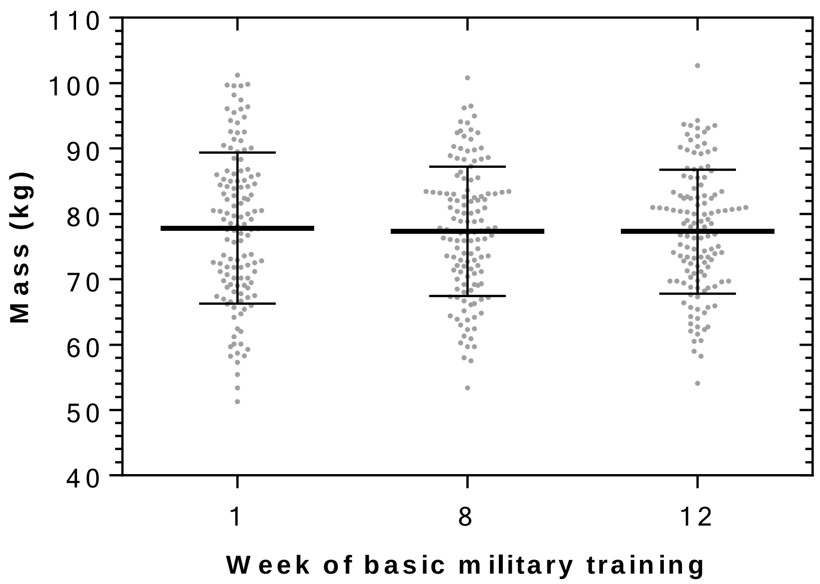

Figure 12: Change in body mass during Weeks 1, 8 and 12 of basic military training. Mean, ± standard deviation and individual data points shown as gray dots. N=128

3.1 The effect of basic military training on existing military assessments for physical fitness

Significant changes were recorded in all existing assessment used to evaluate recruit fitness. Push-up repetition number increased significantly by 18.5% and 19.2% in weeks 8 and 12 respectively compared to Week1 (Figure 13a). However, no significant difference was

observed in push up performance between weeks 8 and 12. A similar response was observed in sit-up performance, with significant improvements from baseline (Week 1), Week 8 (11.3%) and Week 12 (11.8%) ($p<0.0001$), however there was no significant change in trunk muscle endurance between week 8 and 12, ($p<0.33$), (Figure 13b). Unlike the push up assessment, total sit up number was capped at 100, thus it is quite likely given the mean values observed at weeks 8 and 12 within the investigation had reached the ceiling value, further changes in trunk muscle endurance during basic military training could not be detected. An estimated cardiorespiratory endurance was observed 44.1 ± 4.9 $mL.kg^{-1}.min^{-1}$ in Week 1 of basic military training. A significant ($p<0.05$) increase of 5.1 $mL.kg^{-1}.min^{-1}$ (11.9 %) was observed in Week 8. However, cardiorespiratory endurance was not maintained by Week 12 with a significant decline of 1.2 $mL.kg^{-1}.min^{-1}$ (2.4 %) recorded. These measurements were the results from the shuttle run scores (Figure 13c).

3.2 The effect of basic military training on assessments that are part of the occupationally relevant to soldiering duties

Single repetition box lift mass improved significantly ($p<0.05$) in Weeks 8, 3.3 kg (8.1%) and Week 12, 4. 8 kg (11.9%) of basic military training (Figure 14a). This improvement in 1RM box lift strength, ($p <0.0005$), was also significant between Weeks 8 and 12. Although, the mean lift scores of 40.3 kg, 43.6 kg, and 45.1 kg in Weeks 1, 8 and 12 respectively were well above the minimum requirement. Those with the lowest 1RM box lift score (17.5 kg) would require an improvement in excess of 42% to meet the minimum standard of 25 kg at the end of basic military training. Thus, of these recruits (4) only one was able to produce a 1RM box lift of 25 kg. To successfully pass this test, Army requires lifting 25kg as the minimal standard. The test specification was directly linked to the requirements of the manual material handling task and is designed to assess functional muscular strength (Carstairs, *et al.* 2016).

The Lift and carry assessment was limited to a maximum distance of 1000 m, with the 75th percentile reaching the maximum distance by Week 12 of basic military training (Figure 14b). Lift and carry distance improved significantly ($p<0.05$) in Week 8 and Week 12 when compared to Week 1 by 93 m (14.6%) and 65 m (10.2%) respectively. Lift and carriage distance was maintained between Weeks 8 and 12 despite recruits engaging in functional simulations that are their advance conditioning of field exercises in becoming a soldier, in the last four week of basic military training.

Performance of a 3.2 km 22-kg load carriage task improved significantly after 8 and 12 weeks of basic military training (Figure 14c). Load carriage performance improved by 2 min (10%) in Week 8 (113 s, 9.1%) and Week 12 (120 s, 9.7%) in recruits. However, load carriage performance was maintained in the final four weeks of the regimen, despite recruits engaging in field exercises during this phase of training.

3.3 The effect of basic military training on physiological assessments of physical performance

Throughout basic military training no significant change was observed in upper limb strength, as measured by a 1RM bench press (Figure 15a). We did observe significant variability gross upper limb strength, with the range in strength scores exceeding 100 kg or over 3 fold higher than that lowest score obtained by a recruit. Thus, the inherent strength profile of recruits varies considerably upon entry into basic military training.

Peak functional lower limb muscle force (Figure 15b) declined (70 N, 6.9%) significantly ($p<0.05$,) in Week 8 and approached significance ($p=0.052$) in Week 12 with a reduction of 74 N (7.3%). Interestingly, those in the highest quartile for vertical jump peak force,

exhibited a two-fold larger reduction in peak force than the mean of all recruits at Weeks 8 and 12. In contrast, thirty second high intensity work capacity was maintained throughout basic military training when compared to performance at Week 1 of training (Figure 15c). However, a significant ($p<0.05$) decline was observed between Weeks 8 (599 ± 115 W) and Week 12 (574 ± 107 W) of basic military training.

Cardiorespiratory endurance, that is VO_2 peak, was maintained throughout the basic military training regimen (Figure 15d). The military training did not have any effect of the endurance fitness of new recruits. Interestingly some recruits in the lowest quartile appear to have had a reduction in cardiorespiratory during basic military training.

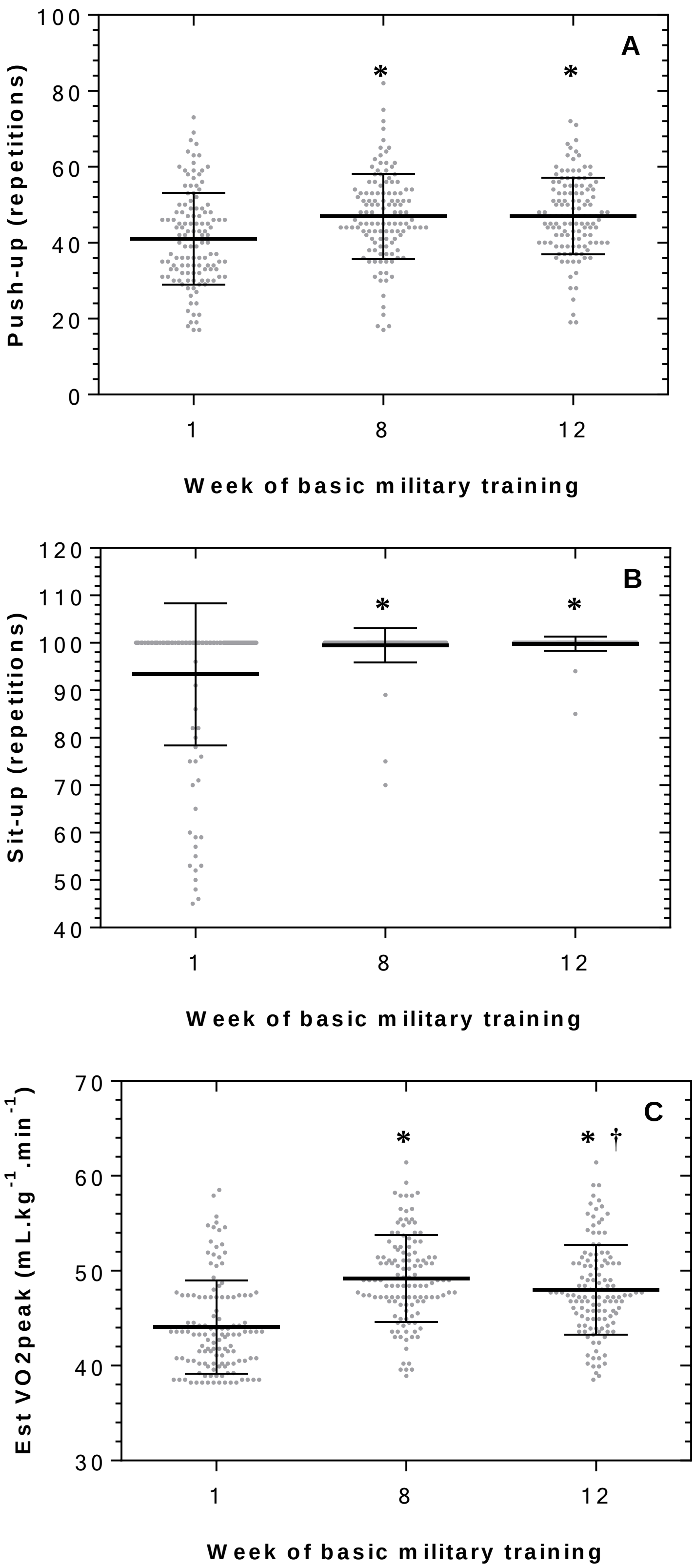

Figure 13: Change performance of existing military physical fitness assessments during basic military training. A) push-ups in 2 min (N=126), B) sit-ups, 3 sec cadence max of 100 (N=126), and C) estimated VO2peak; 20 m shuttle run (N=125). Mean, ± standard deviation with individual data points shown as gray dots. ***** denotes significantly ($p<0.05$) different to Week 1 and † significantly different ($p<0.05$) from Week 8.

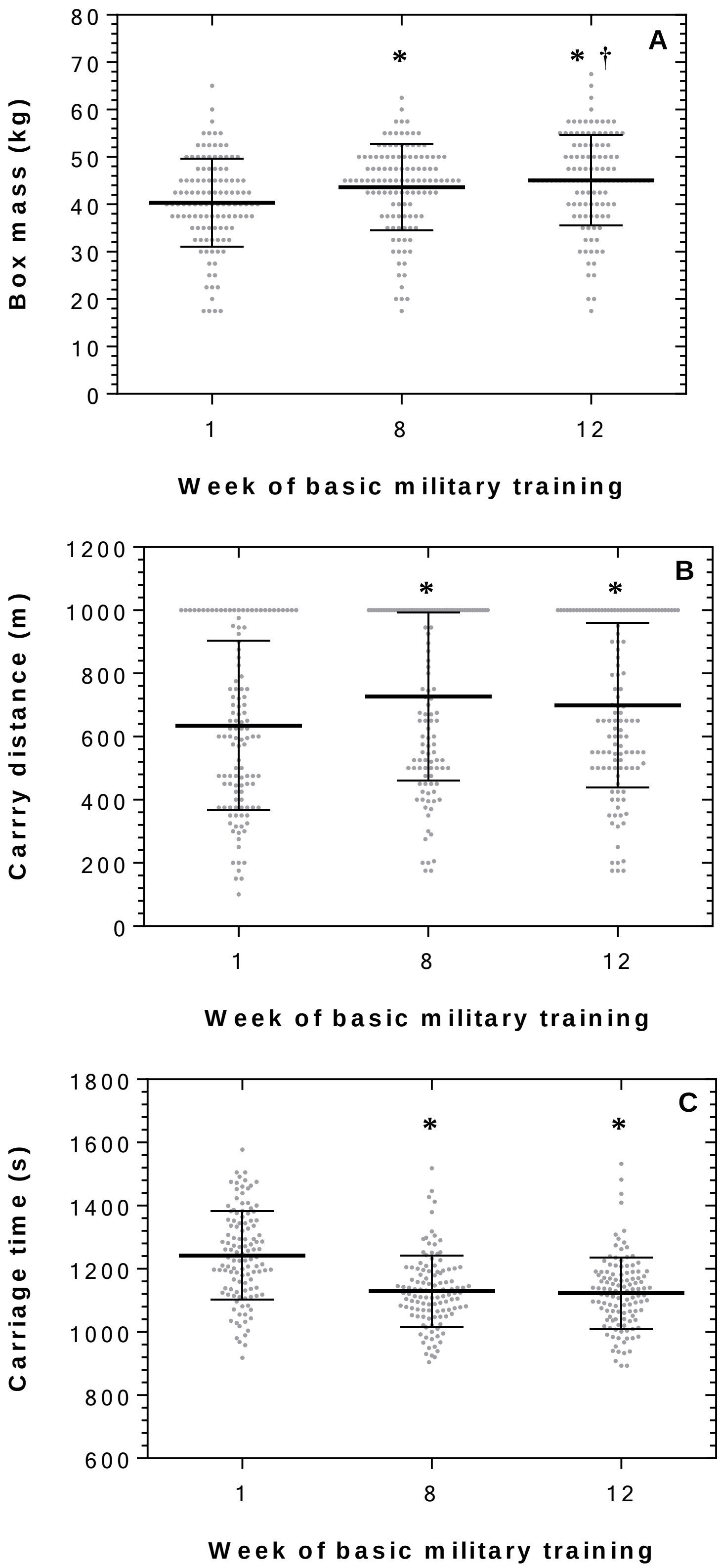

Figure 14: Change performance of occupationally relevant military physical assessments during basic military training. A) single repetition maximum box lift (N=119), B) jerry carry, maximum distance 1000 m (N=119), and C) 3.2 km 22 kg load carriage (N=118). Mean, ± standard deviation with individual data points shown as gray dots. ***** denotes significantly ($p<0.05$) different to Week 1 and † significantly different ($p<0.05$) from Week 8.

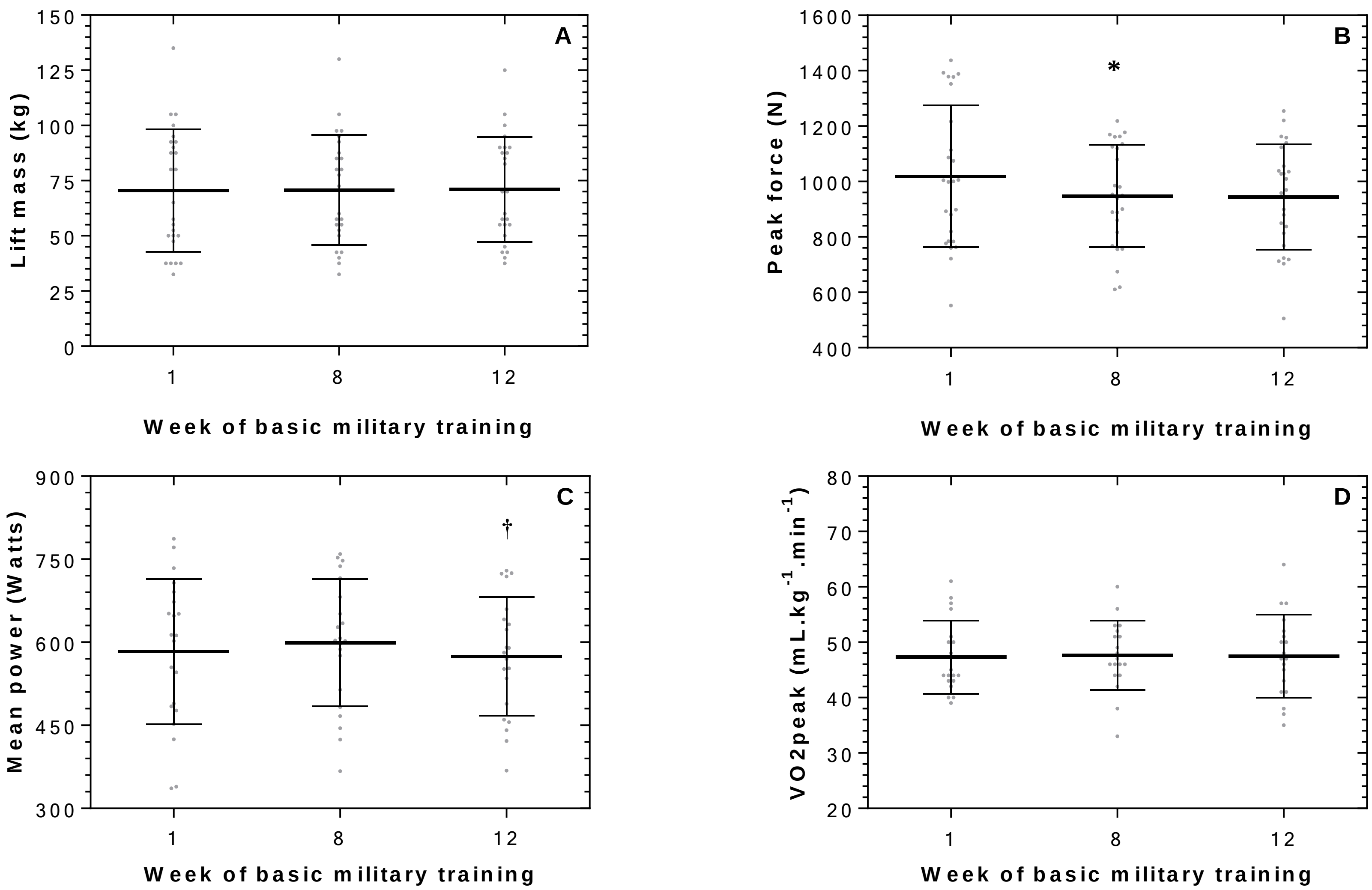

Figure 15: Change performance of physiological assessments during basic military training. A) single repetition maximum bench press (N=25), B) vertical jump (N=25), C) 30-s high intensity cycle capacity (N=21), and D) treadmill VO_2peak (N=19). Mean, ± standard deviation with individual data points shown as gray dots. ***** denotes significantly ($p<0.05$) different to Week 1 and **†** significantly different ($p<0.05$) from Week 8.

3.4 The correlation between occupational relevant assessments of performance and existing military physical fitness assessments.

A moderate relationship (Figure 16a) was observed between predicted maximal oxygen consumption (Weeks 1 and 8) and 3.2 km load carriage performance (Weeks 1 and 8). However, considerably more variability is displayed at the lowest predicted oxygen consumption scores and slower load carriage speed. In contrast, no relationship was seen between occupationally relevant assessments of military duties (1RM box lift and lift and carry) and push-up performance (Figures 16b and 16c).

3.5 The predicted recruit entry standards for occupationally relevant military physical assessments.

Two means of determining entry standards are shown, in tabular form, Week one entry cut point shown. The number of recruits that are able to meet the cut point standard is listed for jerry carry, 150 meter (Table 5.1) and 1RM box lift, 25kg (Table 5.2). Recruits that meet the Week one entry standard, but subsequently did not meet the minimum standard upon completion are listed as false positives, that they were falsely permitted entry (positive) into basic military training but could not meet the minimum standards at completion of the training course. In contrast those recruits that hypothetically would have been inappropriately denied entry into recruit training (false negative) but were able to meet the minimum standard at the end of basic military training are listed. Table 3.1 shows a jerry carry distance of approximately 150 m leads to the lowest number of false positives and negatives. Similarly in Table 3.2 an entry standard of 20 kg, lead only to one recruit that was unable to achieve the minimum 25 kg single repetition lift mass at the completion of basic military training.

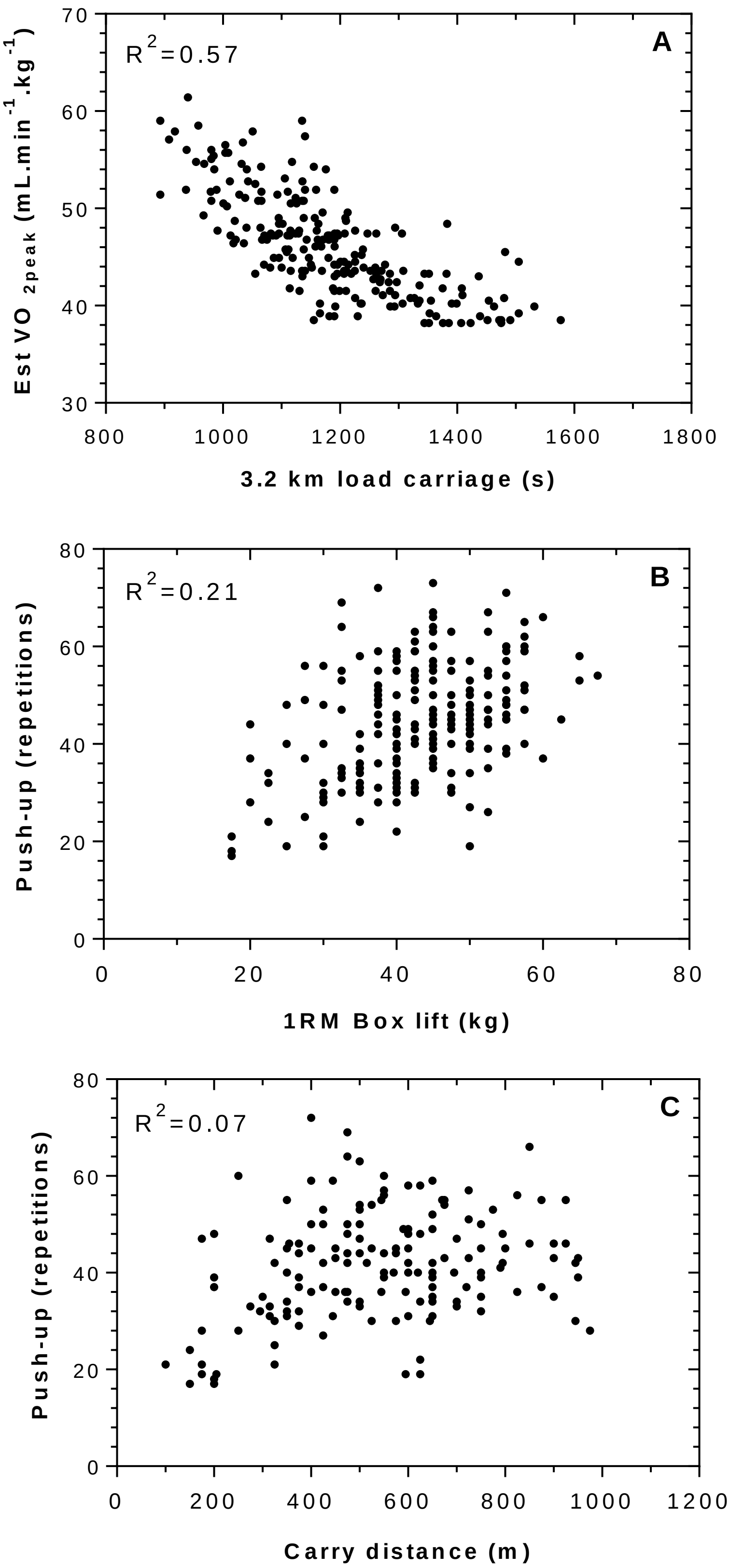

Figure 16: The relationship between A) 20-m shuttle run and 3.2 km 22 kg load carriage time, (p 0.0001) B) push-ups in 2 min and single repetition box lift mass, (p 0.001) and C) push-ups in 2 min and jerry carriage distance (p 0.0003).

Table 5.1: Lift and carry standards and false positives and negatives after BMT

Carriage distance (m)	Recruit number	Meet standard (%)	False positives	False negatives
100	119	100	2	0
125	119	100	2	0
150	118	99	1	0
175	116	97	0	1
200	115	96	0	2

Notes: Carriage distance achieved at week one; recruit number, how many recruits could achieve the carriage distance at Week 1. Meet standard, is the percentage of recruits that are able to meet the carriage distance at Week 1; false positives is the number of recruits that were permitted entry into basic military training on the basis of the carriage distance, but could not attain the minimum 150 m performance standard by Week 12. False negative are those recruits, who hypothetically were not permitted entry into basic military training due to the carriage distance, but were able to achieve a 150 m jerry carry by Week 12.

Table 5.2: Box lift and place standards and false positives and negatives after BMT

1RM box lift (kg)	Recruit number	Meet standard (%)	False positives	False negatives
15	119	100	5	0
17.5	119	100	5	0
20	115	96	1	0
22.5	114	95	1	1
25	111	93	0	3

Notes: Single repetition maximum box lift mass (1RM box lift) attained at week one; recruit number, how many recruits could achieve the 1RM box lift mass at Week 1. Meet standard, is the percentage of recruits that are able to meet the box lift mass at Week 1; false positives is the number of recruits that were permitted entry into basic military training on the basis of the box lift mass, but could not attain the minimum 25 kg performance standard by Week 12. False negatives are those recruits, who hypothetically were not permitted entry into basic military training due to the 1RM box lift mass, but were able to achieve a 25 kg box lift by Week 12.

CHAPTER FOUR: DISCUSSION

4.0 DISCUSSION

Within this investigation some key findings were observed; i) A 12-week basic military training regimen was effective in significantly increasing cardiorespiratory endurance, comparatively however, ii) gains in muscle strength and power were considerably smaller than changes observed in cardiorespiratory endurance, iii) basic training significantly improved local muscular endurance and strength, iv) the time course of adaptation was not linear; the greatest improvements in physical performance observed in the first eight weeks of training. In contrast, within the final four weeks of basic military training maintenance of physical performance was generally observed, and, v) a poor relationship was observed between existing standard assessment of military performance and task that were functionally relevant to military duties.

4.1 Basic military training modifies endurance capacity

Within this investigation we observed 7.5percent increase in estimated peak oxygen consumption as measured by a 20m-shuttle run over the duration of basic training. These findings agree with other recruit training (Pope *et al*., 1999; Cooper *et al*., 2005; Aandstad *et al*., 2011).These results suggest there is a significant increase in cardiorespiratory endurance as a result of basic military training. The elevation we observed in cardiorespiratory endurance is consistent with the findings from other military training regimen (Williams., 1999, 2005; Knapik *et al*., 1980, 1989, 2006; Dyrstad *et al*., 2006). For example, within the U.S. defense force, American officer candidates had a 10% improvement in shuttle run and Coopers 12 minute running performance test after 14 weeks of basic training (Rosendal *et al*., 2003). Similarly, an 8% and 9% increase in estimated VO_{2max} was observed in British recruits who also entered into basic training (Rayson *et al*., 2000; Williams *et al*., 1999, 2005). However these investigations did not observe uniform adaptation in all recruits (Dyrstad et

al., 2006). For example, Rayson *et al*., (2000) observed the recruits who commenced training with below average fitness were most responsive to the training regimen, resulting in a significant elevation in VO_{2max}. Similarly, Dyrstad, *et al*., (2006) reported that recruits with an initial V_{02max} greater than (54.9 $mL.kg^{-1}.min^{-1}$) did not improve cardiorespiratory endurance during basic training. Indeed, basic training has been shown to elicit deconditioning in some recruits, suggesting the training load was of insufficient volume or intensity for some recruits to elicit positive adaptation (Legg and Duggan., 1996; Daniels *et al*., 1979; Marcinik *et al*., 1985).

Within our investigation, we did see a disparate adaptive response in recruit's fitness. Despite observing a significant improvement in estimated V_{02peak} during basic military training, approximately fourteen percent (n= 17) of recruits with a V_{02peak} above $50mL.kg^{-1}.min^{-1}$ displayed a decrease in endurance performance after 12 weeks of basic training (Kraemer, *et al*., 2004; Santtila *et al*., 2012). Furthermore, it appeared that much of this decrease in performance in this subgroup occurred in the final 4 weeks of the regimen. During this stage of training a 3% decrease in shuttle run performance was observed. This is similar to the findings by (Knapik, *et al*., 2006) and (Williams *et al*., 1999) who suggested that the basic training program lack sufficient progression and individualisation to facilitate improvements in all recruits attending basic training. Alternatively, the relative plateau or decline in physical adaptation has been suggested to occur due to a significant and prolonged accumulation of fatigue (Brushøj *et al*., 2008; Rosendal *et al*., 2003). Elevated levels of fatigue are associated with mal-adaptation resulting in an increase in the incidence of musculoskeletal injury during basic military training (Rosendal *et al*., 2003; Kaufman *et al*., 2000; Rudzki., 1997).

Although estimated peak oxygen consumption improved, we observed no change in peak treadmill oxygen consumption in the subgrouping of recruits. This finding suggests the cardiovascular fitness of the recruits was maintained throughout basic training. To seek an explanation of why there was a disparate results. We compared the subgroup average aerobic capacity against the aerobic capacity standard set by the shuttle run test. It was noted that the subgroup average aerobic capacity was 4.7mL.kg^{-1}.min^{-1} greater than the shuttle run minimal standard set by the Army. However, the subgroup when compared to the average aerobic capacity of all recruits that completed the shuttle run was 3.0mL.kg^{-1}.min^{-1} less. This first explanation provides us with an understanding into the subgroup level of fitness, that is being above the minimal standard expected by the Army and possibly having little area for improvement in aerobic capacity. Legg and Duggan., (1996) in their study on British Army recruits also found that the junior infantry recruits who had a higher level of aerobic capacity when compared to the Army aerobic standard saw no change, even a reduction after basic training.

It was found that the emphasis on low intense training like long marching with heavy packs was the cause of the reduction. This contradicts the finding of Rudzki.,(1991).Yet, supporting evidence into the level of basic training, which includes marching, general conditioning (mostly running) and military specific training does have a positive effect on the V_{02max} for those who enter with a low level of fitness (Rudzki 1989). However to those who enter basic training with a high level of aerobic capacity there seems to have minimal effect (Rosendal, *et al*., 2003; Legg and Duggan., 1996). This is true; therefore it might have been beneficial if the selected group of recruits were chosen from shuttle run scores that failed to meet the Army standard. What is important is the maximal rate of oxygen consumption (V_{O2max}) is considered to be the optimal standard for measurement of aerobic fitness (Sutton, 1992) and

is an important determinant of the physical work capacity, of which an individual is capable (Brooks *et al*., 1996). Such importance in occupations that require employees to function at a higher activity level, like the Army, gives confidence that the working task are performed effectively and in a safe manner (Bilzon *et al*., 2001). While taking direct measurement of oxygen consumption using the treadmill provides precise measurement (Leger *et al*., 1988; Noakes *et al*., 1990) it requires motivation by the subject (Rosendal *et al*., 2003) and requires sophisticated equipment, laboratory time, and trained personnel, and it may not be appropriate for some applications (Stickland *et al*.,2003).

Furthermore, the treadmill test is not a familiar test in basic training and is not common to the recruit. For this reason, military services have selected to using the shuttle run as a predictor of recruit's aerobic capacity (Aandstad *et al*., 2011) due to the test being performed on a large scale of recruits (Bilzon *et al*., 2001). Correlations between the treadmill test and the shuttle run in our study was weakR^2 = 0.05. This correlation refers to the VO_2 peak scores over the training duration. This weakness may be related to the results in the treadmill test having no significant change, compared to the shuttle run scores. Therefore in consideration of these factors, we believe changes in 20m-shuttle run performance are a better reflection of adaptive changes in cardiorespiratory endurance performance that the direct measurement peak oxygen consumption while running on a treadmill to volitional exhaustion (Aandstad *et al*., 2011).

On the other hand, our correlations for the shuttle run and the 3.2km 22kg loaded march were stronger, R^2 = 0.63. This leads to our next form of testing and more functional to Army duties, the 3.2km 22 kg load carriage. Carrying external mass is more functional within soldier's tasks (Bilzon *et al*., 2001). The carrying of loads by soldiers is an important aspect

of military operations that can become critical in some situations (Knapik., 1989; Soule *et al*., 1978; Knapik *et al*., 1996).

Within our study, recruits at the end of basic training had a significant improvement in their 3.2km 22kg load carriage task by 9%.When compared to the shuttle run scores, that is, their VO_2 max recruits only increased by 1.5%. It has been illustrated by Wilkinson *et al*., (2014) that the shuttle run test has recently been shown to be a reliable test for monitoring changes in aerobic-related fitness in military personnel and estimating maximum oxygen uptake (Aandstad *et al*., 2011). Also, previous studies have shown that maximum oxygen uptake is highly correlated (R^2 = 0.9) with both shuttle run testing performance and running distances ranging from 2.4 to 10 km (Ramsbottom *et al*.,1988; Paliczka *et al*.,1987). Indeed basic training has positive effects on recruits and their ability to carry external loads (Harman *et al*., 2008; Williams., 2005; Kraemer *et al*., 2001). Within the literature there is a vast difference is loads that are carried between Armies, For example, Rayson *et al*., (2000) found that ten weeks of British Army recruit training reduced 12.8-km, 15-kg load carriage time of twenty men and fourteen women by 6.7% and reduced 12.8-km, 25-kg load carriage time of 50 men by 16%. Thus increased load carriage time is associated with improved load carriage performance (Orr, *et al*., 2014; Knapik, *et al*., 2012).

Furthermore, investigation into improvement in load carriage performance in recruits has considered the inclusion of extra training methods, such as resistance, upper body strength and combination of resistance, endurance and strength (Ham *et al.*, 2010, Harman *et al.*,2008, Harman *et al*., 1997, Hendrickson *et al*., 2010). This has led to improved performance. For example, Kraemer *et al*., (2004) noted that after twelve weeks of training U.S soldiers that perform endurance training alone had a small improvement in their load carriage, however it was suggested concurrent training is important and possibly necessary to achieve

improvement for this type of task. Only the groups performing concurrent training significantly decreased time to completion, whereas resistance training and endurance training alone showed no change in performance. Previously, Kraemer *et al*.,(2001) showed similar improvements for military women performing concurrent and aerobic only training. Williams *et al*., (2002) also reported improvements in loaded marching when heavy resistance training was included with basic training; however, these differences were not significantly from normal basic training.

4.2 Basic military training significantly improves local muscle endurance and strength

Because of the strenuous physical effort involved in military activities, the requirements of the individual's fitness must be of high standard, and, therefore, army recruits engage in a rigorous exercise-training program during their initial months of military recruitment. It is well known that basic training affects a variety of physiological parameters, and one is the muscular endurance (Williams *et al*., 1999; Woodhead and Moynihan., 1994; Har., 1999).

Investigations that have assessed strength development during military training have used isokinetic or isometric procedures, with conflicting results. For example, Knapik *et al*., (1980) observed a positive influence on the muscular strength in both male and female recruits who completed the U.S. Army Basic Initial Entry Training program. The recruits had increases in their upper torso strength, 9.3%, for males and 4.2% for females. Also there was an increase in trunk strength of 15.9% and 8.1% respectively. The female were observed to increase greater than the male cohort and this is due to the females having a lower initial strength levels. In contrast Har., (1999) saw a change in the British Army officer cadets in their basic training of a five to nine percent increase in strength.

However, Marcinik *et al*., (1985) observed a reduction in strength within Naval personal. Within our study we experienced a significant increase in upper and trunk local muscle endurance. This was observed upon completing of the twelve weeks of basic military training with Upper-body local muscle endurance improved by ~19% after 12 weeks of military training. This increase was also observed by Dyrstad *et al*., (2006) with regards to the Norwegian military basic training, where there was a 25% increase in push up performance after ten weeks of training. In developing upper body strength, people will usually train their body to some sort of strength training program in a gym environment (Baker and Newton., 2005; Kraemer *et al*., 1995). It is recommended for increase in strength to occur subjects must train with heavier loads using low repetitions and three to five minutes rest (American College of Sports Medicine., 2009) However, in our study, recruits did not have the opportunity to exercise in a gym environment. However, the recruits were exposed throughout their daily activities to push ups, this replication of the task was one of the major contributors to the increase strength. Plus, there are other segments within the basic training that contribute to the increase in upper body strength. These include heavy backpack marching (Dyrstad *et al*., 2006), combat training (Nindl *et al*.,2002) and other obligatory and optional strength exercises (Faff and Korneta., 2000; Knapik *et al*., 1980).

We observed an 11% increase in the number of sit-ups that recruits could perform over the twelve week duration of the regimen. Again the improvement in the sit-up performance was related to the continued exposure to sit-up exercise throughout the 12-week regimen. Furthermore, recruits are exposed to additional exercise that could contribute to improved trunk strength and endurance. An example of such an exercise was a loaded backpack march, which was completed frequently within basic training and is associated with improved trunk strength and endurance (Kraemer *et al*., 2004). Additionally within the literature improved

recruit sit-up performance has been observed (Dyrstad *et al*., 2006; Legg and Duggan., 1996; Knapik *et al*., 2001). Knapik *et al*., (2001) observed a twenty five percent increase in sit-up performance in U.S recruits that completed basic training. Also Dyrstad *et al*., (2006) reported a thirty five percent increase in Norwegian recruits, significantly higher than that observed within Australian recruits. However, some of the differences observed may be accounted for by methodological differences in the assessment of sit-up performance, where sit-up performance is time-limited (Knapik *et al*., 2001; Childs *et al*., 2010) or performed to volitional termination (Dyrstad *et al*., 2006). Within our study the sit-up test was limited to 100 sit-up repetitions and may explain the lack of sensitivity to observed changes in sit-up performance.

Assessment of trunk strength and endurance, have measured the soldier's ability to carry equipment and supplies on their bodies during military training and operations (Childs *et* al., 2010). Of the many ways to carry loads, carrying loads closest to the body was found to be the most efficient and less energy expenditure (Goldman and, Iampietro.,1962; Soule *et al.*, 1978). However as the loads have increased over time (Knapik *et al*., 2004) the strain it has placed on the trunk region increased exposing soldiers to a greater risk of injury (Knapik *et al*.,1992) mainly to the lower back (Jones *et al*., 1993). It has been suggested that strengthen exercise program be applied to back, abdominal, hamstrings and hip muscle to prevent such injuries (Jones *et al*., 1993). However, poorer sit-up performance in recruits has been associated with a higher incidence of musculoskeletal injuries in training (Knapik *et al*., 1993). The performance of sit-ups can actually be a mechanism of injury due to shear forces associated with the movement which has been recognised mainly in the lumbar spine (Axler and McGill., 1997). This is not favourable, increased muscle activation anteriorly results in both initial hyperextension and subsequent excessive flexion of the lumbar spine,

contributing to large compressive forces during sit-ups (Norris., 1993). In contrast, isometric trunk stabilisation exercise has been shown to significantly improve trunk strength and sit-up performance (Childs *et al*., 2010).

A functional task commonly performed in the military, that combines both upper-body and trunk endurance is the repetitive lift and carry (Rayson *et al*., 2000; Williams., 2005; Sharp, *et al*., 2002). We observed in the first eight weeks of basic training an improvement in jerry carry distance of 27% which was significantly greater than that observed for push-up and sit-ups. Within the literature, different militaries trained their personnel in such a task, however they were not the same protocol as our study but the action was similar. For example, the U.S. military designed a physical conditioning program on load carriage and lifting performance for a group of female soldiers (Harman *et al*., 1997). The program focused on weight training, running, backpack marching and specialized drills. The aim was to improve the females lifting an 18kg box, walk 25 meters and place it on a fifty two inch high surface as many times in ten minutes. After twenty four weeks of the program the outcome saw an increased by 17.5% the number of times in 10 minutes that a eighteen kilogram box could be lifted off the ground, carried 25 feet and lifted onto a fifty two inch high shelf (Harman *et al*., 1997).

Furthermore, it has been acknowledged that the improvement can be attributed to the general physical conditioning recruits perform on regular bases during basic Army training (Nindl *et al*., 2002; Sharp., 1993). Such conditioning like general marching, marching with loaded back packs, obstacle course training with weapons has a positive effect to the increase in physical adaptation of the upper, lower and trunk body (Sharp., 1993). A similar effect was noted by Williams., (2005) who examined both British full time and reserve recruits. During the

twelve week period of basic training, there was different variation in training periods for each group. The regular recruits did ninety periods, of forty minutes, within the first eleven weeks of training, specifically focused for physical training. These ninety periods consisted of, sports (23 periods), circuit training (22 periods), endurance (13 periods), agility (12 periods), swimming (9 periods), material handling (3 periods), and fitness monitoring sessions (8 periods). For the reserve recruits, they had 10 periods of 45 minutes within the first 11 weeks of training (during 5 training weekends) were used specifically for physical training, consisting of endurance (8 periods) and agility (2 periods) (Williams., 2005). After basic training both groups of recruits had improvements in load carriage, despite different variation in training periods between the full time and reserve recruits. Furthermore, there were favourable improvements in aerobic fitness and body composition. It was noted that, for the reserves, an increase in training volume may match the fitness levels of full time Army recruits (Williams., 2005). While local muscle endurance within our study increased in a positive direction, it did however begin to slow, even plateau in the last four weeks of basic training. This plateau may result from the change in training, where the focus is aimed at practical task and not so much fitness base.

Although local muscle endurance (push-ups, sit-ups and jerry carry) was a physical attribute that improved most during basic military training, these changes were observed in the first 8 weeks of the 12-week regimen. In the final four weeks of training we observed no change in each assessment. We believe there are a few reasons for such outcomes. Firstly, this lack of adaptation may be related to a change in the focus of military training from daily physical activities which involve running, swimming, circuit training, running time trials, functional circuits, battle physical training, lift and carries, basic fitness assessment's, rope climbing, obstacle course and loaded pack marching. These daily physical activities would be in

duration from forty minutes to one hundred and twenty minutes. Secondly in the later part of basic training these recruits' activities had more emphasis placed upon basic military skills rather than the development physical fitness. These skills were performed in the field phase and required recruit's to be established outside, in an environment that requires the recruit's mental and physical awareness to be alert for a longer duration, i.e. simulated night attacks from opposition forces. The reduced emphasis on the development of physical capacity may mean there is insufficient exercise duration or more likely exercise intensity to facilitate further gains in physical fitness. This may explain the failure to make further adaptations. Also, recruits had significant levels of residual fatigue during the field phase of basic training. This possibility of fatigue was observed by Booth *et al* (2006) within the Australian Army recruits that were exposed to significant physical and psychological stress that may have caused from the development of overtraining.

4.3 Basic military training results in limited gains in muscle strength and power

Strength is a critical physical attribute for many manual handling tasks (Knapik and Sharp., 1998; Williams *et al*., 1999). In particular within the military, where heavy and awkward loads such as artillery shells, stores and ammunition boxes must be regularly moved or transported without the benefit of mechanised lifting equipment (Kraemer *et al*., 2004; Knapik and Sharp., 1998; Williams *et al*., 1999). Research has shown that recruits have a significant increase in aerobic fitness (Williams., 1999, 2005; Knapik *et al*., 1980, 1989, 2006; Dyrstad *et al*., 2006) yet limited increase in muscular strength during basic military training (Harman *et al*., 2008; Kraemer *et al*., 2004). The limited increase in strength during basic training is partly due to the non-specific way strength is developed. However, some explosive power training such as jumping, sprinting and lifting routines are still performed during the basic training (Kraemer *et al*., 2004; Santtila., 2010). Of course, basic training

activities require the recruits to sustain a higher level of aerobic capacity. Additionally, the recruit's daily activities have gained a greater importance on the neuromuscular performance which serves as a greater importance in military duties (Sale.,1988).

The increase in strength gains in our study can be related to the progressive adaptation of load bearing exercises recruits have to perform on regular bases in their progression of training.

Some of the improvement we observed in the lifting task had significant neural adaptation and cannot be ruled out as a contributing factor, due to replication of the assessment movement within the training regimen (Sale., 1988; Santtila., 2010). Yet it is debatable to ask if the increase in strength in basic training is sufficient to sustain some of the heavy working capacity of Army duties. According to Kraemer *et al*., (2001), three different methods of concurrent strength and endurance training improved occupational performance more than aerobic endurance training supplemented with light resistance band exercises following twenty four weeks of training. Shorter studies by Sharp *et al*. (1993) and Harman *et al.* (1997, 2008) showed that supplementing typical military training with weight-based exercises or performing exercises that replicate the action of occupational tasks improves performance in these activities. These findings reiterate the importance of specificity of training for improving occupational task performance over shorter periods of time. For example, Knapik., (1997) trained female cohort for 14 weeks, performing progressive resistance training three days per week and running with interval training two days per week. The female cohort improved their ability by seventeen percent to lift 15 kg as many times as possible in 10 minute test. It was concluded that a short-term physical fitness program, conducted one hour per day, five days per week, can substantially improve women's manual material handling capability and provide favourable changes in body composition (increased fat-free mass and decreased body fat).

Also, when Williams *et al*., (2002) added resistance training to basic military training they observed improvements in strength and load carriage performance of 12 and 17% respectively compared to basic military training on its own. These investigations indicate that with and appropriate training stimulus, such as assisted pull-up, bench press, seated row, shoulder press, dead lift, high curl, leg press and upright row, significant gains in strength can still be obtained with a basic military training regimen. It seems beneficial to have some form of resistance training included in basic training for significant increase in muscle strength.
This resistance training could possibly provide greater strength gains within our study and also decrease the possibility of injury that some recruits sustain in basic training (Booth *et al*., 2006). Within our selected group that performed the 1 maximal repetition bench press, none of the recruits recorded any significant changes throughout the duration of basic training. In fact, we observed a decrease in lift capacity of approximately two percent.

The limited gains in upper-body strength may have been influenced by the high proportion of endurance training commonly found within basic military training. Endurance training is known to have a detrimental effect on the development of muscular strength (Kraemer, *et al*., 1995). For example, after eight weeks of hard military training, the U.S rangers had a negative effect on their maximal lifting capacity and power outputs by twenty percent (Nindl *et al*., 2007).With this understanding of endurance in mind, upper body strength has an essential role in the performance of functional and manual work tasks (Kraemer *et al*., 2004). As for the impact basic training had on our subjects, Kraemer *et al*., (2004) stated that residual fatigue from endurance training inhibits the ability to generate force during subsequent resistive training on the upper body.

This ability to generate force was also noted in our study on those subjects that completed the Wingate bike test. The Wingate power test is used in the measurement of peak anaerobic power and anaerobic capacity (Smith and Hill., 1991), the purpose in our study was the effect basic training had on recruits. Recruits displayed no significant increase in power output over the three different testing periods. Nevertheless the recruit's ability to maintain their power output in the thirty second test decline significantly. There are two assumptions for this inability to maintain power over a short duration. Firstly, the majority of basic training is based on aerobic fitness and endurance (Knapik *et al*., 2006). Therefore, it is possible that the muscle system, which is the ability to use the anaerobic system, is not fully adapted. Therefore the reduction in high-intensity power may be due to limited available substrates required to maintain exercise intensity, that is decrease ATP-phospho-creatine and or glucose-glycogen levels, enzymatic impairment due to muscle tissue damage, insufficient buffering or dehydration (Beneke *et al*., 2002). Secondly, as mentioned previously, the level of fatigue recruits sustain in basic training effects their performance (Nindl *et al*., 2007). This may explain the outcomes we also noted in the recruits vertical jumping performance. Recruits decrease in jumping performance over the duration of basic training by seven percent.

Regular running, marching, loaded marching and physical activities that are sustained for long periods have a fatiguing effect on recruit's lower limbs and this is possible for the decrease in jump performance (Caiozzo, *et al*., 1992; Rosendal, *et al*., 2003). In contrast, to its ability to increase intermittent endurance capacity, basic training failed to enhance or even preserve functional muscular performance as measured by the jump tests. After twelve weeks of basic training a study by Rosendal, *et al*., (2003) also experienced a detrimental effect on maximal jumping height in ninety three percent of the soldiers they tested. Physiologically as a whole, Nindl, *et al.*, (2007) observed the consequences of U.S. Army rangers in training

and noted on the hormonal level that there was a catabolism in the circulating total testosterone and a decrease in IGF-I, also a noted increase in cortisol. Nindl, *et al.,* (2007) further stated that these findings resulted in an energy deficit, mediated via hypothalamic-pituitary signalling peptides. Alongside the fat free mass loss, a notable decline in testosterone concentrations may be a contribution to the decrease of jumping power (Roy, *et al*., 2002). However, no measurements with regards to energy intake or energy expenditure were conducted in this study. Therefore, the role of the possible decrease at this level remains unclear. Although basic training increases endurance capacities, it seems to have been unsuccessful to improve functional muscular performance as measured by the jump test (Kraemer *et al*., 2004). It is concluded that basic training in the Australian Army produces some favourable adaptations in recruits, especially in terms of aerobic fitness. However, it can be assumed that development of strength and material handling ability during training fails to improve the ability of soldiers to perform some military tasks, and it does little to reduce future injury risk while performing these tasks.

4.4 The correlation between occupational relevant assessments of performance and existing military physical fitness assessments.

Within this investigation the relationship between Army fitness training and tasks performed by recruits was evaluated. As mentioned, the overall aerobic capacity of recruits significantly increased throughout basic training. This increase in aerobic capacity correlated with a moderate relationship between predicted maximal oxygen consumption (weeks one and eight) and 3.2 km load carriage performance (weeks one and eight). Similar changes were observed by Kraemer *et al*., (2004) who examined the effects of high intensity endurance training, resistance training alone on performance of various military tasks. In this study, training was performed four days per week for 12 weeks. The endurance training consisted

of long distance running and sprint interval training. Long distance runs were performed on Mondays and Thursdays and sprint intervals were completed on Tuesdays and Fridays. At the end of the training regimen recruits who performed endurance training were observed to have the greatest decrease in 3.2km load carriage time. Also, Kraemer *et al*., (2001) observed that women who participated in six months of total-body or only upper-body weight-based training plus aerobic training significantly improved the speed at which they could carry 34 kg over a 3.2 km distance.

In our study, there was more variability displayed at the lowest predicted oxygen consumption scores and slower load carriage speed. This possibly is a result of two factors. Firstly the training was not specific to the task that was tested. Secondly a weight bearing test such as the 3.2km loaded march removes the bias towards recruits that are better suited to the shuttle run. With respect to task related activities, Rudzki., (1989) conducted a study comparing two 11-week recruit conditioning programs. One program consisted of endurance running, load carriage, and other conditioning activities (run group). The other group replaced all the running sessions with weight load marching (load-marching group). Rudzki., (1989) found that, although both groups made similar gains in aerobic fitness, the rate of development was different between each group. The run group made significant improvements in aerobic fitness in the first six weeks of the conditioning program while the load marching group made gains in the last five weeks. In the latter case, the time period in which significant improvements occurred coincided with an increase in walking speed (from 5 $km.h^{-1}$ to 7.5 $km.h^{-1}$) and an increase in loads carried (16.2-21.2 kg to 23.8-29 kg). While Rudzki., (1989) did not specifically detail changes to volume (duration) or frequency (times per week) it was anticipated that both of these variables increased in the latter half of the recruit training program, a period of training focused upon field activities. These results

suggest that, to make significant gains in aerobic fitness and load carriage ability, the load carriage program needs to be at an intensity (load and speed) that is sufficient to stimulate adaptation. These findings, together with those of Visser *et al*., (1995), suggest that load carriage intensity (load and speed) is a key factor in improving load carriage performance. In contrast, Vanderburgh., (2008) highlighted that a 3.2km run unloaded, requires recruits to only carry their own body weight. A performance required that is closely linked to maximal oxygen uptake, which is also used widely as a health and fitness component. However, the carriage of load over the same 3.2 km distance, is physical requirement that has direct relevance in military and occupational settings (Vanderburgh., 2008). In physically demanding occupations, especially the military, assessment of physical fitness in loaded conditions is particularly important. As in common military physical fitness tests lighter recruits generally perform better in unloaded assessments of physical performance. However those recruits with a larger stature and mass are often better performers of the physically demanding occupational tasks because they are able to carry greater absolute loads for the same relative burden (Bilzon *et al*., 2002; Lyons *et al*., 2005; Rayson *et al*., 2000). That is larger individuals could more easily support the mass of a casualty or engaged in heavy manual material handling. Thus the inclusion of an assessment of cardiorespiratory fitness that includes a fixed absolute load to be carried may have considerable merit within a military performance test setting (Harman *et al*., 2008b).

4.5 Basic military training and the predicted recruit entry standards for occupationally relevant military physical assessments.

The primary intention of having minimal occupational fitness standards in the military is to select those best suited to the physical and psychological demands of the occupation (Arnold *et al*., 1982; Ayoub *et al*., 1982; Teves *et al*., 1985; Munoz .,2012). These occupational

fitness standards select personnel who have the appearance that they are capable of fulfilling the occupational duties. However, unless the assessments are valid representations of the critical and essential physical demands of the occupation, some employees may pass the assessment without an inherent ability to meet the actual physical demands of the work task. For that reason occupational standards have gone through extensive research to ensure a methodological approach is used to determine those tests that are valid and reliable assessments of the critical physical demands required for the occupation (Reilly *et al*., 2006a; Reilly *et al*., 2006b; Stevenson *et al*., 1992; Jamnik *et al*., 2010; Rayson *et al*., 2000; Taylor and Groeller., 2003; Tipton *et al*., 2013). Although one set of occupational standards may not suit every profession, specific screening of personnel for the essential requisite physical demands has been beneficial (Jamnik *et al*., 2010). Likewise, it can also be burdensome if the screening process fails to screen out applicants who potentially cannot perform the required physical demands. For instance, personnel who fail an occupational task yet continue in the occupation may have an increased risk of injury to themselves or their peers (Knapik *et al*., 2006; Pope *et al*., 1999), suffer long term disability (Feuerstein *et al*., 1997), cause high turnover of employee's or contribute to poor productivity (Pope *et al*., 1999). This has both a human and economic cost (Hogan and Quigley., 1986).

For Army, physical fitness tests can be classified into two categories; a) task simulation tests that replicate important work tasks identified as being physically demanding or essential and b) fitness component tests which identify physiological constructs underlying the successful completion of essential job duties. From these classifications it should be determined whether the performance results attained by recruits can be categorised as a pass, a false negative; not achieving a pass on the fitness standard, or false positive; meet the standard but not have the necessary physical abilities to perform a critical task to the minimum required standard

(Tipton *et al*., 2013). The validation of such tests may be achieved by using either task simulation or generic fitness component test items. In the Australian Army, some of the generic fitness component test items include, push ups, sit ups and a shuttle run. However, Jackson *et al*., (1984) stated that the importance in testing recruits is the accuracy with which selection tests measure important work behaviours. It is known that the current generic assessments of military performance do not have a strong relationship with the physical demands of military service.

In our study, 177 recruits in week one passed the generic fitness component test set by Army. By week twelve, 128 recruits had completed basic training and were permitted to progress. However, 16 recruits that progress were false positive. For example, the jerry carry distance of approximately 150 m led to the lowest number of false positives and negatives (Table 3.1). Despite the fact that most recruits passed the box lift and placement task, three recruits failed to reach the minimal standard of 25 kg (Table 3.2).

Therefore, recruits that failed to meet the minimum standards in basic training and progressed to full time employment could be considered a false positive. Recruits who are false positives are more likely to suffer some form of injury during their time of employment. (Rosendal *et al*., 2003; Pope *et al*., 1999; Knapik *et al*., 2006). In conclusion, our study revealed the physical adaptations of recruits to Australian Army basic training is generally positive. A high percentage of recruits passed the minimal generic and task standards. The mean scores of recruits in both fitness and task tests were well above the minimal pass scores. This indicates improvements in both muscular strength and aerobic fitness. Although a few recruits did not meet the minimal pass score, yet progressed to full employment (false positive). It may be possible to further investigate improvement on task tests on recruits that

are false positive. Our study suggested that a correlation between generic test and task simulations in basic training does not predict a recruit's progress in training. Furthermore, there was a good relation between 3.2 km load carriage (task) and estimated oxygen consumption (generic). An evaluation of a recruit's physical adaptation to basic training is critical. Not only to prepare for the demands of military occupation, but to monitor how effective the training program is for development of the recruit.

4.5.1 Limitations to the study.

There were several limitations to this study. The number of recruits that participated represented a small cohort compared to the large intake of recruits per year. Having the opportunity to test a larger sample of recruits would provide better analysis, especially regarding the female cohort. This would be important when comparing for example, physical fitness (strength) of recruits to a task (lift and carry) that are related to the Army occupation. Understandably, Army organises basic recruit training to a tight timeline. Our time of testing had to mould into this regime, which limited testing to specific periods of the day. Ideally these periods of testing could have been longer or additional days of testing allocated to improve recovery from the assessments and thus may have improved performance. For example recruits were required to perform a peak anaerobic power test, 15-20 minutes prior to assessment of Vo_2peak on a treadmill. However, given the testing schedule was identical at each time point, despite less than optimal sequencing of the assessments, change in performance could still be assessed validly. As a final point, recruits in basic training are required to learn a vast array of Army fitness, skills and tactic's. In this investigation, recruits only had minimal exposure to the tests and therefore had a limited time period to become familiar with each assessment, such as being familiar to wearing the oxygen gas analyser as they were running on the treadmill performing the Vo_2peak.

CHAPTER FIVE: CONCLUSION

5.0 CONCLUSION

This investigation analysed the Australian Army intensive 12–week basic training for new recruits. The aim of basic training is to prepare new recruits for future active military duties. Over the 80-day period, 39 categories of fitness and skills are assessed. Each, last approximately 60-120 minutes per session. The physical training sessions are not evenly distributed, with a greater frequency of training occurring early in the 12-week regimen. The dominant method (nearly one third of all training) used, develops cardiorespiratory fitness, via continuous running at a moderate intensity and prolonged duration load carriage exercise. The initial 12-week basic regimen was effective in improving 3.2 km 22-kg load carriage and 22 kg-jerry carry performance by 9 and 12%, respectively.

The most marked gains in physical performance through-out the twelve-week training regimen were observed in upper-body local muscle endurance (push-ups). Push-up repetition number increased significantly by 18.5% and 19.2% in weeks 8 and 12 respectively compared to Week one. However, the functional relevance of this physical attribute to military occupational performance has been questioned, suggesting that gains in push-up endurance performance will have limited influence on operational activities undertaken within the military. Similarly, gains were observed in the other pre-existing assessments of military performance with trunk endurance (sit-ups) and estimated peak oxygen consumption (shuttle run) improving by 6 and 10%, respectively. It can be suggested that implementing an additional strength and conditioning fitness program for those recruits that fail to meet the physical and task related test be considered. This is to observe any impact it may have on the recruit's performance not only in basic training but in the occupational employment.

CHAPTER SIX: REFERENCES

6.0 REFERENCES

Aandstad, A., Holme, I., Berntsen, S., Anderssen, S. A. (2011). Validity and reliability of the 20 meter shuttle run test in military personnel. *Military Medicine*, *176*(5), 513-518.

Aasa, U., Jaric, S., Barnekow-Bergkvist, M., Johansson, H. (2003). Muscle strength assessment from functional performance tests: role of body size. *The Journal of Strength & Conditioning Research*, *17*(4), 664-670.

Australian Bureau of Statistics. Overweight and Obesity in Adults in Australia: A Snapshot (cat. no. 4842.0.55.001), viewed 24/07/2012, http://abs.gov.au/ausstats/abs@.nsf/mf/4842.0.55.001 <www.abs.gov.au>

American College of Sports Medicine. (2009). American College of Sports Medicine position stand. Progression models in resistance training for healthy adults. *Medicine and Science in Sports and Exercise*, *41*(3), 687.

American College of Sports Medicine. (2013). *ACSM's guidelines for exercise testing and prescription*. Lippincott Williams & Wilkins.

Andersson, E. A., Nilsson, J., Ma, Z., Thorstensson, A. (1997). Abdominal and hip flexor muscle activation during various training exercises. *European Journal of Applied Physiology and Occupational Physiology*, *75*(2), 115-123.

Anderson, T., Kearney, J. T. (1982). Effects of three resistance training programs on muscular strength and absolute and relative endurance. *Research Quarterly for Exercise and Sport*, *53*(1), 1-7.

Arnold, J. D., Rauschenberger, J. M., Soubel, W. G., Guion, R. M. (1982). Validation and utility of a strength test for selecting steelworkers. *Journal of Applied Psychology*, *67*(5), 588.

Arvey, R. D., Landon, T. E., Nutting, S. M., Maxwell, S. E. (1992). Development of physical ability tests for police officers: A construct validation approach. *Journal of Applied Psychology*, *77*(6), 996.

Asfour, S. S., Ayoub, M. M., Mital, A. (1984). Effects of an endurance and strength training programme on lifting capability of males. *Ergonomics*, *27*(4), 435-442.

Åstrand, P. O. (2003). *Textbook of work physiology: physiological bases of exercise*. Human Kinetics.

Ayoub, M. M., Denardo, J. D., Smith, J. L., Bethea, N. J., Lambert, B. K. (1982). Establishing physical criteria for assigning personnel to Air Force jobs. *Texas Technology University Lubbock Institution for Ergonomics Research.*

Axler, C. T., McGill, S. M. (1997). Low back loads over a variety of abdominal exercises: searching for the safest abdominal challenge. *Medicine and Science in Sports and Exercise*, *29*(6), 804-811.

Baker, D., Newton, R. U. (2005). Methods to Increase the Effectiveness of Maximal Power Training for the Upper Body. *Strength & Conditioning Journal*, *27*(6), 24-32.

Bar-Or, O. (1987). The Wingate anaerobic test an update on methodology, reliability and validity. *Sports Medicine, 4*(6), 381-394.

Baumgartner, T. A., Oh, S., Chung, H., Hales, D. (2002). Objectivity, reliability, and validity for a revised push-up test protocol. *Measurement in Physical Education and Exercise Science*, *6*(4), 225-242.

Beneke, R., Pollmann, C. H., Bleif, I., Leithäuser, R., Hütler, M. (2002). How anaerobic is the Wingate Anaerobic Test for humans?. *European Journal of Applied Physiology*, *87*(4-5), 388-392.

Bergman, B. P., Miller, S. S. J. (2001). Equal opportunities, equal risks? Overuse injuries in female military recruits. *Journal of Public Health*, *23*(1), 35-39.

Bilzon, J. L. J., Allsopp, A. J., Tipton, M. J. (2001). Assessment of physical fitness for occupations encompassing load-carriage tasks. *Occupational Medicine*, *51*(5), 357-361.

Blacker, S. D., Fallowfield, J. L., Bilzon, J. L., Willems, M. E. (2010). Neuromuscular function following prolonged load carriage on level and downhill gradients. *Aviation, Space, and Environmental Medicine*, *81*(8), 745-753.

Blair, S. N., Kohl, H. W., Goodyear, N. N. (1987). Rates and risks for running and exercise injuries: studies in three populations. *Research Quarterly for Exercise and Sport*, *58*(3), 221-228.

Blair, S. N., Church, T. S. (2004). The fitness, obesity, and health equation: is physical activity the common denominator. *Journal of the American Medical Association*, *292*(10), 1232-1234.

Booth, M. L., Chey, T., Wake, M., Norton, K., Hesketh, K., Dollman, J., Robertson, I. (2003). Change in the prevalence of overweight and obesity among young Australians, 1969–1997. *The American Journal of Clinical Nutrition*, *77*(1), 29-36.

Booth, C. K., Probert, B., Forbes-Ewan, C., Coad, R. A. (2006). Australian army recruits in training display symptoms of overtraining. *Military Medicine, 171*(11), 1059-1064.

Brock, J. R., Legg, S. J. (1997). The effects of 6 weeks training on the physical fitness of female recruits to the British army. *Ergonomics*, *40*(3), 400-411.

Brooks, G. A., Fahey, T. D., White, T. P. (1996). *Exercise physiology: Human bioenergetics and its applications* (No. Ed. 2). Mayfield publishing company.

Brushøj, C., Larsen, K., Albrecht-Beste, E., Nielsen, M. B., Løye, F., Hölmich, P. (2008). Prevention of Overuse Injuries by a Concurrent Exercise Program in Subjects Exposed to an Increase in Training Load A Randomized Controlled Trial of 1020 Army Recruits. *The American Journal of Sports Medicine*, *36*(4), 663-670.

Caiozzo, V. J., Herrick, R. E., Baldwin, K. M. (1992). Response of slow and fast muscle to hypothyroidism: maximal shortening velocity and myosin isoforms. *American Journal of Physiology*, *263*(1 Pt 1), C86-C94.

Cameron, A. J., Welborn, T. A., Zimmet, P. Z., Dunstan, D. W., Owen, N., Salmon, J., Shaw, J. E. (2003). Overweight and obesity in Australia: the 1999-2000 Australian diabetes, obesity and lifestyle study (AusDiab). *Medical Journal of Australia*, *178*(9), 427-432.

Campos, G. E., Luecke, T. J., Wendeln, H. K., Toma, K., Hagerman, F. C., Murray, T. F., Ragg, K. E., Ratamess, N. A., Kraemer, W. J., Staron, R. S. (2002). Muscular adaptations in response to three different resistance-training regimens: Specificity of repetition maximum training zones. *European Journal of Applied Physiology*, 88(1), 50-60.

Carstairs, G. L., Ham, D.J., Savage, R.J., Best, S.A., Beck, B., Doyle, T.L.A. (2016). A Box Lift and Place Assessment is Related to Performance of Several Military Manual Handling Tasks. Military Medicine 181(3): 258-264.

Catley, M. J., and Tomkinson, G. R. (2011). Normative health-related fitness values for children: analysis of 85347 test results on 9–17-year-old Australians since 1985. *British Journal of Sports Medicine*. 1-12.

Chaffin, D. B. (1987). Manual Materials Handling and the Biomechanical Basis for Prevention of lower back pain in industry- An overview. *American Industrial Hygiene Association Journal*, *48*(12), 989-996

Childs, J. D., Teyhen, D. S., Benedict, T. M., Morris, J. B., Fortenberry, A. D., McQueen, R. M., Preston, J.B., Wright, A.C., Dugan, J.L.,George, S. Z. (2009). Effects of sit-up training versus core stabilization exercises on sit-up performance. *Medicine and Science in Sports Exercise*, *41*(11), 2072-83.

Childs, J. D., Teyhen, D. S., Casey, P. R., McCoy-Singh, K. A., Feldtmann, A. W., Wright, A. C., George, S. Z. (2010). Effects of traditional sit-up training versus core stabilization exercises on short-term musculoskeletal injuries in US Army soldiers: a cluster randomized trial. *Physical Therapy*, *90*(10), 1404-1412.

Cholewicki, J., McGill, S. M. (1996). Mechanical stability of the in vivo lumbar spine: implications for injury and chronic low back pain. *Clinical Biomechanics*, *11*(1), 1-15.

Cink, R. E., Thomas, T. R. (1981). Validity of the Astrand-Ryhming nomogram for predicting maximal oxygen intake. *British Journal of Sports Medicine*, *15*(3), 182-185.

Clarke, H. H., Shay, C. T., Mathews, D. K. (1955). Strength decrements from carrying various army packs on military marches. *Research Quarterly. American Association for Health, Physical Education and Recreation*, *26*(3), 253-265.

Cooper, S. M., Baker, J. S., Tong, R. J., Roberts, E., Hanford, M. (2005). The repeatability and criterion related validity of the 20 m multistage fitness test as a predictor of maximal oxygen uptake in active young men. *British Journal of Sports Medicine*, *39*(4), 1-8.

Crowder, T., and Yunker, C. (1996). Scaling of push-up, sit-up and two-mile run performance by boy weight and fat free weight in young, fit men 1089. *Medicine and Science in Sports and Exercise*, *28*(5), 183.

Crawford, K., Fleishman, K., Abt, J. P., Sell, T. C., Lovalekar, M., Nagai, T., Lephart, S. M. (2011). Less body fat improves physical and physiological performance in army soldiers. *Military Medicine*, *176*(1), 35-43.

Crisco, J. J., Panjabi, M. M. (1991). The intersegmental and multisegmental muscles of the lumbar spine: a biomechanical model comparing lateral stabilizing potential. *Spine*, *16*(7), 793-799.

Daniels, W. L., Kowal, D. M., Vogel, J. A., Stauffer, R. M. (1979). Physiological effects of a military training program on male and female cadets. *Aviation, Space, and Environmental Medicine*, *50*(6), 562-566.

Davis, P. O., Dotson, C. O. (1987). Job performance testing: An alternative to age discrimination. *Medicine and Science in Sports and Exercise*, 19(2), 179-185.

Dean, J. A., Foster, C., Thompson, N. N. (1987). 373: A simplified method of assessing muscular strength. *Medicine and Science in Sports and Exercise*, *19*(2), S63.

Diener, M. H., Golding, L. A., Diener, D. (1995). Validity and reliability of a one-minute half sit-up test of abdominal strength and endurance. *Research in Sports Medicine: An International Journal*, *6*(2), 105-119.

Dinucci, J., McCune, D., Shows, D. (1990). Reliability of a modification of the health-related physical fitness test for use with physical education majors. *Research Quarterly for Exercise and Sport*, *61*(1), 20-25.

Dudley, G. A., Djamil, R. U. S. D. A. N. (1985). Incompatibility of endurance-and strength-training modes of exercise. *Journal of Applied Physiology*, *59*(5), 1446-1451.

Dyrstad, S. M., Soltvedt, R., Hallen, J. (2006). Physical fitness and physical training during Norwegian military service. *Military Medicine*, *171*(8), 736-741.

Ebbeling, C. B., Ward, A., Puleo, E. M., Widrick, J. E. F. F. R. E. Y., Rippe, J. M. (1991). Development of a single-stage submaximal treadmill walking test. *Medicine and Science in Sports and Exercise*, *23*(8), 966-973.

Evan's, O. M., Zgrntn, Y., Faria, M. H., Monod, H. (1983). Physiological responses to load holding and load carriage. *Ergonomics, 26*(2), 161-171.

Faigenbaum, A. D., Westcott, W. L., Loud, R. L., Long, C. (1999). The effects of different resistance training protocols on muscular strength and endurance development in children. *Pediatrics*, *104*(1), e5-e5.

Faff, J., and Korneta, K. (2000). Changes in aerobic and anaerobic fitness in the Polish army paratroopers during their military service. *Aviation, Space, and Environmental Medicine*, *71*(9), 920-924.

Feuerstein, M., Berkowitz, S. M., Peck Jr, C. A. (1997). Musculoskeletal-related disability in US Army personnel: prevalence, gender, and military occupational specialties. *Journal of Occupational and Environmental Medicine*, *39*(1), 68-78.

Fogelholm, M., Malmberg, J., Suni, J., Santtila, M., Kyröläinen, H., Mäntysaari, M. (2006). Waist circumference and BMI are independently associated with the variation of cardio-respiratory and neuromuscular fitness in young adult men. *International Journal of Obesity*, *30*(6), 962-969.

Gagnon, M. (2003). The efficacy of training for three manual handling strategies based on the observation of expert and novice workers. *Clinical Biomechanics, 18*, 601- 611.

Gemmell, I. M. (2002). Injuries among female army recruits: a conflict of legislation. *Journal of the Royal Society of Medicine*, *95*(1), 23-27.

Genaidy, A. M., Davis, N., Delgado, E., Garcia, S., Al-Herzalla, E. (1994). Effects of Job simulated exercise program on employees performing manual handling operations. *Ergonomics, 37*(1), 95-106.

Genaidy, A. M., Gupta, T., Alshedi, A. (1990). Improving Human Capabilities for combined manual handling tasks through a short and intensive physical training program. *American Industrial Hygiene Association Journal, 51*(11), 610- 614.

Gledhill, N., Jamnik, V. K. (1992a). Characterisation of the Physical Demands of Firefighting. *Canadian Journal of Sport Science*, *17*(3), 207-213

Goldman, R. F., Iampietro, P. F. (1962). Energy cost of load carriage. *Journal of Applied Physiology, 17*(4), 675-676.

Gormley, S. E., Swain, D. P., High, R., Spina, R. J., Dowling, E. A., Kotipalli, U. S., & Gandrakota, R. (2008). Effect of intensity of aerobic training on vo2max. *Medicine and Science in Sports and Exercise*, 40(7), 1336.

Green A. Information paper: Cost of a new recruit. DAPE-MPA: 1, 2014

Grenier, J. G., Peyrot, N., Castells, J., Oullion, R., Messonnier, L., Morin, J. B. (2012). Energy cost and mechanical work of walking during load carriage in soldiers. *Medicine and Science in Sports and Exercise*, *44*(6), 1131-40.

Gossard, D., Haskell, W. L., Taylor, C. B., Mueller, J. K., Rogers, F., Chandler, M., Ahn, D. K., Miller, N. H., DeBusk, R. F. (1986). Effects of low-and high-intensity home-based exercise training on functional capacity in healthy middle-aged men. *American Journal of Cardiology*, 57(6), 446-449.

Gumieniak, R., Jamnik, V. K., Gledhill, N. (2011). Physical Fitness Bona Fide Occupational Requirements for Safety Related Physically Demanding Occupations; Test Development Considerations. *Health and Fitness Journal of Canada, 4*(2), 47-52

Gutin, B., Barbeau, P., Owens, S., Lemmon, C. R., Bauman, M., Allison, J., Kang, H. S., Litaker, M. S. (2002). Effects of exercise intensity on cardiovascular fitness, total body composition, and visceral adiposity of obese adolescents. *The American Journal of Clinical Nutrition*, 75(5), 818-826.

Häkkinen, K. (1991). Force production characteristics of leg extensor, trunk flexor and extensor muscles in male and female basketball players. *The Journal of Sports Medicine and Physical Fitness*, *31*(3), 325-331.

Häkkinen, K., Alen, M., Kraemer, W. J., Gorostiaga, E., Izquierdo, M., Rusko, H., Mikkola, J., Hakkinen, A., Valkeinen, H., Kaarakainen,E .,Romu, S ., Erola, V., Ahtianinen, J.,Paavolainen, L. (2003). Neuromuscular adaptations during concurrent strength and endurance training versus strength training. *European Journal of Applied Physiology*, *89*(1), 42-52.

Hall, G. L., Hetzler, R. K., Perrin, D., Weltman, A. (1992). Relationship of timed sit-up tests to isokinetic abdominal strength. *Research Quarterly for Exercise and Sport*, *63*(1), 80-84.

Ham, D. J., Jaffrey, M. A., Billing, D. C. (2010). Development of Strength Based Physical Employment Standards. Defence Science and Technology Organisation.

Har, G. E. (1999). Fitness, performance, and risk of injury in British Army Officer Cadets. *Military Medicine*, *164*(428), 428.

Hart, C. L., Ward, T. E., Mayhew, J. L., Ball, T. E. (1990). Push ups as a measure of upper body strength in males. *Journal of Human Movement Studies*, *18*(6), 287-294.

Hartig, D. E., and Henderson, J. M. (1999). Increasing hamstring flexibility decreases lower extremity overuse injuries in military basic trainees. *The American Journal of Sports Medicine*, *27*(2), 173-176.

Harman, E. A., Gutekunst, D. J., Frykman, P. N., Nindl, B. C., Alemany, J. A., Mello, R. P., Sharp, M. A. (2008). Effects of two different eight-week training programs on military physical performance. *The Journal of Strength & Conditioning Research*, *22*(2), 524-534.

Harman, E., Frykman, P., Palmer, C., Lammi, E., Reynolds, K. (1997). Effects of a Specifically Designed Physical Conditioning Program on the Load Carriage and Lifting Performance of Female Soldiers (No. USARIEM-T98-1). *Army Research Institution of Environmental Medicine* natick ma.

Harman, E. A., and Frykman, P. N. (1992). The relationship of body size and composition to the performance of physically demanding military tasks. *Body Composition and Physical Performance*, 105-18.

Harman, E. A., Gutekunsk, D. J., Frykman, P., Nindl, B. C., Alemany, J. A., Mello, R. P., Sharp, M. A. (2008a). Effects of two different 8-week training programs on military physical performance. *Journal of Strength and Conditioning Research, 22*(2), 524-534.

Harman, E. A., Gutekunst, D. J., Frykman, P. N., Sharp, M. A., Nindl, B. C., Alemany, J. A., Mello, R. P. (2008b). Prediction of Simulated Battlefield Physical Performance from Field Expedient Tests. *Military Medicine, 173*(1), 36-41.

Haskell, W. L., Lee, I. M., Pate, R. R., Powell, K. E., Blair, S. N., Franklin, B. A., Bauman, A. (2007). Physical activity and public health: updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. *Circulation*, *116*(9), 1081.

Heil, D. P. (1997). Body mass scaling of peak oxygen uptake in 20-to 79-yr-old adults. *Medicine and Science in Sports and Exercise*, *29*(12), 1602-1608.

Hendrickson, N. R., Sharp, M. A., Alemany, J. A., Walker, L. A., Harman, E. A., Spiering, B. A., Hatfield, D.L., Yamamoto, L.M., Maresh, C.M., Kraemer, W.J., Nindl, B. C. (2010). Combined resistance and endurance training improves physical capacity and performance on tactical occupational tasks. *European Journal of Applied Physiology*, *109*(6), 1197-1208.

Hermiston, R. T., Faulkner, J. A. (1971). Prediction of maximal oxygen uptake by a stepwise regression technique. *Journal of Applied Physiology*, *30*(6), 833-837.

Hoffman, J. R., Chapnik, L., Shamis, A., Givon, U., Davidson, B. (1999). The effect of leg strength on the incidence of lower extremity overuse injuries during military training. *Military Medicine*, *164*, 153-156.

Hogan, J., Quigley, A. M. (1986). Physical standards for employment and the courts. *American Psychologist*, *41*(11), 1193.

Hunter, G., Demment, R., Miller, D. (1987). Development of strength and maximum oxygen uptake during simultaneous training for strength and endurance. *The Journal of Sports Medicine and Physical Fitness*, *27*(3), 269-275.

Inbar, O., Bar-Or, O., Skinner, J. S. (1996). *The Wingate Anaerobic Test*. Human Kinetics.

Issurin, V. B. (2010). New horizons for the methodology and physiology of training periodization. *Sports Medicine*, *40*(3), 189-206.

Invergo, J. J., Ball, T. E., Looney, M. (1991). Relationship of push-ups and absolute muscular endurance to bench press strength. *The Journal of Strength and Conditioning Research*, *5*(3), 121-125.

Jackson, A. S., Osburn, H. G., Laughery, K. R. (1984). Validity of isometric strength tests for predicting performance in physically demanding tasks. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* (Vol. 28, No. 5, pp. 452-454). SAGE Publications.

Jamnik, V. K., Thomas, S. G., Burr, J. F., Gledhill, N. (2010). Construction, validation, and derivation of performance standards for a fitness test for correctional officer applicants. *Applied Physiology, Nutrition, and Metabolism*, *35*(1), 59-70.

Johnson, R. E., Quinn, T. J., Kertzer, R., Vroman, N. B. (1997). Strength training in female distance runners: impact on running economy. *The Journal of Strength and Conditioning Research*, *11*(4), 224-229.

Jones, D. A., Round, J. M. (1990). *Skeletal muscle in health and disease: a textbook of muscle physiology*. Manchester University Press.

Jones, D. A., Rutherford, O. M., Parker, D. F. (1989). Physiological changes in skeletal muscle as a result of strength training. *Quarterly Journal of Experimental Physiology*, *74*(3), 233-256.

Jones, D. A., Rutherford, O. M. (1987). Human muscle strength training: the effects of three different regimens and the nature of the resultant changes. *The Journal of Physiology*, *391*(1), 1-11.

Jones, B. H., Bovee, M. W., Harris, J. M., Cowan, D. N. (1993). Intrinsic risk factors for exercise-related injuries among male and female army trainees. *The American Journal of Sports Medicine*, *21*(5), 705-710.

Jones, B. H., Reynolds, K. L., Rock, P. B., Moore, M. P. (1993). Exercise related musculoskeletal injuries: risks, prevention and care. *ACSM's resource manual for guidelines for exercise testing and prescription. Philadelphia: Lea and Febiger*.

Jones BH, Cowan DN, Tomlinson JP, Robinson JR, Polly DW, Frykman PN. (1993). Epidemiology of injuries associated with physical training among young men in the army. *Medicine and Science in Sports and Exercise*. ;25(2):197–203.

Jones, B. H., Knapik, J. J. (1999). Physical training and exercise-related injuries. *Sports Medicine*, *27*(2), 111-125.

Kamen, G. (2005). Aging, resistance training, and motor unit discharge behaviour. *Canadian Journal of Applied Physiology, 30*(3), 341-351.

Kaufman, K. R., Brodine, S., Shaffer, R. (2000). Military training-related injuries: surveillance, research, and prevention. *American Journal of Preventive Medicine, 18*(3), 54-63.

Kay, D., Gibson, A. S. C., Mitchell, M. J., Lambert, M. I., Noakes, T. D. (2000). Different neuromuscular recruitment patterns during eccentric, concentric and isometric contractions. *Journal of Electromyography and Kinesiology*, *10*(6), 425-431.

Keren, G., Epstein, Y., Magazanik, A., Sohar, E. (1981). The energy cost of walking and running with and without a backpack load. *European Journal of Applied Physiology and Occupational Physiology*, *46*(3), 317-324.

Knapik, J. J., Wright, J. E., Kowal, D. M., Vogel, J. A. (1980). The influence of US Army Basic Initial Entry Training on the muscular strength of men and women. *Aviation, Space, and Environmental Medicine, 51*(10), 1086-1090.

Knapik, J. (1989). The Army Physical Fitness Test (APFT): a review of the literature. *Military Medicine*, *154*(6), 326-329.

Knapik, J. (1989). Loads carried by soldiers: historical, physiological, biomechanical and medical aspects (No. USARIEM-T19-89). *Army Research Institute of Environmental medicine.* Natick ma.Knapik, J., Reynolds, K., Staab, J., Vogel, J. A., Jones, B. (1992). Injuries associated with strenuous road marching. *Military Medicine*, *157*(2), 64-67.

Knapik, J., Ang, P., Reynolds, K., Jones, B. (1993). Physical fitness, age, and injury incidence in infantry soldiers. *Journal of Occupational and Environmental Medicine*, *35*(6), 598-603.

Knapik, J., Harman, E., Reynolds, K. (1996). Load carriage using packs: A review of physiological, biomechanical and medical aspects. *Applied Ergonomics*, *27*(3), 207-216.

Knapik, J. J., & Gerber, J. (1996). The influence of physical fitness training on the manual material-handling capability and road-marching performance of female soldiers: DTIC Document.

Knapik, J. J. (1997). The influence of physical fitness training on the manual material handling capability of women. *Applied Ergonomics*, *28*(5), 339-345.

Knapik, J. J., Sharp, M. A. (1998). Task-specific and generalized physical training for improving manual-material handling capability. *International Journal of Industrial Ergonomics*, *22*(3), 149-160.

Knapik, J. J., Harper, W., Crowell, H. P. (1999). Physiological factors in stretcher carriage performance. *European Journal of Applied Physiology and Occupational Physiology*, *79*(5), 409-413.

Knapik, J. J., Canham-Chervak, M., Hauret, K., Hoedebecke, E., Laurin, M. J., Cuthie, J. (2001). Discharges during US Army basic training: injury rates and risk factors. *Military Medicine*, *166*(7), 641-647.

Knapik, J. J., Sharp, M. A., Canham-Chervak, M. I. C. H. E. L. L. E., Hauret, K. E. I. T. H., Patton, J. F., Jones, B. H. (2001). Risk factors for training-related injuries among men and women in basic combat training. *Medicine and Science in Sports and Exercise*, *33*(6), 946-954.

Knapik, J. J., Hauret, K. G., Arnold, S., Canham-Chervak, M., Mansfield, A. J., Hoedebecke, E. L., McMillian, D. (2003). Injury and fitness outcomes during implementation of physical readiness training. *International Journal of Sports Medicine*, 24(5), 372-381.

Knapik, J. J., Reynolds, K. L., Harman, E. (2004). Soldier load carriage: historical, physiological, biomechanical, and medical aspects. *Military Medicine*, *169*(1), 45-56.

Knapik, J. J., Darakjy, S., Scott, S. J., Hauret, K. G., Marin, R. E., Rieger, W., Jones, B. H. (2005). Evaluation of a standardized physical training program for basic combat training. *The Journal of Strength and Conditioning Research*, 19(2), 246-253.

Knapik, J. J., Darakjy, S., Hauret, K. G., Scott, S., Rieger, W., Marin, R., Jones, B. H. (2006). Increasing the physical fitness of low-fit recruits before basic combat training: an evaluation of fitness, injuries, and training outcomes. *Military Medicine*, *171*(1), 45-

Knapik, J. J., Harman, E. A, Steelman, R. A, and Graham, B. S. (2012). A systematic review of the effects of physical training on load carriage performance. The Journal of Strength & Conditioning Research, 26(2), 585-597) 54.

Knuttgen, H. G., Kraemer, W. J. (1987). Terminology and measurement in exercise performance. *The Journal of Strength and Conditioning Research*, *1*(1), 1-10.

Komi, P., Viitasalo, J., Rauramaa, R., Vihko, V. (1978). Effect of isometric strength training on mechanical, electrical, and metabolic aspects of muscle function. *European Journal of Applied Physiology and Occupational Physiology*, 40(1), 45-55.

Komi, P. V. (1986). Training of muscle strength and power: interaction of neuromotoric, hypertrophic, and mechanical factors. *International Journal of Sports Medicine*, (7 Suppl 1), 10-5.

Kopelman, P. G. (2000). Obesity as a medical problem. *Nature-London-*, pg 635-643.

Kowal, D. M., Patton, J. F., Vogel, J. A. (1978). Psychological states and aerobic fitness of male and female recruits before and after basic training. *Aviation, Space, and Environmental Medicine*, *49*(4), 603-606.

Kraemer, W. J., Patton, J. F., Gordon, S. E., Harman, E. A., Deschenes, M. R., Reynolds, K., Newton, R.U., Triplett, N.T., Dziados, J. E. (1995). Compatibility of high-intensity strength and endurance training on hormonal and skeletal muscle adaptations. *Journal of Applied Physiology*, *78*(3), 976-989.

Kraemer, W. J., Mazzetti, S. A., Nindl, B. C., Gotshalk, L. A., Volek, J. S., Bush, J. A., . Hakkinen, K. (2001). Effect of resistance training on women's strength/power and occupational performances. *Medicine and Science in Sports and Exercise, 33*(6), 1011-1025.

Kraemer, W. J., Vescovi, J. D., Volek, J. S., Nindl, B. C., Newton, R. U., Patton, J. F., Dziados, J.E., French, D.N., Hakkinen, K. (2004). Effects of concurrent resistance and aerobic training on load-bearing performance and the Army physical fitness test. *Military Medicine*, *169*(12).

Kraemer, W. J., Ratamess, N. A. (2005). Hormonal responses and adaptations to resistance exercise and training. *Sports Medicine*, *35*(4), 339-361.

Kraemer, W. J., Szivak, T. K. (2012). Strength training for the warfighter. *The Journal of Strength and Conditioning Research*, *26*, S107-S118.

Kuntzleman, C. T., Reiff, G. G. (1992). The decline in american children's fitness levels. *Research Quarterly for Exercise and Sport*, *63*(2), 107-111.

Kyröläinen, H., Pullinen, T., Candau, R., Avela, J., Huttunen, P., Komi, P. V. (2000). Effects of marathon running on running economy and kinematics. *European Journal of Applied P*hysiology, *82*(4), 297-304.

Kyröläinen, H., Karinkanta, J., Santtila, M., Koski, H., Mäntysaari, M., Pullinen, T. (2008). Hormonal responses during a prolonged military field exercise with variable exercise intensity. *European Journal of Applied Physiology*, *102*(5), 539-546.

Kyröläinen, H., Häkkinen, K., Kautiainen, H., Santtila, M., Pihlainen, K., Häkkinen, A. (2008). Physical fitness, BMI and sickness absence in male military personnel. *Occupational Medicine*, *58*(4), 251-256.

Laing Treloar, A. K., Billing, D. C. (2011). Effect of load carriage on performance of an explosive, anaerobic military task. *Military Medicine*, *176*(9), 1027-1031.

Léger, L. A., Lambert, J. (1982). A maximal multistage 20-m shuttle run test to predict\ dot VO2 max. *European Journal of Applied Physiology and Occupational Physiology, 49*(1), 1-12.

Leger, L. A., Mercier, D., Gadoury, C., Lambert, J. (1988). The multistage 20 metre shuttle run test for aerobic fitness. *Journal of Sports Sciences*, *6*(2), 93-101.

Leger, L., Gadoury, C. (1989). Validity of the 20 m shuttle run test with 1 min stages to predict VO2max in adults. *Canadian Journal of Sport Sciences*, *14*(1), 21-26.

Legg, S. J., and Pateman, C. M. (1984). A Physiological study of the repetitive lifting capabilities of healthy young males. *Ergonomics*, *27*(3), 259-272.

Legg, S. J., Duggan, A. (1996). The effects of basic training on aerobic fitness and muscular strength and endurance of British Army recruits. *Ergonomics*, *39*(12), 1403-1418.

Leyk, D., Gorges, W., Ridder, D., Wunderlich, M., Rüther, T., Sievert, A., Essfeld, D. (2007). Hand-grip strength of young men, women and highly trained female athletes. *European Journal of Applied Physiology*, *99*(4), 415-421.

Lim, C. L., Lee, L. K. (1994). The effects of 20 weeks basic military training program on body composition, VO2max and aerobic fitness of obese recruits. *The Journal of Sports Medicine and Physical Fitness*, *34*(3), 271-278.

Lutz, L. J., Gaffney-Stomberg, R. E., Scisco, R. J. L., Karl, J. P., Young, R. A. J., McClung, J. P. (2013). Assessment of Dietary Intake Using the Healthy Eating Index During Military Training. *The Foundation of a system for health: Army Medicine's PerformanceTriad*, 91.

Macaluso, A., De Vito, G. (2004). Muscle strength, power and adaptations to resistance training in older people. *European Journal of Applied Physiology*, *91*(4), 450-472.

Macera, C. A., Jackson, K. L., Hagenmaier, G. W., Kronenfeld, J. J., Kohl, H. W., Blair, S. N. (1989). Age, physical activity, physical fitness, body composition, and incidence of orthopedic problems. *Research Quarterly for Exercise and Sport*, *60*(3), 225-233.

Marcinik, E. J., Hodgdon, J. A., Mittleman, K. A. R. E. N., O'Brien, J. J. (1985). Aerobic/calisthenic and aerobic/circuit weight training programs for Navy men: a comparative study. *Medicine and Science in Sports and Exercise*, *17*(4), 482-487.

Marcinik, E. J., Hodgdon, J. A., Vickers Jr, R. R. (1985). The effects of an augmented and the standard recruit physical training program on fitness parameters. *Aviation, Space, and Environmental Medicine*, *56*(3), 204-207.

Martinez, J. F., Huffman, A. H., Adler, A. B., Castro, C. A. (2001). Assessing Psychological Readiness in the US Soldiers Following NATO Operations. *Army Medical Research Unit- Europe Apo Ae* 09042.

Markovic, G., Jaric, S. (2004). Movement performance and body size: the relationship for different groups of tests. *European Journal of Applied Physiology*, *92*(1-2), 139-149.

McArdle, A., Vasilaki, A., Jackson, M. (2002). Exercise and skeletal muscle ageing: cellular and molecular mechanisms. *Ageing Research Reviews*, *1*(1), 79-93.

McCarthy, J. P., Pozniak, M. A., Agre, J. C. (2002). Neuromuscular adaptations to concurrent strength and endurance training. *Medicine and Science in Sports and Exercise*, *34*(3), 511-519.

MacDougall, J. D., Wenger, H. A., Green, H. J. (Eds.). (1991). *Physiological testing of the high-performance athlete*. Champaign, Ill.: Human Kinetics Books.

McGill, S. M. (1995). The mechanics of torso flexion: sit-ups and standing dynamic flexion manoeuvres. *Clinical Biomechanics*, *10*(4), 184-192.

McGill, S. M. (2001). Low back stability: from formal description to issues for performance and rehabilitation. *Exercise and Sport Sciences Reviews*, *29*(1), 26-31.

McLaughlin, R., Wittert, G. (2009). The obesity epidemic: implications for recruitment and retention of defence force personnel. *Obesity Reviews*, *10*(6), 693-699.

Moss, B. M., Refsnes, P. E., Abildgaard, A., Nicolaysen, K., Jensen, J. (1997). Effects of maximal effort strength training with different loads on dynamic strength, cross-sectional area, load-power and load-velocity relationships. *European Journal of Applied Physiology and Occupational Physiology*, 75(3), 193-199.

Munoz Jr, D. (2012). The Perceived Relationship Among Personnel Readiness, Job Performance and Work Demands: A Case for Physical Ability Testing. *Naval Postgraduate School Montery CA Department of Operations Research.*Nindl, B. C., Leone, C. D., Tharion, W. J., Johnson, R. F., Castellani, J. W., Patton, J. F., Montain, S. J. (2002). Physical performance responses during 72 h of military operational stress. *Medicine and Science in Sports and Exercise*, *34*(11), 1814-1822.

Nindl, B. C., Rarick, K. R., Castellani, J. W., Tuckow, A. P., Patton, J. F., Young, A. J., Montain, S. J. (2006). Altered secretion of growth hormone and luteinizing hormone after 84 h of sustained physical exertion superimposed on caloric and sleep restriction. *Journal of Applied Physiology*, *100*(1), 120-128.

Nindl, B. C., Barnes, B. R., Alemany, J. A., Frykman, P. N., Shippee, R. L., Friedl, K. E. (2007). Physiological consequences of US Army Ranger training. *Medicine and Science in Sports and Exercise*, *39*(8), 1380.

Nindl, B. C. (2009). Insulin-like growth factor-I as a candidate metabolic biomarker: military relevance and future directions for measurement. *Journal of Diabetes Science and Technology*, *3*(2), 371-376.

Nindl, B. C., Alemany, J. A., Tuckow, A. P., Rarick, K. R., Staab, J. S., Kraemer, W. J., Frystyk, J. (2010). Circulating bioactive and immunoreactive IGF-I remain stable in women, despite physical fitness improvements after 8 weeks of resistance, aerobic, and combined exercise training. *Journal of Applied Physiology*, *109*(1), 112-120.

Noakes, T. D., Myburgh, K. H., Schall, R. (1990). Peak treadmill running velocity during the V O2 max test predicts running performance. *Journal of Sports Sciences*, *8*(1), 35-45.

Norris, C. M. (1993). Abdominal muscle training in sport. *British Journal of Sports Medicine*, *27*(1), 19-27.

O'Connor, F. G., Deuster, P. A., Davis, J., Pappas, C. G., & Knapik, J. J. (2011). Functional movement screening: predicting injuries in officer candidates. *Medicine and Science in Sports and Exercise*, *43*(12), 2224-30.

Orme, C. W. (2005). *Army Physical Conditioning Model* (No. PERS-98-6).

Orr, R., Pope, R., Johnston, V., Coyle, J. (2011). Load carriage and its force impact. *Australian defence force journal: Journal of the Australian profession of arms*, *185*, 52-63.

Orr, R. M., Pope, R., Johnston, V., Coyle, J. (2014). Soldier occupational load carriage: a narrative review of associated injuries. *International Journal of Injury Control and Safety Promotion*, *21*(4), 388-396.

Packnett, E. R., Niebuhr, D. W., Bedno, S. A., Cowan, D. N. (2011). Body mass index, medical qualification status, and discharge during the first year of US Army service. *The American Journal of Clinical Nutrition*, *93*(3), 608-614.

Paliczka, V. J., Nichols, A. K., Boreham, C. A. (1987). A multi-stage shuttle run as a predictor of running performance and maximal oxygen uptake in adults. *British Journal of Sports Medicine*, *21*(4), 163-165.

Patton, J. F., Daniels, W. L., Vogel, J. A. (1980). Aerobic power and body fat of men and women during army basic training. *Aviation, Space, and Environmental Medicine*, *51*(5), 492-496.

Patton, J. F., Murphy, M. M., Frederick, F. A. (1985). Maximal power outputs during the Wingate anaerobic test. *International Journal of Sports Medicine*, *6*(2), 82-85.

Patton, J. F., Vogel, J. A., Damokosh, A. I., Mello, R. P. (1989). Effects of continuous military operations on physical fitness capacity and physical performance. *Work and Stress*, *3*(1), 69-77.

Peterson, M. D., Dodd, D. J., Alvar, B. A., Rhea, M. R., Favre, M. (2008). Undulation training for development of hierarchical fitness and improved firefighter job performance. *Journal of Strength and Conditioning Research*, *22*(5), 1683-1695.

Polcyn, A. F., Bensel, C. K., Harman, E. A., Obusek, J. P., Pandorf, C. (2002). Effects of weight carried by soldiers: Combined analysis of four studies on maximal performance, physiology, and biomechanics (No. NATICK/TR-02/010). *Army Natick Soldier Centre MA Supporting Science and Technology Directorate*

Pope, R., Herbert, R., Kirwan, J. (1998). Effects of ankle dorsiflexion range and pre-exercise calf muscle stretching on injury risk in army recruits. *Australian Journal of Physiotherapy*, *44*(3), 165-172.

Pope, R. P., Herbert, R., Kirwan, J. D., Graham, B. J. (1999). Predicting attrition in basic military training. *Military Medicine*, *164*(10), 710-714.

Pope RP, Herbert RD, Kirwan JD, and Graham BJ. (2000). A randomized trial of preexercise stretching for prevention of lower-limb injury. *Medicine and Science in Sports and Exercise* 32: 271-277.

Popper, S. E. (1997). Incorporating occupational medicine methodology into military fitness for duty and readiness issues. *Aviation, Space, and Environmental Medicine*, *68*(8), 740-745.

Protzman, R. R., Colonel, L. (1979). Physiologic performance of women compared to men Observations of cadets at the United States Military Academy. *The American Journal of Sports Medicine*, *7*(3), 191-194.

Putman, C. T., Xu, X., Gillies, E., MacLean, I. M., Bell, G. J. (2004). Effects of strength, endurance and combined training on myosin heavy chain content and fibre-type distribution in humans. *European Journal of Applied Physiology*, *92*(4-5), 376-384.

Quesada, P. M., Mengelkoch, L. J., Hale, R. C., Simon, S. R. (2000). Biomechanical and metabolic effects of varying backpack loading on simulated marching. *Ergonomics*, *43*(3), 293-309.

Ramsbottom, R., Brewer, J., Williams, C. (1988). A progressive shuttle run test to estimate maximal oxygen uptake. *British Journal of Sports Medicine*, *22*(4), 141-144.

Rayson, M., Holliman, D., Belyavin, A. (2000). Development of physical selection procedures for the British Army. Phase 2: relationship between physical performance tests and criterion tasks. *Ergonomics*, *43*(1), 73-105.

Reilly, T., Wooler, A., Tipton, M. (2006). Occupational fitness standards for beach lifeguards. Phase 1: the physiological demands of beach lifeguarding. *Occupational Medicine*, *56*(1), 6-11.

Reilly, T., Iggleden, C., Gennser, M., Tipton, M. (2006). Occupational fitness standards for beach lifeguards. Phase 2: the development of an easily administered fitness test. *Occupational Medicine*, *56*(1), 12-17.

Restorff, W. V. (2000). Physical fitness of young women: carrying simulated patients. *Ergonomics*, *43*(6), 728-743.

Rhea, M. R., Alvar, B. A., Gray, R. (2004). Physical fitness and job performance of firefighters. *The Journal of Strength and Conditioning Research*, *18*(2), 348-352.

Rice, V. J., Sharp, M. A. (1994). Prediction of performance on two stretcher-carry tasks. *Work: A Journal of Prevention, Assessment and Rehabilitation*, *4*(3), 201-210.

Rosendal, L., Langberg, H., Skov-Jensen, A., Kjær, M. (2003). Incidence of injury and physical performance adaptations during military training. *Clinical Journal of Sport Medicine*, *13*(3), 157-163.

Ross, J., Woodward, A. (1994). Risk factors for injury during basic military training: is there a social element to injury pathogenesis. *Journal of Occupational and Environmental Medicine*, *36*(10), 1120-1126.

Rothman, K. J. (2008). BMI-related errors in the measurement of obesity. *International Journal of Obesity*, *32*, S56-S59.

Roy, T. A., Blackman, M. R., Harman, S. M., Tobin, J. D., Schrager, M., Metter, E. J. (2002). Interrelationships of serum testosterone and free testosterone index with FFM and strength in aging men. *American Journal of Physiology-Endocrinology and Metabolism*, *283*(2), E284-E294.

Rudzki, S. J. (1989). Weight-load marching as a method of conditioning Australian Army recruits. *Military Medicine*, *154*(4), 201-205.

Rudzki, S. J. (1997). Injuries in Australian Army recruits. Part I: Decreased incidence and severity of injury seen with reduced running distance. *Military Medicine*, *162*(7), 472-476.

Rudzki, S. J., Cunningham, M. J. (1999). The effect of a modified physical training program in reducing injury and medical discharge rates in Australian Army recruits. *Military Medicine*, *164*(9), 648-652.

Ruscio, B. A., Jones, B. H., Bullock, S. H., Burnham, B. R., Canham-Chervak, M., Rennix, C. P., Smith, J. W. (2010). A process to identify military injury prevention priorities based on injury type and limited duty days. *American Journal of Preventive Medicine*, *38*(1), S19-S33.

Sale, D. G. (1988). Neural adaptation to resistance training. *Medicine and Science in Sports and Exercise*, *20*(5 Suppl), S135-45.

Santtila, M., Kyröläinen, H., Vasankari, T., Tiainen, S., Palvalin, K., Häkkinen, A., and Häkkinen, K. (2006). Physical fitness profiles in young Finnish men during the years 1975–2004. *Medicine and Science in Sports and Exercise*, *38*(11), 1990-1994.

Santtila, M., Keijo, H., Laura, K., Heikki, K. (2008). Changes in cardiovascular performance during an 8-week military basic training period combined with added endurance or strength training. *Military Medicine*, *173*(12), 1173-1179.

Santtila, M. (2010). Effects of added endurance or strength training on cardiovascular and neuromuscular performance of conscripts during the 8-week basic training period. University of Jyväskylä.*Studies in Sport, Physical education and Health.*146, 1-85

Santtila, M., Hakkinen, K., Kraemer, W. J., Kyrolainen, H. (2010). Effects of basic training on acute physiological responses to a combat loaded run test. *Military Medicine*, 175(4), 273-279.

Santtila, M., Häkkinen, K., Nindl, B. C., Kyröläinen, H. (2012). Cardiovascular and Neuromuscular Performance Responses Induced by 8 Weeks of Basic Training Followed by 8 Weeks of Specialized Military Training. *The Journal of Strength and Conditioning Research*, *26*(3), 745-751.

Schell, J., and Leelarthaepin, B. (1990). Physical fitness assessment in exercise and sport science. *Leelar Biomediscience Services*.

Serresse, O., Lortie, G., Bouchard, C., Boulay, M. R. (1988). Estimation of the contribution of the various energy systems during maximal work of short duration. *International Journal of Sports Medicine*, *9*(06), 456-460.

Sharp, M. A., Harman, E. A., Boutilier, B. E., Bovee, M. W., Kraemer, W. J. (1993). Progressive resistance training program for improving manual materials handling performance. *Work: a Journal of Prevention, Assessment and Rehabilitation*, *3*(3), 62-68.

Sharp, M. A. (1993). Physical fitness, physical training and occupational performance of men and women in the US Army*:* A review of literature (No. USARIEM-TN-93-7).*Army Research Institution of Environmental Medicine Natick MA.*

Sharp, M. A. (1994). Physical fitness and occupational performance of women in the US Army. *Work: A Journal of Prevention, Assessment and Rehabilitation*, *4*(2), 80-92.

Sharp, M. A., Patton, J. F., Vogel, J. A. (1996). A Data Base of Physically Demanding Tasks Performed by US Army Soldiers. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* (Vol. 40, No. 13, pp. 673-677). SAGE Publications.

Sharp, M. A., Knapik, J. J., Patton, J. F., Smutok, M. A., Hauret, K. (2000). Physical fitness of soldiers entering and leaving basic combat training: DTIC Document.

Sharp, M.A., Patton, J.F., Knapik, J.J., Havret,K., Mello, M.I., Frykman, P.N. (2002). Comparison of the physical fitness of men and women entering the US Army. *Medicine and Science in Sport and Exercise*, *3,* 56-363.

Sharp, M. A., Rosenberger, M., Knapik, J. J. (2009). Common Military Task: Manual Handling. *In: Jaenen, S.P, Van Dijk, J (eds). North Atlantic Treaty Organisation Research and Technology Organisation Research Technical Group-019, Optimizing Operational Physical Fitness Technical Report*(TR-HFM-080), 5-1-5-38.

Shephard, R. J. (1997). *Aging, physical activity, and health*. Human Kinetics Publishers.

Sherrard, J., Lenne, M., Cassell, E., Stokes, M., Ozanne-Smith, J. (2004). Injury prevention during physical activity in the Australian Defence Force. *Journal of Science and Medicine in Sport*, *7*(1), 106-117.

Smith, J. C., Hill, D. W. (1991). Contribution of energy systems during a Wingate power test. *British Journal of Sports Medicine*, *25*(4), 196-199.

Soule, R. G., Pandolf, K. B., Goldman, R. F. (1978). Energy expenditure of heavy load carriage. *Ergonomics*, *21*(5), 373-381.

Sparling, P. B., Millard-Stafford, M., Snow, T. K. (1997). Development of a cadence curl-up test for college students. *Research Quarterly for Exercise and Sport*, *68*(4), 309-316.

Stacy, R. J., Hungerford, R. L., McMahon, B. B. (1982). The effect of basic training on aerobic capacity and body fat in New Zealand army recruits. *The New Zealand Medical Journal*, *95*(722), 876-878.

Stevenson, J. M., Bryant, J. T., Andrew, G. M., Smith, J. T., French, S. L., Thomson, J. M., Deakin, J. M. (1992). Development of physical fitness standards for Canadian Armed Forces younger personnel. *Canadian Journal of Sport Sciences*, *17*(3), 214-221.

Stickland, M. K., Petersen, S. R., Bouffard, M. (2003). Prediction of maximal aerobic power from the 20-m multi-stage shuttle run test. *Canadian Journal of Applied Physiology, 28*(2), 272-282.

Suni, J. H., Oja, P., Laukkanen, R. T., Mülunpalo, S. I., Pasanen, M. E., Vuori, I. M., Bös, K. (1996). Health-related fitness test battery for adults: aspects of reliability. *Archives of Physical Medicine and Rehabilitation*, *77*(4), 399-405.

Sutton, J. R. (1992). Limitations to maximal oxygen uptake. *Sports Medicine*, *13*(2), 127-133.

Taylor, N. A., Groeller, H. (2003). Work-based physiological assessment of physically-demanding trades: a methodological overview. *Journal of Physiological Anthropology and Applied Human Science*, *22*(2), 73-81.

Teves, M. A., Wright, J. E., Vogel, J. A. (1985). Performance on selected candidate screening test procedures before and after Army basic and advanced individual training (No. USARIEM-T-13/85).*Army Medical Research and Development Command Fort Detrick MD*.

Tipton, M. J., Milligan, G. S., Reilly, T. J. (2013). Physiological employment standards I. Occupational fitness standards: objectively subjective. *European Journal of Applied Physiology*, *113*(10), 2435-2446.

Thomas, J. L., Adler, A. B., Wittels, P., Enne, R., Johannes, B. (2004). Comparing elite soldiers' perceptions of psychological and physical demands during military training. *Military Medicine*, *169*(7), 526.

Tomkinson, G. R., Léger, L. A., Olds, T. S., Cazorla, G. (2003). Secular trends in the performance of children and adolescents (1980–2000). *Sports Medicine*, *33*(4), 285-300.

Tomkinson, G. R., Olds, T. S. (2007). *Secular changes in aerobic fitness test performance of Australasian children and adolescents* (Vol. 50, pp. 168-182). Karger Publishers.

Tremblay, M. S., Shephard, R. J., Mckenzie, T. L., Gledhill, N. (2001). Physical activity assessment options within the context of the Canadian Physical Activity, Fitness, and Lifestyle Appraisal. *Canadian Journal of Applied Physiology*, *26*(4), 388-407.

Tsigilis, N., Douda, H., Tokmakidis, S. P. (2002). Test-retest reliability of the Eurofit test battery administered to university students. *Perceptual and Motor Skills*, *95*(3f), 1295-1300.

United States. Department of Health, and Human Services. (1996). *Physical activity and health: a report of the Surgeon General*. DIANE Publishing.

Vanderburgh, P. M., Maha, M. T. (1995). Scaling of 2-Mile Run Times by Body Weight and Fat-Free Weight in College-Age Men. *The Journal of Strength and Conditioning Research*, *9*(2), 67-70.

Vanderburgh, P. M., Flanagan, C. S. (2000). The backpack run test: a model for a fair and occupationally relevant military fitness test. *Military Medicine, 165(5), 418-421*. Vanderburgh, P. M., Crowder, T. A. (2006). Body mass penalties in the physical fitness tests of the Army, Air Force, and Navy. *Military Medicine*, *171*(8), 753-756.

Vanderburgh, P. (2008). Occupational relevance and body mass bias in military physical fitness tests. *Medicine and Science in Sports and Exercise*, *40*(8), 1538.

Vandewalle, H., Péerès, G., Monod, H. (1987). Standard anaerobic exercise tests. *Sports Medicine*, *4*(4), 268-289.

Vickers Jr, R. R., Barnard, A. C. (2010). Effects of Physical Training in Military Populations: A Meta-Analytic Summary (No. NHRC-11-17). *Naval Health Research Centre San Diego CA*Vogel, J. A., Crowdy, J. P., Amor, A. F., Worsley, D. E. (1978). Changes in aerobic fitness and body fat during army recruit training. *European Journal of Applied Physiology and Occupational Physiology*, *40*(1), 37-43.

Vogel, J. A. (1985). A review of physical fitness as it pertains to the military services (No. USARIEM-T14/85). *Army Research Institution of Environmental Medicine Natick MA*

Wang, H., Frame, J., Ozimek, E., Leib, D., Dugan, E. L. (2013). The Effects of Load Carriage and Muscle Fatigue on Lower-Extremity Joint Mechanics. *Research Quarterly for Exercise and Sport*, *84*(3), 305-312.

Warr, B. J., Alvar, B. A., Dodd, D. J., Heumann, K. J., Mitros, M. R., Keating, C. J., Swan, P. D. (2011). How do they compare: an assessment of pre deployment fitness in the Arizona National Guard. *The Journal of Strength and Conditioning Research*, *25*(11), 2955-2962.

Wenger, H. A., Bell, G. J. (1986). The interactions of intensity, frequency and duration of exercise training in altering cardiorespiratory fitness. *Sports Medicine*, *3*(5), 346-356.

Westphal, K. A., Friedl, K. E., Sharp, M. A., King, N., Kramer, T. R. (1995). Health, Performance, and Nutritional Status of US Army Women during Basic Combat Training (No. USARIEM-T96-2).*Army Research Institution of Environmental Medicine Natick MA.*

Whaley, M. H., Brubaker, P. H., Otto, R. M. (Eds.). (2000). *ACSM's Guidelines for Exercise Testing and Prescription* (Sixth ed.). Baltimore and Philidelphia: Lippincott Williams and Wilkins.

Wilkinson, D.M., Blacker, S.D., Richmond, V.L., Rayson, M.P., Bilzon, J.L.J., (2014). "Relationship Between the 2.4-km Run and Multistage Shuttle Run Test Performance in Military Personnel", *Military Medicine*, vol. 179, no. 2, pp. 203-7.

Williams, A. G., Rayson, M. P., Jones, D. A. (1999). Effects of basic training on material handling ability and physical fitness of British Army recruits. *Ergonomics*, *42*(8), 1114-1124.

Williams, A. G., Rayson, M. P., Jones, D. A. (2002). Resistance training and the enhancement of the gains in material-handling ability and physical fitness of British Army recruits during basic training. *Ergonomics*, *45*(4), 267-279.

Williams, A. G. (2005). Effects of basic training in the British Army on regular and reserve army personnel. *The Journal of Strength and Conditioning Research*, *19*(2), 254-259.

Williams, A. G., Rayson, M. P. (2006). Can simple anthropometric and physical performance tests track training-induced changes in load-carriage ability. *Military Medicine*, *171*(8), 742-748.

Williamson, D. A., Martin, P. D., Allen, H. R., Most, M. M., Alfonso, A. J., Thomas, V., Ryan, D. H. (2002). Changes in food intake and body weight associated with basic combat training. *Military Medicine*, *167*(3), 248-253.

Woodhead, A. B., Moynihan, M. E. (1994). The effect of Aviation Officer Candidate's School on aerobic and anaerobic fitness. *Military Medicine*, *159*(2), 118-120.

Yanovich, R., Evans, R., Israeli, E., Constantini, N., Sharvit, N., Merkel, D., Epstein, Y., Moran, D. S. (2008). Differences in physical fitness of male and female recruits in gender-integrated army basic training. *Medicine and Science in Sports and Exercise,* 40(11), 654-659.

Zagatto, A. M., Beck, W. R., Gobatto, C. A. (2009). Validity of the running anaerobic sprint test for assessing anaerobic power and predicting short-distance performances. *The Journal of Strength and Conditioning Research*, *23*(6), 1820-1827.

7.0 CHAPTER SIX: APPENDICES

7.0 APPENDICES

Appendix One: Ethics Approval.

JOINT HEALTH COMMAND

ADHREC, CP2-7-100, Campbell Park Offices, PO Box 7911, Canberra BC ACT 2610

2011/1245233

ADHREC/OUT/2012/R11322959

Dr Tim Doyle

Dr Daniel Billing

Dr Denise Linnane

Dr Herbert Groeller

Mr Simon Burley

Dear Researchers

AUSTRALIAN DEFENCE HUMAN RESEARCH ETHICS COMMITTEE (ADHREC) PROTOCOL 645-11 BACK-CASTING APPLICANT AND RECRUIT STANDARDS FROM JOB RELATED PHYSICAL EMPLOYMENT STANDARDS FOR INCUMBENTS

ADHREC has considered your protocol amendments, as submitted on 24 April 2012 (protocol version 4) and has cleared your project to proceed, subject to the return of signed Researcher's Agreements from all Chief Investigators.

Please note that ethical clearance from ADHREC does not automatically confer access to Australian Defence Force (ADF) personnel; this will have to be sought from the relevant military commanders. Similarly, ADHREC approval is not to be interpreted as endorsement by the wider Defence organisation.

The Researcher's Agreement attached, is to be signed by **all** Chief Investigators, formatted in PDF and returned to ADHREC **before the project commences**.

Your protocol has been allocated **ADHREC Protocol Number 645-11** and this number should be quoted in all correspondence. Your protocol has been approved for a period of three years. If your research is to continue over the three year approval time, ADHREC approval for an extension is to be sought in writing.

ADHREC requires you to provide six-monthly progress reports. The first report is due on 01 **November 2012**. As part of your report would you please include:

- A narrative describing the progress to date;
- Any events of significance occurring in the conduct of the protocol, in particular any adverse outcomes;
- Outcome in the case of completed research;
- Maintenance and security of your records;
- Compliance with the approved protocol;
- Any amendments or modifications to the protocol; and
- Compliance with any other special conditions that ADHREC may have required.

If your protocol requires any modification, ADHREC approval must be sought in writing, detailing all modifications required.

For Clinical trials, ADHREC is to be notified in writing of all Serious Adverse Events (SAE) within 72 hours of the event occurring.

I have attached ADHREC's Guidelines for Volunteers, a copy of which is to be given to each study participant.

The Committee wishes you well with your research. Please contact me if I can be of any assistance.

Yours sincerely

Sarah Blackledge

Secretary

ADHREC

Tel (02) 6266 3807

Fax (02) 6266 3072

E-mail: ADHREC@defence.gov.au

27 Apr 2012

Attachments:

A. ADHREC Researchers Agreement

B. ADHREC Guidelines for Volunteers

ATTACHMENT A TO

ADHREC/OUT/2011/R11322959

Australian Government

Department of Defence

ATTACHMENT A TO
ADHREC/OUT/2011/R11322959

RESEARCHER'S AGREEMENT

The Australian Defence Human Research Ethics Committee (ADHREC) requires your agreement to the following conditions in order to secure its endorsement of your project.

Please Initial

□ **1 You must quote your ADHREC number and title of your protocol in all correspondence:**

ADHREC PROTOCOL 645-11 Back-Casting Applicant and Recruit Standards from Job Related Physical Employment Standards for Incumbents

□ 2 If you do not commence data collection within twelve months of this approval, the protocol will need to be resubmitted.

□ 3 The approval of your protocol is for a period of three years. If your research is to continue beyond the three-year approval time, an extension is to be sought in writing.

□ 4 You are required to submit six-monthly progress reports, the first of which is due **01 November 2012.**

□ 5 The Committee requires confirmation that your project has begun, or notification that it has been delayed or abandoned.

□ 6 The Committee requires that a copy of the ADHREC Guidelines for Volunteers be given to every participant when they are recruited for the protocol.

□ 7 Committee approval **must** be sought before any modifications to the protocol are instituted.

□ 8 The Committee **must** be informed of any deviations from the approved protocol and immediately informed of any protocol deviations with real or potential ethical implications.

□ 9 The Committee **must** be informed immediately of unforeseen event that might affect the continued ethical acceptability of this project.

□ 10 The Committee **must** be informed immediately of any untoward effects with respect to the medical, personal or administrative management of participants, or which may have ethical and / or publicity implications.

□ 11 ADHREC gives it ethical approval subject to your explicit agreement to an intention to publish. Publication should be in a refereed journal or other source open to public audit. It would be appropriate to include in your submission for publication the phrase "Ethical clearance for this project was provided by the Australian Defence Human Research Ethics Committee". Should a security classification make publish in an open source inappropriate, ADHREC is to be notified in writing.

□ 12 ADHREC requires a comprehensive **Final Report** which details the conduct of the project and its findings. This report is to be submitted as soon as possible after the project has finished.

□ 13 The ADHREC Secretariat requires that you provide notification of any change in your contact details. Point of Contact is the Executive Secretary at ADHREC@defence.gov.au.

For Clinical Trials Only

□ 14 ADHREC requires that the nominal roll of participants, for the purpose of future tracing, is to be kept for the requisite time by you, according to the NHMRC National Statement on Ethical Conduct in Human Research.

□ 15 The Committee must be informed of any 'adverse events' and immediately informed of any 'serious adverse events' (SAE) which are considered by the Principal Investigator (PI) to be possibly drug related **within 72 hours of their occurrence**.

□ 16 You must retain records of your volunteers' details, any who withdraw, the reasons for that withdrawal (if known) and provide such on request.

I agree to abide by the conditions above:

Signature ………………………………………

Surname………………………………………….

First Name………………………………………

Position/Rank …………………………………...

Contact No Work:……………………………Work Mobile……………………

Email……………………………………………………

Date………………………………………………

Executive Secretary

Australian Defence Human Research Ethics Committee

CP2-7-100 PO Box 7911 CANBERRA BC ACT 2610 AUSTRALIA

Tel (02) 6266 3807

Fax (02) 6266 3072

E-mail: ADHREC@defence.gov.au

Useful Information

Useful information may be obtained from the following website:

http://www.defence.gov.au/health/research/adhrec/i-adhrec.htm

ATTACHMENT B TO

ADHREC/OUT/2011/R11322959

AUSTRALIAN DEFENCE HUMAN RESEARCH ETHICS COMMITTEE— GUIDELINES FOR VOLUNTEERS

Thank you for taking part in Defence Research. Your involvement is much appreciated. This pamphlet explains your rights as a volunteer.

What is the Australian Defence Human Research Ethics Committee

· ADHREC is the Australian Defence Human Research Ethics Committee. It was established in 1988, to make sure that Defence complied with accepted guidelines for research involving human beings.

· After World War II (WWII), there was concern around the world about human experimentation. The Declaration of Helsinki was made in 1964, which provided the basic principles to be followed wherever humans were used in research projects.

· The National Health and Medical Research Council (NHMRC) in Australia has published the National Statement on Ethical Conduct in Human Research (NHMRC 2007). This Statement describes how human research should be carried out.

· ADHREC follows both the Declaration of Helsinki and the NHMRC Statement.

What Australian Defence Human Research Ethics Committee approval means

· If you are told that the project has ADHREC approval, what that means is that ADHREC has reviewed the research proposal and has agreed that the research is ethical.

· ADHREC approval does not imply any obligation on commanders to order or encourage their Service personnel to participate, or to release personnel from their usual workplace to participate. Obviously, the use of any particular personnel must have clearance from their commanders but commanders should not use ADHREC approval to pressure personnel into volunteering.

Voluntary participation

· As you are a volunteer for this research project, you are under no obligation to participate or continue to participate. You may withdraw from the project at any time without detriment to your military career or to your medical care.

· At no time must you feel pressured to participate or to continue if you do not wish to do so.

· If you do not wish to continue, it would be useful to the researcher to know why, but you are under no obligation to give reasons for not wanting to continue.

Informed consent

· Before commencing the project you will have been given an information sheet which explains the project, your role in it and any risks to which you may be exposed.

· You must be sure that you understand the information given to you and that you ask the researchers about anything of which you are not sure.

· Before you participate in the project you should also have been given a consent form to sign. You must be happy that the consent form is easy to understand and spells out what you are agreeing to. Again, you should keep a copy of the signed consent form.

Clinical trials.

The NHMRC requires that the researcher provide a nominal roll of study participants where the study is a clinical trial (e.g. when the researchers are trialling a new treatment or device). For trials conducted by large Defence institutions like the Defence Science and Technology

Organisation, the Submarine and Underwater Medicine Unit, the Army Malaria Institute, the Institute of Aviation Medicine or the Centre for Military and Veterans' Health, this roll is kept by them on ADHREC's behalf. These records will not be used to consider your medical employment standard or for compensation purposes.

All ADHREC protocol files are secured in a locked filing cabinet and only the Secretariat has access to these. ADHREC will not pass your contact information to a third party without your permission.

Complaints

· If at any time during your participation in the project you are worried about how the project is being run or how you are being treated, then you should speak to the researchers.

· If you don't feel comfortable doing this, you can contact the Executive Secretary of ADHREC. Contact details are:

Executive Secretary

Australian Defence Human Research Ethics Committee

CP2-7-100 PO Box 7911 CANBERRA BC ACT 2610 AUSTRALIA

Tel (02) 6266 3807

Fax (02) 6266 3072

E-mail: ADHREC@defence.gov.au

More information

· If you would like to read more about ADHREC, visit the ADHREC website at:

http://www.defence.gov.au/health/research/adhrec/i-adhrec.htm