DEFENCE PHYSICAL EMPLOYMENT STANDARDS PROJECT
Infantry and Airfield Defence Guards

REPORT 5

TRADE TASKS RISK ANALYSIS AND RISK MITIGATION: INFANTRY AND ADG

J F Culvenor
D A Pascoe
W R Payne
J T Harvey
W L Knez
J E Cunningham

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CONTACT

Professor Warren Payne
Project Manager
Defence Physical Employment Standards Project
School of Human Movement and Sport Sciences
University of Ballarat
PO Box 663 Ballarat Victoria 3353
Phone: 03 5327 9693
Fax: 03 5327 9060
Email: w.payne@ballarat.edu.au

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Infantry and Airfield Defence Guards

COMPLETED AND PLANNED REPORTS

No.	Short Title[1]	Date[1]	Type
	Completed Reports		
1	Selection of Key Trade Tasks for Detailed Observation	Mar 04	Minor
2	Selection of Potential Endurance Tests & Anthropometric Measures	Sep 04	Minor
3	Review of Injury Data: Infantry and ADG	Feb 05	Minor
4	Trade Tasks Movement Analysis: Infantry and ADG	Apr 05	Minor
5	Trade Tasks Risk Analysis and Risk Mitigation: Infantry and ADG	Jul 06	Minor
6	The Effect of Physically Demanding Infantry and ADG Trade Tasks on Cognitive Performance: a Pilot Observational Study	Apr 05	Minor
8	Selection of Criterion Trade Tasks: Infantry and ADG	Mar 05	Minor
10	Reliability of Potential Physical Employment Tests: Infantry and ADG	May 06	Minor
	Planned Reports		
7	Retrospective Survey of Injuries: Infantry and ADG	Sep 06	Minor
9	Trade Task Analysis: Infantry and ADG	Sep 06	Major
11	Normative Physical Performance Data: Infantry and ADG	Sep 06	Major
12	Physical Performance Standards: Infantry and ADG	Oct 06	Major
13	Capacity of Women to Improve Physical Performance: a Review	Sep 06	Major

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THE AUTHORS

Dr John Culvenor is an engineer in independent practice specialising in workplace safety and ergonomics, and a Senior Research Fellow at the University of Ballarat. Dr Culvenor works with public companies, law firms and state and federal authorities on work involving workplace hazard analysis and design, expert witness opinions, training, teaching, and policy and research projects. His work has spanned automotive, retail, manufacturing, construction, banking, meat, food processing, road transport, air transport, health care, defence, agriculture, and mining industries. His special interests include safe design, new thinking/creative thinking and hazard areas such as manual handling, plant and equipment, and fall prevention. Dr Culvenor is a consultant to the Defence Physical Employment Standards Project (DPESP).

Deborah Pascoe is a lecturer in the School of Human Movement and Sport Sciences at the University of Ballarat. She is an active teacher and has extensive experience as a clinician in musculoskeletal injury and rehabilitation. Deborah has taught at the tertiary level for over 20 years and currently is the Course Coordinator for the Masters in Exercise Rehabilitation program and Clinical Director of the Unisports Exercise Rehabilitation Centre. In the DPESP, Ms Pascoe's role is in the analysis of injury risk.

Professor Warren Payne is the Professor of Human Movement Science in the School of Human Movement and Sport Sciences at the University of Ballarat. He is an exercise physiologist with over 20 years of research and consulting experience. This experience has included working with a variety of groups and individuals from a range of backgrounds including elite athletes (rowing, cycling, badminton and swimming) and workers involved in heavy manual trades (sheep shearers, fire fighters, aircraft baggage handlers and plasterers). Professor Payne is the Project Manager and Research Leader of the DPESP.

Dr Jack Harvey is a Senior Research Fellow in the School of Information Technology and Mathematical Sciences at the University of Ballarat. He is a mathematical statistician with over 20 years experience in applied research in many contexts including human movement science, health sciences, occupational health and safety, and social and behavioural sciences. In the DPESP, Dr Harvey has professional roles in research design, data management and statistical analysis, and is also Technical Manager of the Project.

Dr Wade Knez is a Lecturer in the School of Human Movement and Sport Sciences at the University of Ballarat. He is an exercise physiologist and also has qualifications in psychology. He has eight years of experience working with athletes at all levels from recreational to elite professional. His specific area of expertise is field based studies. In the DPESP, Dr Knez's roles include leadership of field testing teams, movement analysis and cognitive analysis.

Dr. John Cunningham is an Advanced Orthopaedic Training Registrar, currently working in Sydney. He has extensive research and publication experience in the areas of pain research, biomaterials and orthopaedic clinical and scientific practice. He has also served in the Australian Regular Army on operations in East Timor, Bougainville, the Solomon Islands and at the Olympic Games. He brings to the DPESP his personal knowledge of many of the tasks analysed, the soldiers' approach to tasks, and the orthopaedic risks and their consequences.

EXECUTIVE SUMMARY

Military operational tasks are physically demanding and incur risks for injury. In order to address the issues and costs associated with the high injury rates and focus on ways to reduce the risk of injury to Australian Defence Force (ADF) personnel, the ADF Chiefs of Service Committee (COSC) has endorsed a number of injury prevention strategies aimed at examining, analysing and evaluating injury-related risks and hazards within the ADF. In line with those strategies, COSC has affirmed that ADF employment policy is to be competency based and agreed that physical employment standards should be developed for combat arms trades. The purpose of the Defence Physical Employment Standards Project (DPESP) is to develop these performance-based competency standards.

The ADF has employed the services of the University of Ballarat (UB) to undertake the DPESP. This involves reviewing combat arms trade tasks (CATTs), establishing a set of criterion CATTs, developing a battery of simulation and predictive tests based on the criterion CATTs to be used to assess the physical competency of ADF combat personnel, and making recommendations for associated physical employment standards.

In the initial phase, the study is focused on one Army corps - Infantry, and one Air Force mustering - Airfield Defence Guards (ADG).

The central purposes of this component of the work were:

- to perform a risk analysis for the dual purposes of developing a risk register for general use and identifying risk issues in relation to the development of physical employment standards which pose a minimum possible risk to test candidates; and
- to identify risk mitigation strategies that may be implemented or developed for use in Infantry and/or Airfield Defence Guards.

Risk Analysis

Video recordings of 33 tasks were provided. These were broken into 122 subtasks. Risk analysis of musculoskeletal risks arising from manual handling aspects of the subtasks was undertaken using observation of movements and postures. A biomechanical modelling approach was taken for high-effort short duration tasks. Repetitive tasks were analysed using an approach in which a composite risk measure is derived on the basis of intensity and duration of effort together with frequency of repetition of each action within the task. The outputs of the biomechanical and repetitive task analyses were both scaled to produce numerical risk scores in the range 0-10.

Limitations to the quantitative risk assessment methodology employed are discussed in the report. Whilst these factors limit the accuracy of specific quantitative estimates, they are not considered sufficiently limiting as to invalidate the comparative assessment of risks and the division of tasks into three broad categories of risk. This view is supported by the concordance between these categorical assessments and assessments made independently by key Defence informants in the initial stages of the DPESP.

The risk analysis included the division of each task into component subtasks and the derivation of a risk score for each part of the body for each subtask. These scores were combined to produce composite overall risk scores for each task. Most tasks were shown to involve one or more high-risk subtasks. Some of these could be improved through changes to equipment design, task design, and/or training.

On the basis of the risk analysis, 20 tasks were categorised as high risk. For the 15 of these tasks for which independent ratings by key Defence informants were available, all were rated as either being high physical demand or high risk or both. The 20 tasks in this high risk group, in decreasing order of risk score, are:

- Casualty evacuation (combined)
- Dig to stage 1
- Shell scrape
- Rope climb

- Casualty evacuation (drag)
- Casualty evacuation (carry)
- Forced march
- Mortar route march
- Sustained patrol
- Section attack with roll (bush)
- Patrol in marching order
- Tunnel crawl
- Section attack with roll (oval)
- Section attack (oval)
- Company level replenishment
- Pursuit
- Star picket lift
- Ladder lift
- Second storey drop
- Section attack (bush)

Among the remaining tasks, four were not categorised as high risk by the risk analysis, but were rated by key Defence informants as being either physically demanding or high risk. These are considered as being possibly high risk. The tasks in this group, in decreasing order of risk score, are:

- Debus
- Population protection and control
- Loading and unloading UNIMOG
- Bayonet assault

Nine tasks were not categorised as high risk by the risk analysis, and were either not rated by key Defence informants or were rated as not physically demanding and not high risk. These tasks are not without risk – they are simply the tasks that appear to involve lower risks from among the 33 tasks analysed. It should be noted that most of these tasks include a high-risk subtask. The nine tasks in this group, in decreasing order of risk score, are:

- Patrol in patrol order
- Jerry can carry
- Wall climb
- Category 1 wiring (Infantry)
- Category 1 wiring (ADG)
- Forced entry and stair climb
- Urban patrol
- Sandbagging
- Ammunition box carry

Recommendations from the Risk Analysis

In addition to the overall assessment of risk for each task contained in this report, the risk analysis data for each subtask is presented as a risk register. It is recommended that the listing of subtasks in the register be maintained. It is the subtasks that have particular risk characteristics. It is these characteristics that need to be addressed through solutions. Whilst a solution might require changing the entire task, to understand the risks attention needs to be given to the detail of the subtasks. The risks should also be identified according to the body part as this helps identify the particular problem with the subtask.

To facilitate ongoing evaluation and review, it is recommended that the data in the risk register be used to establish a risk database. Individual entries in the database should be at the subtask level, but entries should also be linked to tasks so that all the hazards associated with a particular task can easily be identified and collated. There should be provision for recording details including a hazard description, part of the body affected, risk score, suggested actions and person/position responsible for risk reduction.

It is recommended that the risk register/database should be reviewed within the Australian Defence Force in line with other recent or contemporaneous risk assessments conducted in programs such as RAAFSAFE.

With specific reference to the DPESP, it is recommended that in selecting Criterion Tasks on which to base Physical Employment Tests (PETs), account should be taken of the risk assessments herein, and if possible PETs should be based on lower risk tasks. However, it is noted that most tasks, regardless of the overall level of risk, contain subtasks that present high risks to one or more body parts. Therefore, even if it is possible to utilize the lower risk tasks for the PETs, it is recommended that close consideration be given to the high-risk components of selected criterion tasks. Removal or modification of the high risk subtasks when developing the PET protocols would significantly reduce the overall risk of the PET.

Risk Mitigation

The work of the combat arms trades needs to be made as safe as practicable over the long term to ensure the soldiers/airmen enjoy long, safe and productive careers. To this end, a Risk Mitigation Workshop was held for the purpose of examining the 24 tasks identified by the risk analysis as being high risk or possibly high risk. Participants were challenged with the role of generating ideas and strategies to reduce the risks of injury identified during the risk analysis phase of the project. Examples from industrial safety used in the automotive industry, hospital and health care systems and the use of safety at the design stage as a national priority were presented as a catalyst for the development of new thinking to be applied to the Defence Force tasks.

To develop the risk mitigation strategies the workshop participants reviewed each task in either a small group or whole group problem solving approach. Each task was reviewed to identify the nature of the task, the purpose of the task and the hazards inherent in the completion of the task. The group then explored possible best practice strategies. Practice strategies were considered from other areas of the Australian armed services, other military operations and current civilian industries. Each task was viewed using the universal problem-solving tool of the “hierarchy of control”. This included consideration of the following components; *elimination* of the whole task, or hazardous elements of the task; *engineering* to develop new tools, equipment or modify the design of current equipment to decrease risk of injury; *substitution* of materials and/or equipment; *procedures* reviewed to ensure the task is organised in a safe and efficient way; and, *protective clothing* to provide better protection from injury.

The results of the workshop were collated by grouping together tasks which involve similar workloads and/or performance demands, as follows:

- Lifting and sustained carrying of loads, marching and patrolling
- Go to ground, aim, crawl, rise and run
- Urban movement and building access
- Population protection and control drills
- Casualty evacuation
- Bayonet assault
- Loading and unloading trucks
- Digging
- Debussing

This grouping of related tasks facilitated the evaluation of risk of injury, the examination of relevant research, and the generation ideas for solutions such as modification of tasks, development of equipment and modification to training and technique to be considered.

Recommendations Regarding Risk Mitigation

Risk mitigation strategies proposed in the report include the following:

- Redesign of helmets
- Neck strengthening activities.
- Development of safer evacuation drag technique
- Redesign of webbing.
- Development of safer ‘going to ground’ technique.
- Gradation of training with regard to use of body armour.
- Adherence to appropriate and consistent weapon handling in training.

It is also recommended that Defence should:

- Prioritise the ideas put forward from the workshop.
- Develop steps to advance these to the next developmental or implementation stage, including allocating responsibilities, determining agencies that should be involved and determining research needs for specific ideas (Defence Materiel Organisation, Defence Science and Technology Organisation, University of Ballarat).
- Attempt to better understand the impact of the various CATTs on injury and disease costs. At present, it appears that costs of injury and disease are not able to be allocated in a way that makes a clear connection to a given CATT.
- Communicate the ideas and solutions contained within this report to those responsible for allied projects such as Project Wundarra and Land 125 in order to ensure that appropriate solutions are incorporated into the design of new and emerging equipment.
- Undertake research to better understand and define the impact of operations on safe long-term human performance. This could involve considering the applicability of manual handling models to the defence environment.
- Review policy on injury and disease prevention by considering opportunities to strengthen policy to emphasise that good safety is essential to maximise operational capability.

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ABBREVIATIONS AND ACRONYMS

ADF	Australian Defence Force
ADG	Airfield Defence Guard
AFDW	Airfield Defence Wing
CATT	Combat Arms Trade Task
COSC	Chiefs of Service Committee
DPESP	Defence Physical Employment Standards Project
IET	Initial Employment Training
PES	Physical Employment Standards
PET	Physical Employment Test
PTI	Physical Training Instructor
2 RAR	2nd Battalion Royal Australian Regiment
2 AFDS	2nd Airfield Defence Squadron

1 INTRODUCTION

1.1 Background

1.1.1 Military operational tasks are physically demanding and incur the risk of injury. In order to address the issues and costs associated with the high injury rates and focus on ways to reduce the risk of injury to Australian Defence Force (ADF) personnel, the ADF Chiefs of Service Committee (COSC) has endorsed a number of injury prevention strategies aimed at examining, analysing and evaluating injury-related risks and hazards within the ADF. In line with those strategies, COSC has affirmed that ADF employment policy is to be competency based and agreed that physical employment standards should be developed for combat arms trades. The purpose of the Defence Physical Employment Standards Project (DPESP) is to develop these performance-based competency standards.

1.1.2 The ADF has employed the services of the University of Ballarat (UB) to undertake the DPESP. This involves reviewing combat arms trade tasks (CATTs), establishing a set of criterion CATTs, developing a battery of simulation and predictive tests based on the criterion CATTs to be used to assess the physical competency of ADF combat personnel, and making recommendations for associated physical employment standards (See Reference Documents A and B).

1.1.3 In the initial phase, the study is focused on one Army corps - Infantry, and one Air Force mustering - Airfield Defence Guards (ADG).

1.1.4 The steps in the DPESP study are:

a. identification and observation of CATTs;
b. analysis of physical demands and cognitive effects of CATTs;
c. identification and analysis of injury risks of CATTs;
d. identification of criterion CATTs on which to base tests of physical performance;
e. development of a set of potential physical employment tests (PETs), and establishment of their reliability and validity;
f. collection of normative data on the PETs;
g. selection of the final battery of PETs and determination of minimum performance standards on each.

1.2 Aim

1.2.1 Within this context, the purposes of this component of the work (WBS 1.2.3 Trade Task Risk Analysis) were:

a. to perform a risk analysis for the dual purposes of developing a risk register for general use and identifying risk issues in relation to the development of physical employment standards which pose a minimum possible risk to test candidates; and
b. to identify risk mitigation strategies that may be implemented or developed for use in Infantry and/or Airfield Defence Guards.

The first of these aims is addressed in Part A of this report, and the second in Part B.

PART A: RISK ANALYSIS

2 METHODS OF RISK ASSESSMENT

2.1 Conceptual Framework

2.1.1 The purpose of the work module was to assess the musculoskeletal risks of the trade tasks, including risk of cumulative trauma disorders and repetitive motion disorders, and to produce a risk register. Risk can be defined in different ways; it is generally agreed to have a number of components or dimensions, although the terminology used to identify these components or dimensions is not standardised. Risk is often described as being composed of the frequency (also probability or likelihood) of an event and the consequences (also severity) of that event (e.g. Terry 1991; Standards Australia and Standards New Zealand 1999; Kletz 1999). A common method of assessing risk is to make an assessment of the frequency and consequence and combine these using a risk matrix. The model in an appendix to the Australian and New Zealand Standard is an example of such a matrix.

2.1.2 The consequence component is relatively straightforward. However, the frequency component is less so, since it can be broken down into two further components, sometimes referred to as probability and exposure. For purposes of clarification we define the following terms. An *episode* is the performance of a CATT by an individual soldier or airman. An *event* is the occurrence of an injury during an episode. The *probability* of injury is the long run average number of events per episode. The *exposure* is the number of episodes per time period (usually one year) for an individual (*individual exposure*) or for all the individuals in an organisation (*organisational exposure*). Exposure can be similarly defined for a particular unit within an organisation. The *frequency* of injury is the number of events per year, either per individual (*individual frequency*) for the organisation as a whole (*organisational frequency*), or for a unit within the organisation. Thus defined, *frequency* = *probability* × *exposure*.

2.1.3 In terms of these definitions, three types of risk can be described and assessed. The *episodic risk* or *risk per episode* is a combination of the consequences and the probability. The *annual risk* for an individual (*individual annual risk*) is a combination of the consequences and the individual frequency. The *annual risk* for an organisation (or *organisational annual risk*) is a combination of the consequences and the organisational frequency.

2.1.4 Probability and exposure are each unidimensional and, in principle at least, relatively easy to quantify; they are combined multiplicatively to arrive at frequency. However, risk is generally not considered to be a simple multiplicative combination of either frequency or probability with consequence. This is partly because consequences are more difficult to characterise in a single numerical value. Even if consequences can be quantified, nomograms employing non-linear scales are often used to combine the components of risk in a non-linear fashion. Categorical or matrix methods can also be used, particularly if any of the three components (consequence, probability or exposure) cannot be numerically quantified. Both episodic risk and annual risk can be assessed by matrix methods, with one dimension being consequences and the other being respectively either probability or frequency.

2.1.5 Probability and consequence, and hence the episodic risk, can be assessed by observation of the CATT being performed. Assessment of annual risk requires exposure data for individuals, units and/or for the organisation as a whole. For the most part, this report is based on task observations and focused on episodic risks. However, reference is also made to Report 1 in this series (Reference Document C), in which key Defence informants made assessments of annual risk based on their knowledge of both the nature of the tasks and levels of exposure.

2.2 Methods of Risk Assessment Based on Observational Data

2.2.1 Available methods may be described as qualitative, semi-quantitative, or quantitative.

2.2.2 The musculoskeletal risks arising from the CATTs exist primarily because of manual handling – lifting, carrying, climbing, pushing, pulling, etc. An assessment method of at least a semi-quantitative nature was sought for these central manual handling risks. Some tasks however involve ancillary musculoskeletal risks that are not strictly due to manual handling but are related. These include falls, trips, twisted ankles on rough ground and the like. These ancillary risks can depend heavily on the environmental context such as the ground conditions. Qualitative assessment was sought for this type of ancillary risk. In addition the opinions of Defence personnel familiar with the task were included. This was achieved by drawing on the data in Report 1 of this series (Reference Document C), where ratings of physical demands and task risks were reported.

2.2.3 With regard to manual handling, throughout the Australian jurisdictions employers are required to examine the issues that give rise to manual handling risk. Three examples are shown below.

2.2.4 In the Commonwealth the following factors are to be considered (*Occupational Health and Safety (Commonwealth Employment) (National Standards) Regulations 1994*, r.5.03(2)):

a. actions and movements involved in the task;
b. layout of the workplace or wherever the task is done;
c. layout of the workstation;
d. posture and position;
e. duration;
f. frequency;
g. location of each load;
h. distance that a load is moved;
i. weight involved;
j. force required;
k. characteristics of each load;
l. characteristics of any plant that is used;
m. organisation of work at the workplace or wherever the task is done;
n. work environment at the workplace or wherever the task is done;
o. skills and experience;
p. age;
q. clothing;
r. special needs of each individual;
s. any other matter that is considered relevant following consultations required under the Act or these Regulations.

2.2.5 In Victoria employers are required to consider the following factors when assessing manual handling risk (*Occupational Health and Safety (Manual Handling) Regulations 1999*, r.14(2)):

a. postures adopted;
b. movements undertaken;
c. forces exerted;
d. environmental conditions, including heat, cold and vibration, that act directly on the person carrying out the task; and
e. the duration and frequency of the task.

2.2.6 In South Australia, employers must consider (*Occupational Health, Safety and Welfare Regulations, 1995*, r.2.9.3(2)):

a. actions and movements;
b. workplace and workstation layout;
c. postures and positions;
d. duration and frequency;
e. location of the loads and distances they must be moved;
f. weights and forces involved;
g. characteristics of the loads and equipment used;
h. organisation of the work;
i. work environment;
j. skill and experience of the operators;
k. personal characteristics of the operators;
l. clothing; and
m. any other relevant factor.

2.2.7 Similar requirements to those above can be found in other jurisdictions. As a result, guidance material in the form of codes of practice further outline tools to aid the examination of the various risk factors. Checklists are often used for this purpose. The checklists prompt the user/investigator to analyse and identify the aspects of a task that might present a risk of injury.

2.2.8 Observation and description of the risk issues were adopted. In general these methods could be described as qualitative in nature. These methods also captured additional musculoskeletal risks that could arise from traumatic events including falls, jumping from height, tripping, and stumbling.

2.2.9 Risk-modeling tools were sought which were specific to manual handling and which provided a close exploration of the risk factors as well as providing semi-quantification. An analysis method as described by Rodgers (1992) was used for repetitive tasks. Biomechanical modeling was used to highlight overexertion hazards – those that involve high load but not necessarily repetitive or sustained actions. These semi-quantitative methods focused on the central manual handling risks (as against the related traumatic risks of falls, etc).

2.3 Analysis Frameworks

2.3.1 Two frameworks have been proposed for the analysis of movement. Carr and Shepherd (2000) propose three major components of movement: joint displacement, muscle action and the spatio-temporal relationships among muscles for the duration of the task or movement. Fisher and Yakura (1993) use four biomechanical descriptors of movement behavior which must be observed during analysis of movement tasks: base of support; alignment; sequence of movement, and stability/mobility. In the following paragraphs, movement analysis is discussed largely within the Fisher and Yakura paradigm, but with reference to aspects of the Carr and Shepherd paradigm.

2.3.2 During observation of the functional tasks, the overall dimensions of the base of support and how it changes during the activity - from the starting posture throughout the movement itself to the ending posture - is closely noted. Knowledge of joint anatomy and biomechanics is then applied to discover whether the activity inappropriately moves the centre of gravity of the body from the body's base of support. This method is used to determine whether the base of support or the structures that support weight are causing a problem for the soldier/airman during a particular activity.

2.3.3 Alignment refers to both the relationship of the body's centre of mass over the base of support and the relationships of the body segments to each other. The alignment is also observed from the initial posture and throughout the movement until final posture. The initial postural alignment of a person dictates the movement options available. Pathologic postures and the resulting movements lack harmony and economy and reduce the ability for fine adjustment during the task. With postural misalignment, strain on the passive structures increases, and inappropriate demands are made of the musculature.

2.3.4 Fisher and Yakura (1993) define 'sequence' as the order of occurrence, timing of changes and direction of movement of the segments. They emphasize that the initiation of the movement or which body segment moves first influences the progression of the entire movement. This is usually addressed in the teaching of correct or preferred technique using appropriate posture and skilled performance parameters. In the learning of these techniques the performer needs to be provided with appropriate demonstrations and guidance and continual feedback with verbal, visual and tactile cues to correct the performer's movement pattern during the application and practice of the tasks.

2.3.5 To analyze a task properly Fisher and Yakura (1993) also attempt to identify the body segments that form part of a postural support system and serve as moving segments. For body movement purposes the trunk acts mainly as a stabilizing center for posture and peripheral movements. Through synergistic and antagonistic muscle activity (dynamic stabilization) the trunk is able to receive, absorb and transmit incoming movement forces. The pelvis helps control, coordinate and transmit the forces generated by the legs to the vertebral column. By absorbing many weight-bearing forces the legs contribute to the health of the spinal column. The head requires great mobility to properly scan the environment with eyes, ears and nose. The arms are considered the region of manual skill and allow the body to interact with the environment with great precision. The arms generally act independently of each other (Goldstein, 1995).

2.3.6 Carr and Shepherd (2000) also consider whether conditions change from one attempt to the next. The environmental variability, terrain and context of the task will influence the ability of the body to adapt to the changing conditions of the task. If the task is of a repetitive nature, consideration needs to be given to time of one repetition, number of repetitions and total time of task. The spatio-temporal patterning required to complete the task or variations that may be factored into the task will influence fatigue and recovery.

2.3.7 The principles contained within these frameworks are embodied in the analysis methods for hazards of repetitive tasks and hazards of overexertion introduced in Sections 2.4 and 2.5.

2.4 Analysis of Hazards Associated with Repetitive Tasks

2.4.1 Repetitive strain injury risks were analysed using the methodology of Rodgers (1992). The approach requires an analysis of three factors: effort intensity; effort duration; and efforts per minute. Each of these is rated on a three-point scale according to the guidelines shown in Table 1. Guidance for the effort rating is provided for the following muscle groups: back; legs and ankles; neck; shoulder; arms and wrists; and fingers and thumbs (Table 2). In the actual application hazards are identified for even more specific groups. For instance knee and ankle are separately identified. In the case of the analysis here, the broad groups listed were those used, with the exception of fingers and thumbs. This category of risk was not included in the analysis in order to concentrate on the larger muscle groups. Analysis using Rodgers' (1992) approach results in a three-factor score for each task. The combinations of these three factors are converted to a risk description using the scales shown in Table 3.

2.4.2 Rodgers (1992, p. 696) wrote that the method has been used in a range of industries but not scientifically validated. She notes however that; "…*it has proved to be a workable system to make the evaluation of jobs less subjective. Participants in the process find that the three-number rating system forces them to look carefully at the job requirements.*"

2.4.3 The Ford Motor Company of Australia utilizes Rodgers' model in its risk assessment process[1]. The Ford approach splits Rodgers' four risk categories into 10 categories as shown in Table 4. Thus scores 1-4 relate to low; 5-7 to moderate; 8-9 to high; and 10 to very high. Like Rodgers (1992) methodology, the further breakup into 10 categories has not been subjected to any validation; however experience in the field by one of the authors of this report has confirmed the functionality of this method. This approach was adopted for the analysis of the tasks for this report.

[1] Known as *Process Safety Review*, the process put in place in 1997 was recognized in 1998 for its value as overall winner of the Victorian WorkCover Authority Safety Awards (Miller 1998).

Table 1. Repetitive Strain Injury Ratings of Effort, Duration (Rodgers 1992)

Rating	Effort intensity	Effort duration	Effort frequency[1]
1	Combined effect of force and joint posture according to the guidance shown in Table 2	< 6 seconds	< 1 per minute
2		6-19 seconds	1-4 per minute
3		20-40 seconds	5-15 per minute

Table 2. Repetitive Strain Injury Descriptions of Effort Levels (Rodgers 1992)

Body part	Light=1	Moderate=2	Heavy=3
Neck	Head turned partly to side or back or forward slightly.	Head turned to one side; head fully back; forward about 20º.	Same as moderate but with force or weight; head stretched forward.
Shoulders	Arms slightly away from sides; arms extended with some support.	Arms away from body, no support; working overhead.	Exerting forces or holding weight with arms away from body or overhead.
Back	Leaning to side or bending; arching back.	Bending forward, no load; lifting moderately heavy loads near body; working overhead.	Lifting or exerting force while twisting; high force or load while bending.
Arms, elbows	Arms away from body, no load; light forces/lifting near body.	Rotating arm while exerting moderate force.	High force exerted with rotation; lifting with arms extended.
Hands, fingers, thumbs, wrists.	Light forces or weights handled close to the body; straight wrists; comfortable power grips.	Grips with wide or narrow span; moderate wrist angles, especially flexion; use of gloves with moderate forces.	Pinch grips; strong wrist angles; slippery surfaces.
Legs, knees, ankles, feet and toes/	Standing, walking without bending or leaning; weight on both feet.	Bending forward, leaning on table; weight on one side; pivoting while exerting force.	Exerting high forces while pulling or lifting; crouching while exerting force.

Table 3. Repetitive Strain Injury Categories of Risk (Rodgers 1992)

Risk Priority Category	Very high	High		Moderate			Others not listed (presumably "low")			
Effort/Duration/Frequency rating combinations	332	322	313	312	231	132	311	211	121	112
	331	321	223	232	222	123	221	131	113	111
	323				213		212	122		

[1] The term *frequency* used in Tables 1, 3 and 4 pertains to the frequency of repetition of an action during the performance of a task, and should not be confused with the frequency of performance of the task discussed in Section 2.1.

Table 4. Repetitive Strain Injury Risk Scores
(Ford Motor Company of Australia 1997; based on Rodgers 1992)

Rogers Risk Priority Category	Very high	High		Moderate			Low			
Ford Risk Priority Number	10	9	8	7	6	5	4	3	2	1
Effort/Duration/Frequency rating combinations	332 331 323	322 321	313 223	312 232	231 222 213	132 123	311 221 212	211 131 122	121 113	112 111

2.5 Analysis of Hazards Associated with Overexertion

2.5.1 Overexertion hazards are those that involve high loads on any part of the body. Overexertion hazards can be assessed using a range of models such as the tables of Snook and Ciriello (1991); biomechanical modelling using the University of Michigan software programs[1]; or the Revised NIOSH Lifting Equation (Waters et al., 1994). The Revised NIOSH Lifting Equation is specifically designed for lifting tasks under reasonably stereotypical industrial circumstances such as loading pallets of goods with cartons. The Snook and Ciriello tables are more comprehensive, offering tables of maximum acceptable push, pull, lift, lower and carry. The tables include effects of repetition and duration. These tables would be applicable to many defence tasks. However since an additional model was proposed to analyse repetitive tasks (Rodgers model – see Section 2.3) it was decided to utilize biomechanical modelling for the overexertion hazards.

2.5.2 Biomechanics "…is the study of forces on the human body." (Tracy, 1995). The University of Michigan write that "The University of Michigan's 3D Static Strength Prediction Program™ (3D SSPP) is based on over 25 years of research at the Center for Ergonomics regarding the biomechanical and static strength capabilities of the employee in relation to the physical demands of the work environment." A technical discussion of the static strength model used in the program is provided in Chaffin et al. (1999).

2.5.3 The inputs to the University of Michigan program are: posture (by inputting body angles and viewing a set of stick-figures); gender; body size (percentile can be set or weight and height can be input); and forces on the hands. The force magnitude and direction can be independently set for each hand. The program calculates compression in the spine (and some other measures). The spine compression is a common output sought in occupational settings. This value (in Newtons) can be compared with the 3400N guideline of the National Institute for Occupational Safety and Health (Waters et al., 1993). The program also calculates torque about other joints (ankle, knee, hip, torso, shoulder and elbow). The torque figure is compared with population strength data for those joints and a percent capable figure[2] is output.

1 www.engin.umich.edu/dept/ioe/3DSSPP/index.html
2 The percentage of the population who are capable of exerting a torque of a given magnitude.

3 METHODOLOGY USED IN THIS STUDY

3.1 Task Observation

3.1.1 Task Observation was carried out at 2 AFDS (Amberley) during 12-20 May 2004 and 2 RAR (Townsville) during 2-18 June 2004. Full details are given in Report 4 in this series (Reference Document D).

3.1.2 Tasks were videotaped from selected vantage points. The videotapes were analysed as described in Section 2 and Sections 3.2-3.4. Ancillary information including object weights was provided as a result of the task analysis exercise (see Reference Document D).

3.2 Hazards of Repetitive Tasks

3.2.1 Repetitive strain injury risks were analyzed using the methodology of Rodgers (See Section 2.4).

3.3 Hazards of Overexertion

3.3.1 Biomechanical modelling was undertaken using the University of Michigan's 3D Static Strength Prediction Program™ (3D SSPP) (See Section 2.5). The outputs of the biomechanical model were converted into risk scores according to the guideline shown in Table 5. The logic is that this scale places those tasks with compression in excess of 3400N and joint percent capable less than 75% in the high-risk area (8 and above). At the other end of the scale a compression of about 500N or below is about the figure that could be expected when a person is standing upright and not exerting any force. In the case of joint percent capable, those tasks with 100% capable score the lowest risk level. Categorization of risk levels between the extremes is simply a convenient break down of the values. The elbow percent capable is used for "arm". The lowest (worst) percent capable figure for ankle and knee is used for "leg". No output is available for the neck either in terms of spine compression or percent capable. Overexertion risk is however of interest. Without determining a risk score for overexertion of the neck, the neck risk will be only measured through the repetitive risk analysis. It is common to relate overexertion injury risk of the neck to the forceful exertions of the hands and arms and in particular the load at the shoulder. The 1997 NIOSH review (Bernard 1997) of the evidence of links between musculoskeletal injuries and workplace factors did not draw a clear distinction between neck and shoulder, but rather was couched in terms of "neck and neck/shoulder musculoskeletal disorders". This review reveals evidence for a link between neck disorders and forceful exertions of the arm and shoulder, which indicates that neck exertion is related to shoulder exertion. Therefore in the current analysis, in the absence of a direct calculation of neck forces, it was decided to use shoulder forces as a surrogate for neck forces. Hence the risk value calculated for the shoulder was also used as the risk value for the neck (in the case of overexertion assessment only).

Table 5. Risk Priority Numbers for Overexertion

Risk Priority Number	Lumbar spine compression	Joint percent capable
10	>5000N	0-24%
9	4000-5000N	25-49%
8	3400N-4000N	50-74%
7	3000-3400N	75-79%
6	2500-3000N	80-84%
5	2000-2500N	85-89%
4	1500-2000N	90-94%
3	1000-1500N	95-98%
2	500-1000N	99%
1	<500N	100%

3.4 Analysis at the Subtask and Task Level

3.4.1 The data encompass 33 tasks. These were broken into subtasks for analysis. The effect of those subtasks was broken into five body segments and given a risk score using the more relevant of the two methods (see Section 2.5) in each case. This resulted in hundreds of risk estimations.

3.4.2 Reporting of results is at two levels. The primary aim of this report was not to focus on the particular risks at the subtask level, but rather to assess the overall risk for each task. However, all the risk estimates for particular body parts at the subtask level are reported in a Risk Register (Annex 1), which could form the basis for a database of risks. The body of the report contains aggregated risk estimates at the task level.

3.4.3 Two approaches were taken to aggregate the risks of the subtasks into composite scores for the tasks. The first was to identify the maximum subtask risk for each body part, and average these maximum scores to obtain the risk score for the task. The second was to average the subtask risks for each body part, and then average these averages to obtain the risk score for the task. This second approach was modified in the case of lengthy endurance tasks which also included subtasks of comparatively very short duration. In these cases only the risk scores for the dominant subtask/s were used to calculate the average risk score for each body part. These figures were then averaged to arrive at the task risk score.

3.4.4 The maximum and average risk scores for each body part, together with the averages of each of these across body parts, are included in the Risk Register for each task, and form the basis of Section 4 of this report.

3.5 Consideration of Assessments from Report 1

3.5.1 In Table 10 of Report 1 in this series (Reference Document C), tasks were categorised as high or low both for physical demand and for risk. The latter were assessments of cumulative risk (see Section 2.1), since key Defence informants took their knowledge of comparative exposure levels into consideration in making these assessments. These assessments of physical demand and cumulative risk were considered in conjunction with the assessments of intrinsic risk made in this report, in order to identify a final list of CATTs which should be examined for the purpose of identifying risk mitigation strategies.

4 RESULTS

4.1 Data

4.1.1 The primary data sources were video recordings of 33 CATTs, 26 of which are performed by both Infantry and ADG, two by Infantry only and seven by ADG only. Twenty tasks were observed at 2 RAR (Infantry) and 13 at 2 ADS (ADG). The tasks are listed alphabetically in Table 6. Table 7 shows still photographs of each task derived from the videotapes.

Table 6. List of Tasks

Observed at	Performed by	CATT
ADG	Both	Ammunition box carry
Infantry	Both	Bayonet assault
Infantry	Both	Casualty evacuation (carry)
ADG	Both	Casualty evacuation (combined)
Infantry	Both	Casualty evacuation (drag)
ADG	Both	Category 1 wiring
Infantry	Both	Category 1 wiring
Infantry	Both	Company level replenishment
ADG	ADG	Debus
ADG	Both	Dig to stage 1
Infantry	Both	Forced entry and stair climb
Infantry	Infantry	Forced march
ADG	Both	Jerry can carry
Infantry	Both	Ladder lift
ADG	Both	Load and unload UNIMOG
Infantry	Both	Mortar route march
Infantry	Both	Patrol in marching order
Infantry	Both	Patrol in patrol order
Infantry	Both	Population protection and control
ADG	ADG	Pursuit
Infantry	Both	Rope climb
ADG	Both	Sandbagging
Infantry	Both	Second storey drop
Infantry	Infantry	Section attack (bush)
Infantry	Infantry	Section attack (oval)
ADG	ADG	Section attack with roll (bush)
ADG	ADG	Section attack with roll (oval)
ADG	Both	Shell scrape
Infantry	Both	Star picket lift
ADG	ADG	Sustained patrol
Infantry	Both	Tunnel crawl
Infantry	Both	Urban patrol
Infantry	Both	Wall climb

Table 7. Task Photographs

Ammunition box carry			
Bayonet assault			
Casualty evacuation (carry)			
Casualty evacuation (combined)			
Casualty evacuation (drag)			

Category 1 wiring (Infantry)

Category 1 wiring (ADG)

Company level replenishment

Debus

Dig to stage1

Forced entry and stair climb



Forced march



Jerry can carry

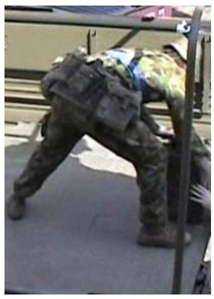


Ladder lift



Load and unload UNIMOG





Mortar route march



Patrol in marching order



Patrol in patrol order



Population protection and control



Pursuit



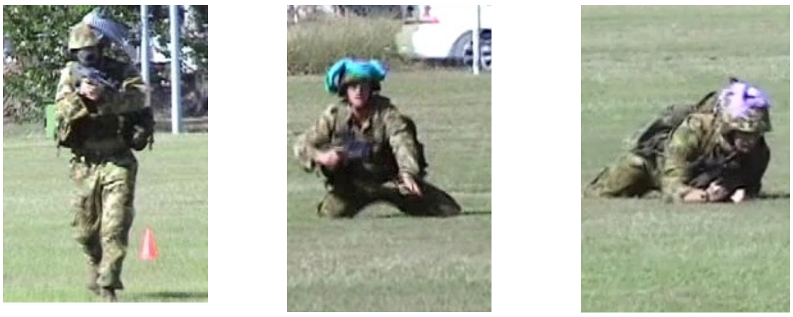
Rope climb

Sandbagging

Second storey drop

Section attack (bush)

Section attack (oval)



Section attack with roll (bush)

Section attack with roll (oval)

Shell scrape

Star picket lift

Sustained patrol

Tunnel crawl

Urban patrol

Wall climb

4.2 Task and Subtask Risk Scores and Descriptions

4.2.1 The risk scores are shown in Annex 1. This report is focused at the task level, but utilises analyses at the subtask level. Table 1 in Annex 1 lists the risk estimates for the subtasks by each of the major body parts. The maximum subtask risk and the average of the subtask risks for each body part are shown.

4.3 Task Risk Scores: Based on Highest Risk Subtask

4.3.1 Table 8 shows the list of tasks and the maximum subtask risk score for each body part. The average of the maxima for each body part is also shown. High risk scores (8.0 or greater) are in boldface. The tasks are listed in order of the highest to lowest average. The figures show that for most tasks at least one subtask involves a high risk to each major body part. Table 8 also shows the tasks identified as being physically demanding or high risk by Defence subject matter experts (Reference Document C).

Table 8. Task Risk Scores Based on Maximum Subtask Risk Scores

(Tasks are ordered from highest to lowest based on average over the body parts Risk scores of 8.0 or greater are in boldface)

Observed at	Performed by	Description	Maximum Subtask Risk Scores for each body part					Average maximum risk score	From Table 10, Report 1	
			Legs, knees, ankles	Back	Neck	Shoulder	Arms, elbow, wrist		Physically Demanding	High risk
Infantry	Infantry	Forced march	**8.0**	**10.0**	**9.0**	**9.0**	**9.0**	9.0	**Yes**	**Yes**
Infantry	Both	Mortar route march	**8.0**	**10.0**	**9.0**	**9.0**	**9.0**	9.0	**Yes**	**Yes**
Infantry	Both	Star picket lift	5.0	**10.0**	**10.0**	**10.0**	**10.0**	9.0	-	-
ADG	ADG	Sustained patrol	**8.0**	**10.0**	**9.0**	**9.0**	**9.0**	9.0	**Yes**	**Yes**
Infantry	Both	Wall climb	5.0	**10.0**	**10.0**	**10.0**	**10.0**	9.0	-	-
ADG	Both	Casualty evacuation (combined)	**8.0**	**10.0**	**6.0**	**10.0**	**10.0**	8.8	**Yes**	No
ADG	Both	Load and unload UNIMOG	**8.0**	**10.0**	**9.0**	**9.0**	**8.0**	8.8	No	**Yes**
Infantry	Both	Category 1 wiring	7.0	**10.0**	**9.0**	**9.0**	**8.0**	8.6	No	No
ADG	Both	Dig to stage 1	6.0	**10.0**	**10.0**	**8.0**	**8.0**	8.4	**Yes**	No
Infantry	Both	Population protection and control	**9.0**	**9.0**	6.0	**9.0**	**9.0**	8.4	**Yes**	No
ADG	ADG	Section attack with roll (bush)	8.0	**9.0**	**9.0**	**8.0**	**8.0**	8.4	**Yes**	**Yes**
ADG	Both	Shell scrape	6.0	**10.0**	**10.0**	**8.0**	**8.0**	8.4	**Yes**	**Yes**
Infantry	Both	Tunnel crawl	**10.0**	**10.0**	**10.0**	6.0	6.0	8.4	-	-
Infantry	Both	Company level replenishment	6.0	7.0	**8.0**	**10.0**	**10.0**	8.2	No	**Yes**
Infantry	Both	Bayonet assault	**8.0**	**9.0**	**9.0**	**8.0**	6.0	8.0	**Yes**	**Yes**
ADG	ADG	Debus	**8.0**	**9.0**	**9.0**	**8.0**	6.0	8.0	No	**Yes**
Infantry	Both	Ladder lift	**9.0**	**9.0**	4.0	**9.0**	**9.0**	8.0	-	-
Infantry	Both	Rope climb	**8.0**	6.0	6.0	**10.0**	**10.0**	8.0	-	-
Infantry	Infantry	Section attack (bush)	**8.0**	**9.0**	**9.0**	**8.0**	6.0	8.0	**Yes**	**Yes**
Infantry	Infantry	Section attack (oval)	8.0	**9.0**	**9.0**	**8.0**	6.0	8.0	**Yes**	**Yes**
ADG	ADG	Section attack with roll (oval)	8.0	**9.0**	**9.0**	**8.0**	6.0	8.0	**Yes**	**Yes**
ADG	Both	Category 1 wiring	7.0	**10.0**	6.0	**8.0**	**8.0**	7.8	No	No
Infantry	Both	Casualty evacuation (drag)	**8.0**	**8.0**	6.0	**8.0**	**8.0**	7.6	**Yes**	No
ADG	Both	Jerry can carry	**8.0**	7.0	7.0	7.0	**9.0**	7.6	No	No
Infantry	Both	Casualty evacuation (carry)	**8.0**	**10.0**	6.0	6.0	6.0	7.2	**Yes**	No
Infantry	Both	Patrol in marching order	6.0	**10.0**	6.0	6.0	6.0	6.8	**Yes**	No
ADG	Both	Sandbagging	6.0	**9.0**	6.0	6.0	6.0	6.6	No	No
ADG	ADG	Pursuit	**8.0**	6.0	6.0	6.0	6.0	6.4	No	**Yes**
Infantry	Both	Second storey drop	4.0	4.0	4.0	**9.0**	**9.0**	6.0	-	-
ADG	Both	Ammunition box carry	7.0	**10.0**	3.0	3.0	6.0	5.8	No	No
Infantry	Both	Patrol in patrol order	6.0	6.0	3.0	6.0	6.0	5.4	No	No
Infantry	Both	Urban patrol	6.0	6.0	3.0	6.0	6.0	5.4	-	-
Infantry	Both	Forced entry and stair climb	**8.0**	4.0	4.0	4.0	4.0	4.8	-	-

4.4 Task Risk Scores: Defining Three Categories of Risk Based on Average of Subtask Risks and Consultation-based Assessments of Physical Demands and Risk Level

4.4.1 Table 9 shows the list of tasks and the average of the subtask risk scores for each body part. The average of the body part averages is also shown. Risk scores of 7.0 and above are in boldface. The tasks are ordered based on the average from highest to lowest. This approach provides a more even discrimination of the tasks than does the approach of taking the maximum of the subtask risk scores, which results in more clustered scores in the middle and upper end of the range.

Table 9. Task Risk Scores Based on Average Subtask Risk Scores

(Tasks are ordered from highest to lowest based on average over the body parts Risk scores of 7.0 or greater are in boldface)

Observed at	Performed by	Description	Average Subtask Risk Scores for each body part					Average average risk score	From Table10, Report 1	
			Legs, knees, ankles	Back	Neck	Shoulder	Arms, elbow, wrist		Physically Demanding	High risk
ADG	Both	Casualty evacuation (combined)	**8.0**	**8.0**	6.0	**10.0**	**10.0**	8.4	**Yes**	No
ADG	Both	Dig to stage 1	6.0	**10.0**	**10.0**	**8.0**	**8.0**	8.4	**Yes**	No
ADG	Both	Shell scrape	6.0	**10.0**	**10.0**	**8.0**	**8.0**	8.4	**Yes**	**Yes**
Infantry	Both	Rope climb	**8.0**	6.0	6.0	**10.0**	**10.0**	8.0	-	-
Infantry	Both	Casualty evacuation (drag)	**8.0**	**8.0**	6.0	**8.0**	**8.0**	7.6	**Yes**	No
Infantry	Both	Casualty evacuation (carry)	**8.0**	**10.0**	6.0	6.0	6.0	7.2	**Yes**	No
Infantry	Infantry	Forced march	**8.0**	**10.0**	6.0	6.0	6.0	7.2	**Yes**	**Yes**
Infantry	Both	Mortar route march	**8.0**	**10.0**	6.0	6.0	6.0	7.2	**Yes**	**Yes**
ADG	ADG	Sustained patrol	**8.0**	**10.0**	6.0	6.0	6.0	7.2	**Yes**	**Yes**
ADG	ADG	Section attack with roll (bush)	6.5	**7.0**	**8.3**	**7.0**	6.5	7.1	**Yes**	**Yes**
Infantry	Both	Patrol in marching order	6.0	**10.0**	6.0	6.0	6.0	6.8	**Yes**	No
Infantry	Both	Tunnel crawl	**7.3**	**7.3**	**7.3**	6.0	6.0	6.8	-	-
ADG	ADG	Section attack with roll (oval)	6.0	6.3	**8.0**	6.7	6.0	6.6	**Yes**	**Yes**
Infantry	Infantry	Section attack (oval)	6.0	6.3	**8.0**	6.7	6.0	6.6	**Yes**	**Yes**
Infantry	Both	Company level replenishment	6.0	6.0	4.5	**8.0**	**8.0**	6.5	No	**Yes**
ADG	ADG	Pursuit	**8.0**	6.0	6.0	6.0	6.0	6.4	No	**Yes**
Infantry	Both	Star picket lift	4.3	**8.0**	6.7	6.7	5.3	6.2	-	-
Infantry	Both	Ladder lift	6.8	5.3	3.5	**7.3**	**7.3**	6.0	-	-
Infantry	Both	Second storey drop	4.0	4.0	4.0	**9.0**	**9.0**	6.0	-	-
Infantry	Infantry	Section attack (bush)	5.5	5.8	**7.0**	6.0	5.5	6.0	**Yes**	**Yes**
ADG	ADG	Debus	4.7	5.7	**7.3**	5.7	5.0	5.7	No	**Yes**
Infantry	Both	Population protection and control	6.0	6.3	4.0	6.0	6.0	5.7	**Yes**	No
ADG	Both	Load and unload UNIMOG	4.9	6.4	6.1	6.1	3.9	5.5	No	**Yes**
Infantry	Both	Patrol in patrol order	6.0	6.0	3.0	6.0	6.0	5.4	No	No
ADG	Both	Jerry can carry	5.5	**7.0**	4.5	4.5	5.0	5.3	No	No
Infantry	Both	Wall climb	4.3	6.0	5.5	5.7	4.8	5.3	-	-
Infantry	Both	Category 1 wiring	4.5	6.6	4.0	5.0	5.5	5.1	No	No
Infantry	Both	Bayonet assault	4.8	5.2	5.0	4.5	4.3	4.8	**Yes**	**Yes**
ADG	Both	Category 1 wiring	4.6	5.5	3.7	4.6	5.9	4.8	No	No
Infantry	Both	Forced entry and stair climb	5.5	3.5	4.0	4.0	4.0	4.2	-	-
Infantry	Both	Urban patrol	4.7	4.7	2.7	4.0	4.0	4.0	-	-
ADG	Both	Sandbagging	5.0	6.2	3.2	2.7	2.7	3.9	No	No
ADG	Both	Ammunition box carry	3.4	**7.1**	2.1	2.1	2.7	3.5	No	No

4.4.2 In order to gain a sense of the higher-risk versus lower-risk tasks, the tasks were divided into three groups.

4.4.3 **High risk tasks (n=20):** The first group consists of the 20 tasks with risk scores equal to or greater than 6.0[1] (those above the dividing line in Table 9). Table 9 also shows the rating of "physical demands" (Yes or No) and "high risk of injury" (Yes or No) from the consultation described in Report 1 (Reference Document C). For the 15 tasks for which data were available, all were rated as either being high physical demand or high risk or both. Therefore there is validation of this group as being the notably higher risk tasks.

[1] The cutoff value of 6.0 was chosen on the basis that, with three exceptions, tasks with aggregate scores of 6.0 and above had at least one subtask with an average risk score of 8.0 or above, corresponding to the Rogers "high" risk category. No tasks with an aggregate score below 6.0 had any subtasks with "high" average risk scores.

4.4.4 **Possible high-risk tasks (n=4):** Among the remaining tasks are four tasks rated below 6.0 but rated through consultation as either physically demanding or high risk or both. These four tasks are unshaded in Table 9.

4.4.5 **Tasks not identified as high-risk tasks (n=9):** Nine tasks were scored below 6.0 and were either not rated through consultation or rated as not physically demanding and not high risk. These tasks are not without risk – they are simply the tasks that appear to involve lower risks from among the 33 tasks analysed. It should be noted that most of these tasks include a high-risk subtask. It should therefore not be assumed that these tasks are without risk.

5 SUMMARY AND CONCLUSIONS

5.1.1 Video recordings of 33 tasks were provided. These were broken into 122 subtasks. Risk analysis of musculoskeletal risks of the subtasks was undertaken using observation of movements and postures. A biomechanical approach was taken for high-effort short duration tasks. An approach based on the work of Rodgers (1992) was taken for the analysis of overuse or repetitive tasks. These models facilitated exploration of recognized risk issues of effort magnitude, effort and continuous effort duration. The biomechanical and repetitive task analyses both enabled the calculation of numerical scores. Averages and maximum values for the tasks were calculated based on the subtask scores. Limitations of the methodology used should be kept in mind, such as: the analysis was conducted from video recordings rather than first-hand observation; some loads are estimated; the methods used to aggregate subtasks into risk scores may not reflect the appropriate influence of each subtask; neither the biomechanical or overuse model reflects the risk of impact forces such as when jumping from a height or falling to the knees from a standing position; some other tasks could not be modelled biomechanically – such as the load on the one leg when it is stretched to the top of a wall and used to lift the body; etc. Whilst these factors limit the accuracy of specific quantitative estimates, they are not considered sufficiently limiting as to invalidate the comparative assessment of risks and the division of tasks into three broad categories of risk. This view is supported by the concordance between these categorical assessments and assessments made independently by key Defence informants in the initial stages of the DPESP.

5.1.2 The results of the risk analysis are shown in the risk register at Annex 1. Most tasks involve one or more high-risk subtasks. Some of these could be improved through changes to equipment design, task design, and training. With regard to the levels of risk of each of the 33 tasks examined, the following conclusions have been drawn.

5.1.3 Twenty tasks were allocated risk scores equal to or greater than 6.0. For the 15 of these tasks for which data were available, all were also rated by key Defence informants as either being high physical demand or high risk or both. The 20 tasks in this **high risk** group, in decreasing order of risk score, are:

a. Casualty evacuation (combined)
b. Dig to stage 1
c. Shell scrape
d. Rope climb
e. Casualty evacuation (drag)
f. Casualty evacuation (carry)
g. Forced march
h. Mortar route march
i. Sustained patrol
j. Section attack with roll (bush)
k. Patrol in marching order
l. Tunnel crawl
m. Section attack with roll (oval)
n. Section attack (oval)
o. Company level replenishment
p. Pursuit
q. Star picket lift
r. Ladder lift
s. Second storey drop
t. Section attack (bush)

5.1.4 Among the remaining tasks, four were rated through the process of consultation with key Defence informants as being either physically demanding or high risk. These could be termed as being **possible high risk**. The tasks in this group, in decreasing order of risk score, are:

a. Debus
b. Population protection and control
c. Loading and unloading UNIMOG
d. Bayonet assault

5.1.5 Nine tasks were scored below 6.0 and were either not rated through consultation or rated as not physically demanding and not high risk. These tasks are not without risk – they are simply the tasks that appear to involve lower risks from among the 33 tasks analysed. It should be noted that most of these tasks include a high-risk subtask. The nine tasks in this group, in decreasing order of risk score, are:

a. Patrol in patrol order
b. Jerry can carry
c. Wall climb
d. Category 1 wiring (Infantry)
e. Category 1 wiring (ADG)
f. Forced entry and stair climb
g. Urban patrol
h. Sandbagging
i. Ammunition box carry

PART B: RISK MITIGATION

6 CONCEPTUAL FRAMEWORK

6.1 Using Industrial Safety as a Source of Ideas

6.1.1 In a modern standing defence force, the work of a soldier or Airfield Defence Guard is not a one-off or intermittent activity. The "work" of a soldier or airman is a long-term, full-time job. The work of the combat arms trades needs to be made as safe as practicable over the entire career of the serviceman. Survival during operations is vital, but with operational work and high intensity training becoming more the norm rather than the exception, attention must be given to the long-term exposure to working conditions that give rise to injuries and diseases. Many diseases and injuries accumulate over a period of time; among the most common are musculoskeletal disorders known as cumulative trauma disorders. It is possible that a single event can cause someone to "do their back" or some other joint. But it is likely that these events, however significant, were the "straw that broke the camel's back". And so the potential for both acute and chronic injury must be considered.

6.1.2 How much can a person carry or lift? For short term engagements, without any consideration of the long-term consequences, this question is essentially about functional capacity. How much the individual can carry could be simply determined by observation. Did they carry their 45kg pack (for example) over the set distance in the set time or not?

6.1.3 However "how much can a person carry, lift etc … safely over a career?" is a very different question. It is not a matter of functional capacity. Most manual handling injuries result from people performing work that they "can do" – this is self-evident. The exception is when a person exerts maximum effort, causes an injury, and still fails to achieve the task. This is possible but more commonly manual handling injuries accumulate over the long term as a result of people working well within their maximum capacity. Hence functional capacity is not particularly relevant. To illustrate, we can look at the example of nursing. Until recently nurses working in hospitals and other health care facilities were required to manually move patients. Nurses "could do" this work. The work was getting done. They had the functional capacity. But could it be done safely over a career? The answer to this was clearly "no". Nurses suffered serious injuries as a result of doing work that they could do. The problem was viewed as intractable for some time. The problem was placed in the "too hard" basket. Like military jobs, many civil sector jobs have characteristics that make implementation of better methods of work seem difficult. The object being handled by nurses was of course a person. The person was heavy, awkward and generally unwell and therefore in need of careful handling. The problem did not seem to fit with typical strategies of solving a manual handling problem: the "object", being a person, could not be reduced in weight, packed in smaller containers, or packed in large containers and handled in bulk!

6.1.4 In 1998, unions, government and hospitals made a joint commitment that nursing back injuries were unacceptable, that they were solvable and that methods involving patient handling without lifting should be developed and implemented. From this vision, methods were developed and implemented. This involves significant amounts of work on all the different types of patient handling that is required. Since 1998, the Victorian government has run a seed-funding program to boost uptake of these patient-handling systems. Over the past seven years, $7M has been specifically allocated to health care facilities like public hospitals and the hospitals themselves have topped this up to $24M with existing funds. This is a significant investment. A recent evaluation involving some of the authors of this report found encouraging results with the cost of the intervention rapidly being recouped through reduced injury incidence and compensation costs (Martin et al., 2004). Great conceptual change has occurred with regard to patient handling. With regard to manual handling, the nursing industry has transformed from one relying completely on manual methods and with a history of serious injuries to one that operates under radically different principles.

6.1.5 Another example can be taken from the area of automotive assembly. The Ford Motor Company, with whom one of the authors has a long association, has an approach to occupational health and safety that is highly developed and very successful. This includes their approach toward manual handling. Ford conducts a "Process Safety Review" of all processes (Miller, 1998). These reviews are conducted at various stages, including design. The process was enacted initially to comply with the Victorian Occupational Health and Safety (Plant) Regulations (1995) but was extended to all processes. Each job among the thousands needed to manufacture motor vehicles is intended to be included. The reviews take into account many hazard types. Manual handling is one of the most common but each job can include a multitude of hazards including noise, electrical hazards, machinery hazards, falls, etc. The process is a simple, fluid and living process. Each review is documented on a database along with the various associated hazards. The total number of documented hazards extends into the tens of thousands. Hazards above the nominated risk level cannot be introduced. This creates a powerful incentive for safe design and is a great driver of innovation. There is no better time to eliminate or reduce hazards than before they are introduced. Problems are often eliminated at little cost. Other times solutions can be costly but the organisation holds to its goals. The effort to find safety solutions often also yielded better ways of designing a process for productivity, ease of maintenance, quality, etc.

6.1.6 A good example of forward thinking was tackling the posture problems of working inside the vehicle cabin and engine bay. Conducting assembly work while crouched inside the cabin presented a manual handling risk. Operators could hit their head on sharp edges while getting in and out of the cabin. The ankles, knees, hips, back and neck were all placed in awkward postures for many tasks. Ultimately this could be only addressed by assembling the vehicle without getting inside the body or even inside the engine bay. This was set out as a vision for the development of the AU Falcon in the early 1990s and continues today (see Figure 1). Two examples of putting this vision into action were to remove the doors during assembly (left photograph). This enabled the use of materials handling technology such as hoists to handle items such as the pedal box (right photograph). The operator works in a comfortable and upright posture. These results were achieved by beginning with a design concept of assembly without entering the car. Ideas to make this a reality such as removing the doors thus enabling the design of lifting systems for parts like the pedal box then followed. Imagine the awkward postures and difficult handling that would be necessary if the doors were on the vehicle and the pedal box was fitted into the foot well manually. Further imagine the efficiency and quality benefits of an easy to use and comfortable system. Further it is clear that removing the doors would reduce door damage as vehicles more along the assembly line – hence reducing costly rework. Removing the doors also enables door fit out to be completed on an assembly line – again with quality, efficiency and safety improvements over attempting to complete fit out while the door is attached to a moving vehicle. Thus we see from a vision for safety that the innovation needed to meet the vision helps drive not only safety but process improvement.

a. Removal of doors for ease of access

Photograph: P Bramich Thanks to Ford Motor Company

b. Use of hoists

Photograph: Unknown Thanks to Ford Motor Company

Figure 1. Risk Mitigation Strategies in Automotive Assembly

6.2 Safety at the Design Stage: a National Priority

6.2.1 The National Occupational Health and Safety Strategy sets out five national priorities for the ten-year period 2002-2012. These are to:

a. Reduce high incidence/severity risks
b. Improve the capacity of business operators and workers to manage OHS effectively
c. Prevent occupational disease more effectively
d. Eliminate hazards at the design stage
e. Strengthen the capacity of government to influence OHS outcomes

6.2.2 To "eliminate hazards at the design stage" is one of the five priorities agreed to by the Workplace Relations Minister's Council (National Occupational Health and Safety Commission, 2002). With regard to the elimination of hazards at the design stage, they wrote:

"Responsibility to eliminate hazards or control risk rests at its source. This principle applies to all sources of hazards. Responsibility falls on a wide range of parties, including those outside of the workplace such as designers, manufacturers, constructors or suppliers." (p. 9).

6.3 Driving New Thinking with the Hierarchy of Control

Occupational Health and Safety Law Requires Problem Solving not Prescribed Standards

6.3.1 During the 1980's all Australian jurisdictions implemented the UK-style "Robens" form of legislation (Committee for Health and Safety at Work, 1972). The legislation pivots on a restatement of the common law duty of care. Prescribed safety standards are uncommon as the model relies on a high standard of problem solving at industry and organisation level to find the most practicable solution for a given problem. Hazard elimination at the source is fundamental and we see "eliminate hazards at their source" noted in the objects of many of the statutes[1].

Hierarchy of Control

6.3.2 A universal problem-solving tool found throughout Australian jurisdictions is the "hierarchy of control" process. Examples are:

6.3.3 *Occupational Health, Safety and Welfare Regulations 1995 (SA)* reg 1.3.3, employer's duty to control risk in general:

a. elimination;
b. engineering controls, including substitution, isolation, modifications to design and guarding and mechanical ventilation;
c. administrative controls, including safe work practices;
d. personal protective equipment.

6.3.4 *Occupational Health and Safety Regulation 2001 (NSW)* clause 5:

a. elimination;
b. substitution;
c. isolation;
d. engineering;

[1] For example: *Occupational Health, Safety and Welfare Act 1986* (SA) s3(b); *Occupational Health and Safety Act 2004* (Vic) s2(1)(b) (as per 1985 Act).

e. administration;
f. personal protective equipment.

6.3.5 It is noted that in the ADF context 'administrative controls, including safe work practices' encompasses the application physical employment standards and the institution of adequate physical conditioning programs.

A Creative Effort

6.3.6 The hierarchy of control is a tool for creative thinking. The prompt words, "eliminate", "substitute", etc can prompt new ideas. Elimination, substitution, engineering involve rethinking how something is done rather than adding on something else. For this reason they can be conceptually difficult. In contrast the lower-order solutions like administrative controls and personal protective equipment are easier to conceptualise and involve adding something on, rather than making a change, to a system. For this reason these low-order solutions can seem attractive. However, they require a high level of ongoing effort with regard to training and supervision, do not make any fundamental changes to the hazardous situation, and have little capacity to achieve any other benefit. On the other hand high order solutions require more effort in the thinking stage and more effort in initial implementation but in the long-term demand less in terms of training. These solutions improve safety through a fundamental change to the hazardous situation, and because creative effort is required may give other benefits. "Safe design" is sometimes used as shorthand for this work. Safe design is often the best way, and sometimes the only way, to achieve the intent of the workplace safety legislation. Some examples are shown below to illustrate how "safe design" can deliver effective improvement to safety and innovate how work is done.

6.4 Taking a Look at Some Other Industrial Examples

6.4.1 Table 10 shows some examples of how hard work and dangerous work has been changed over recent times.

Table 10. Comparison of Old and New Ways of Performing Demanding and High Risk Tasks

(Photographs: John Culvenor)

The Old Way	**The New Way**
Manual waste/recycling collection.  Hazards include: passing traffic; movement of waste vehicle; falls from steps; crushing unit hazards; bending and lifting; lifting to above shoulder height; carrying; biological hazards; sharps; ultraviolet light exposure; low and high temperatures; occasional poor visibility; roadside hazards including kerbs, uneven surfaces, trees, poles, etc; and so on.	Driver-only waste collection.  The hazards of the manual collection are too profound to be solved effectively by incremental improvements. Transformational change to driver-only collection eliminates these hazards. Further it provides a more efficient means of collection.

The Old Way	**The New Way**
Car carrying trailers without fall protection.  Cars are nearly as wide as the trailer. The person loading and unloading the vehicles therefore has a very narrow space to stand. The footing surface is the frame of the trailer and often not ideal. The surfaces can also be wet. The potential fall is several metres and can be onto a public road with passing traffic. Traditionally trailers are made like this one – without any fall protection.	Railing fitted to a car carrying trailer.  This is a good example of an incremental change. The operator remains working at height. However the relatively simple addition of railing provides a substantial improvement.
Milk tankers  Workers collecting milk needed to climb onto the tanker to operate valves, to reach access hatches, and for cleaning. Similar problems exist on other liquid transport vehicles.	Two solutions – one incremental – one transformational   One solution (left photo) is to fit collapsible railing. The operator needs to work at height as before but with the benefit of the protection offered by the railing. A transformational solution (right photo) is to eliminate routine access to the top of the tanker. The tanker shown has access ports fitted to the underside. Valves are remotely operated. The operator of these tankers also said that they were lighter (hence could carry more milk within the gross weight limit), easier to clean, and cheaper to buy.

The Old Way	**The New Way**
Traditional windmill – an Australian icon.  The windmill in rural areas is an Australian icon. It is also responsible for many serious injuries. This one is at least six meters high, with a narrow open ladder and a very small un-railed platform on which to work. Of course – in addition they are usually found in windy places making a fall even more likely. A fall from this height will almost always result in serious injury and possibly death.	A solar "windmill" – "solar pump"?  This solar wind pump is a transformational change. The work at heights hazards are essentially eliminated. The farmer who owned this set up also explained that it works better than a windmill. Why? Because when he mostly needs water pumped – in the summer – is when the sun it strongest but wind is weakest.
Sheep shearing and crutching  Sheep shearing and crutching has traditionally been performed with the animal on the floor. The shearer's posture is fully bent forward for much of the working day.	Crutching cradles  There are many devices available to make crutching a much less demanding task. The unit shown enables the shearer to tip the sheep from a raised race and work with the animal raised on a cradle. This posture is not ideal but is much closer to an upright position. This improves safety but also allows greater productivity and allows workers who could no longer work the traditional way to continue in the industry.

6.5 A Military Example

6.5.1 Knapik and his colleagues (1997) examined the feasibility of redesigning tasks within a range of military occupational specialities, including medical specialist, tracked vehicle mechanic and chemical operations specialist. As an example, they reported that medical specialists were able to carry a stretcher 9.4 times as long, whilst experiencing a decrease in perceived effort, as a result of a redesign of equipment based on ergonomic principles.

7 METHODOLOGY

7.1 Risk Mitigation Workshop

7.1.1 The Risk Mitigation Workshop was held on 23 and 24 March 2005. The purpose was to consider the 24 tasks identified by the risk analysis as being high-risk or possibly high-risk (see paragraphs 5.1.3 and 5.1.4), and wherever possible to identify risk mitigation strategies. The workshop participants are listed in Table 11.

Table 11. Risk Mitigation Workshop Participants

Name	Affiliation	Role/Specialisation
WO1 Peter Bradley	Combat Arms Training Centre	Infantry trade policy
Dr John Culvenor	University of Ballarat	Consultant: Risk analysis
Dr John Cunningham	Army Reserve	Orthopaedic Registrar
Mr Daniel Ham	University of Ballarat	DPESP Senior Research Assistant; Exercise physiology
Dr Wade Knez	University of Ballarat	DPESP Research Fellow; Exercise physiology & psychology
WOFF Stuart Lane	Training Command – Air Force	ADG training
Mr Craig Lee	University of Ballarat	DPESP Research Assistant; Exercise physiology
WGCDR John Leo	HQ Combat Support Group	ADG Category Sponsor
LTCOL David McKerral	Army Liaison; Infantry	Trade management
Mr John Mathieson	Defence PES Project Office	Defence PES Project Manager: Human resource management
Assoc Prof Leonie Otago	University of Ballarat	Injury epidemiology
Ms Deborah Pascoe	University of Ballarat	Injury risk analysis
Prof Warren Payne	University of Ballarat	DPESP Project Manager; Exercise physiology
Dr Rod Pope	Defence Health Services	Preventative Health
Dr Bob Stacy	Human Performance Optimisation	Consultant: Ergonomics

7.1.2 The main focus of the Risk Mitigation Workshop was CATT training activities rather than activities in operational contexts. It is recognised that mitigation strategies that can be applied under training conditions may not be possible under combat conditions, or may not be desirable because they jeopardise effective operational performance of CATTS. The view has also been expressed that application of risk mitigation during training may reduce the stress of training thus degrading the training response (work hardening) in relation to real stress in combat. Hence the potential for reduced risk of injury during training must be balanced against the potential for increased risk of operational injury and reduced operational effectiveness. However, it can be argued conversely that, if musculo-skeletal injuries arise from the cumulative effect of long-term exposure, then a reduction in cumulative damage during training would result in a greater capacity to absorb operational stresses. The competing aims of minimising training-related injury and achieving physical readiness for combat can be resolved by instituting safe physical conditioning programs and reducing the reliance on training involving unsafe combat tasks (Sharp et al., 1993).

7.1.3 A mix of whole-group and small-group problem solving was used in the workshop. For each task the following protocol was used as a guide to developing ways to reduce the risks.

Review the task

a. What is the task?
b. What is the purpose of the task?
c. What are the hazards inherent in completion of each task?

Explore the best practice

a. How do other parts of the Australian armed services deal with this problem?

b. How do other military operations deal with this problem?

c. How do civilian industries deal with this problem?

Generate new ideas and modifications – "what if we could…"

a. *Elimination*: Can the whole task be eliminated? Can any of the hazards be eliminated?

b. *Engineering*: Are there engineering solutions available (a tool, a step, a better balanced tool, a lighter implement, a tool better fitted to the human body, a lifting implement, a powered implement, etc)?

c. *Substitution*: Can safer materials be substituted for hazardous materials?

d. *Procedures*: Are there better ways to organise the task?

e. *Protective clothing*: Are there better ways to protect the person from injury using clothing and other equipment?

8 RESULTS AND DISCUSSION: RECOMMENDATIONS AND OPTIONS FOR ACTION

8.1 Introduction

8.1.1 The results of the review of the designated 24 tasks (see paragraphs 5.1.3 and 5.1.4) in the Risk Mitigation Workshop were collated into nine task groupings, each of which involve similar workloads and/or performance demands, as follows:

a. Lifting and sustained carrying of loads, marching and patrolling
b. Go to ground, aim, crawl, rise and run
c. Urban movement and building access
d. Population protection and control drills
e. Casualty evacuation
f. Bayonet assault
g. Loading and unloading trucks
h. Digging
i. Debussing

Each of these groups of tasks is considered in turn.

8.2 Lifting and Sustained Carrying of Loads; Marching and Patrolling

Company level replenishment
Carrying variable loads of up to 40 kg over distances of up to 200 m.



Mortar forced march
Move to fire support position carrying pack, mortar components, weapon and ammunition; total load: 50-70 kg carried for up to 8 km at 4 $km.hr^{-1}$



Forced march
Total load: 50 carried for up to 10 $hr.day^{-1}$ at 5 $km.hr^{-1}$ after allowing for 10 min rest every 50 min.



Patrol in marching order
Total load: 50 kg, carried for up to 10 $hr.day^{-1}$ over a distance of up to 20 km at approximately 2 $km.hr^{-1}$.

Sustained patrol
Total load 21.6 kg, carried for 10 $hr.day^{-1}$ at 2 $km.hr^{-1}$.

Pursuit
Total load 21.6 kg, carried for 2.8 km at 10 $km.hr^{-1}$.

Introduction

8.2.1 Anecdotally it was reported that Australian soldiers are being asked to carry more and more weight and supplies in their packs, and that the weight of the load carried is a significant contributor to the risk of the tasks outlined above. This is supported by information provided by Knapik et al. (2004) in their review of military load carriage, where they reported a steady increase in the weight of load carried by American soldiers (whom Australian soldiers appear to mirror in this instance) from approximately 35 kg in Vietnam to 55 kg in Kuwait. Knapik et al. (2004) also cited a plethora of studies to link load carriage to acute and chronic musculo-skeletal injury.

Risks

8.2.2 A qualitative analysis of the CATTs depicted above indicated that these CATTs involve risk of injury to the lower back, shoulders, elbows, upper limb musculature, lower limbs and neck due to lifting and carrying loads. Injuries sustained to the back, neck and shoulders may be acute and/or chronic in nature due to the lifting and carrying phases of these tasks. The risk of chronic injury for all body areas is due to the repetitive or sustained nature of the task. Injuries to the lower back may be sustained due to the need to bend forward and lift a pack or supplies from ground level. This action may need to be repeated several times with a sustained carry being performed in between each lift. Sustained carrying of heavy and sometimes awkward loads also increases risk of injury to shoulders, elbows and upper limb musculature. At times soldiers are constantly changing the carrying position of the load because of the weight, size or shape of the material being carried. For example shorter soldiers cannot carry jerry cans in a sustained straight armed hang position and therefore must carry them above their shoulders or maintain a bent elbow position which will increase the fatigue experienced by the upper limb musculature. To a lesser extent, this is also seen in the sustained weapon carrying position during patrolling. Added weight with either a pack or sustained carrying of equipment increases the risk of injury to the lower limbs during all marching and patrolling activities as seen in the Infantry Tasks 2, 5, 15 and 17 and ADG Tasks 7 and 9. Injuries that may be sustained include tendon and muscle strains and ligament sprains, as well as a variety of overuse injuries (eg. stress fractures to the feet and lower limb and patella tendonitis). Depending on the carrying techniques of individual soldiers and the fitting of packs, the lower back would also be vulnerable to overuse sprains, strains and inter-vertebral disc injuries. The risk to these areas of the body would be further exacerbated by the increase in ground reaction forces absorbed by the lower body and back when running is introduced to the above tasks. Finally, the neck may also be vulnerable to injury and load from equipment being carried or supported on the shoulder. This causes the soldier to bear weight on the neck and position the neck in a sustained awkward position. In the ADG Pursuit Task the weight of the helmet with constant rotation from side to side may add to overuse injuries to the neck muscles, ligaments and discs.

Research

8.2.3 There is a great deal of research into military load carriage (Dziados et al., 1987; Vacheron et al., 1999; Quesada et al., 2000; Knapik et al. 2004). Not withstanding the fact that load carriage capacity is dependent upon individual qualities, the existing literature indicates that factors such as stride length, footwear and the location of the pack relative to the centre of mass of the body affect the resultant strain placed upon the shoulders (Vacheron et al., 1999). In particular, Bobet and Norman (1984) examined the effect of varying the placement of the load upon back muscle activity. They reported that placing the load just above the shoulders results in significantly higher levels of muscle activity than placing the load just below the mid-back. It is noteworthy that heart rates taken during the two different load carriages did not differ significantly, which indicates that when assessing tasks which rely on local muscle demands, metabolic measures alone are not sufficient to adequately assess the potential injury risks of the task. Further, Lloyd and Cooke (2000) found that a load carriage system that allows the load to be distributed between the back and front of the trunk is more appropriate for carrying relatively heavy loads than loads carried on the back alone. Holewijn (1990) also reported that the use of hip straps significantly reduced the pressure on the shoulders by a factor of 13.5 and reduced the muscular effort in the shoulder area. This view is supported by Harman et al. (2000) who suggest that backpacks be designed to distribute a major portion of the load on the hips.

8.2.4 Load carrying capacity is also directly related to soldier fitness and research supports the inclusion of concentric and eccentric exercise for strengthening the erector spinae, abdominals and quadriceps muscles to improve load carriage performance (Harman et al. 2000). There are also a range of individual qualities that may affect load carriage capacity. These qualities may be biomechanical, physiological or psychological. From a physiological and anthropometric perspective march performance while carrying a load has been significantly related to aerobic capacity (absolute $\dot{V}O_{2max}$) and leg strength Dziados et al. (1987) and body size (Knapik, Staab et al., 1990). Further, the specific benefits of load carriage training were demonstrated by Knapik, Bahrke et al. (1990), who reported that soldiers who included load carriage in their training were able to march at greater speeds than those soldiers who did not include load carriage in their training.

8.2.5 The use of carts to transport loads has been considered in some military settings. Notwithstanding the fact that carts can be noisy and difficult to manoeuvre in rough terrain, the use of carts when marching on roads has been demonstrated to reduce energy expenditure by 88% (Haisman et al., 1972) and increase the speed of movement over mixed terrain (paved road, dirt road, field and rough trail) when carrying 61 kg loads by 44% (Harman and Frykman, 1995).

Options for Action

Logistics Support

8.2.6 There is an urgent need to review and improve the capacity for the ADF to use vehicles to bring supplies closer to the required location. Alternatively, it is suggested that the use of animals to carry loads in inhospitable terrains could be investigated. It was reported that such lateral thinking had been employed recently to reduce the load carried by SAS soldiers and others by using donkeys as load carriers in Afghanistan. It was also noted that trials are currently underway of 'Gator' six-wheeled vehicle and All Terrain Vehicles (ATVs) for carrying supplies. Strategies such as these would reduce significantly the load carried and thereby the acute and chronic injury risk to soldiers.

Equipment

8.2.7 Given the demonstrated injury risk associated with carrying heavy loads, the risk mitigation strategy is primarily focused upon reducing the load carried by introducing equipment modifications to reduce the size and weight carried. Another part of the solution is to move away from the apparent assumption that a pack must be suitable for all operational environments and to introduce small tools and/or equipment adaptations that are designed for specific environments. An example of fitting the pack to the terrain and environment is found in the way in which the Scandinavians tow sleds while skiing and then affix detachable balloon wheels to the sleds for use in other terrains.

8.2.8 In reviewing the risk of injury associated with lifting and carrying sustained loads it was suggested that investigation of various carrying mechanisms is needed. The options raised for consideration include the following:

Fold-up Stretcher

8.2.9 A fold-up stretcher arrangement made of aluminium or another suitable light and strong material could be used to transport larger, heavier and awkward to carry pieces of equipment. There are several similar devises currently in use within the overall Defence system at present that could be used in this way (e.g. NATO stretcher). If possible this needs to be included in the vehicle Complete Equipment Schedule (CES).

Carts

8.2.10 As indicated in Section 8.1.3, the use of carts has been shown to be effective in many environments. Additional recommendations are to:

a. engineer the stretcher unit to include detachable wheels and hence the stretcher could be 'wheeled' along a road or other suitable surface; and to
b. fit the frames of the back packs with wheels and telescoping handles. It would not be practical to wheel the pack in all conditions but when able to be used the attachment would reduce the load upon the soldier and increase movement speed.

Back Pack Adjustments

8.2.11 There are a range of potential adjustments to the back pack that may be implemented to reduce the stresses experienced by the soldiers when carrying loads. Some options include the following:

a. The development of an adaptable pack that can be fitted to enable other equipment to be carried in the most efficient manner possible. An attachment such as a flip down shelf would enable items such as jerry cans or ration packs to be carried with less injury risk by taking the load off the arms as well as reducing the overall stabilizing requirements for the trunk and the shear and compressive forces placed through a number of joints.
c. Use of hooks placed over the front of the shoulder that can be used to attach objects to the front of the body and assist in balancing the load on the back (currently in use by some units).

Wheeled Platforms

8.2.12 It may be possible to adapt the wheeled platforms used by furniture removalists for use when moving heavy objects during CATTs that are administrative in nature.

Training

8.2.13 If it is not possible to use technological adaptations or alterations to logistical support to reduce the load carried by soldiers and airmen, it is necessary to implement carefully structured training regimens to enable the soldiers and airmen to carry the required loads in as safe a manner as possible. The training requirements for the above tasks require an awareness of the need to progressively build up to the required distance, weight and load. These training requirements should also incorporate limits or guidelines for distance/load carriage.

8.2.14 Given the potential for potential for thermal discomfort, heat incapacitation and heat injury, it was also recommended that where possible, soldiers and airmen avoid wearing ballistic vests when engaged in administrative tasks and that standard ADF heat management practices are implemented.

8.3 Go to Ground, Aim, Crawl, Rise and Run

Section attack (oval)
Total load: 21.6 kg carried over a distance of approximately 100 m in 2 min.

Section attack (bush)
Total load: 21.6 kg carried over a distance of 100 m in 2-15 min (depending on the tactical context).

Section attack with roll (oval)
Total load: 21.6 kg carried over a distance of approximately 100 m in 2 min.

Section attack with roll (bush)
Total load: 21.6 kg carried over a distance of 100 m in 2-15 min (depending on the tactical context).

Introduction

8.3.1 The tasks involved in the Section Attack CATT include fire and movement, leopard crawling and the fight through. These are fundamental tasks for the infantry soldier and the ADG airman and are undertaken in a variety of terrain and under numerous tactical scenarios. A significant change to this CATT in recent times has been the introduction of body armour (helmet and ballistic vest as a minimum) as standard equipment. The helmet and vest weigh a total of 10.2 kg and combined with the weight of the standard weapon and webbing result in the soldier/airman carrying 21.6 kg during these CATTs.

Risks

8.3.2 A visual assessment of the CATTs illustrated above indicated that the risk of injury to the shoulder, arms, back, knees and neck is affected by the terrain over which the activities are undertaken and the general and individual techniques employed. The Section Attack on the oval decreases the potential injury risk compared to the forest setting by eliminating the unknown and uncontrolled ground surfaces that may be contacted in "going to ground" or running over unpredictable, uneven ground surfaces. The tasks however have inherent potential for injury due to technique and military requirements of the task. The load carried (webbing, helmet and weapon) adds weight to each task and therefore increases the resultant stress placed upon each body part. The risks will be outlined according to body part.

Elbows and Shoulders

8.3.3 The need for the soldiers/airmen to support their body weight and the weight of their weapon on their elbows when holding the weapon in the 'ready' position means there is a high risk of elbow and shoulder injuries including dislocation and fractures. This risk is exacerbated by the need to support weight through the elbows and shoulders while performing the leopard crawl and when assuming the firing position. Satisfactory execution of these tasks requires high levels of strength and endurance of the muscles of the upper limb, upper back and chest and stability of the anatomically 'unstable' shoulder joint. It is apparent that this task is a necessary combat task for both infantry and ADGs and as such cannot be modified to any great extent.

Ankles and Knees

8.3.4 There is potential risk of sprains of the ankles and knees when running on rough ground. It is difficult to prevent or control this risk when the section attack is conducted in the forest due to the unpredictable terrain. The knees are also vulnerable to load impact injury during the fall to ground phase of the section attack. Depending on the technique adopted for going to ground, the airmen and infantry soldiers may place the resultant force generated by their velocity and the mass of their body plus webbing, weapon, and helmet through one knee. These forces may substantially increase the risk of posterior cruciate ligament injury and either fractures or osteochondral injuries to the patella. The going to ground activity is often performed as a fall rather than a controlled landing and may be able to be examined in detail in order to identify a suitable technique to lessen the impact forces exerted upon the knee. Placing some form of padding on the knee would also be of benefit by reducing the forces transmitted through the knee from impact when going to ground and in sustained weight bearing during leopard crawling.

Back

8.3.5 The back is forced to undergo hyperextension to assume the going to ground position and this position needs to be maintained during leopard crawling activities. This hyperextension places large shear forces through the lumbar spine and increases the potential for disc injuries and stress fractures. The lumbar spine may also be at risk of further disc and muscle injury during the twist and rolling; either at the time of going to ground or during the leopard crawl phase.

Neck

8.3.6 Stress on the neck is exacerbated from hyperextension of the neck during leopard crawling and the extra forces resulting from the weight of the helmet. Ill-fitting helmets contribute to this problem as soldiers and airmen perform small whiplash movements of the neck in an attempt to control the helmet slipping forward and becoming unbalanced on the head or interfering with vision. The injury risk associated with neck positioning is increased by the need to maintain the hyper-extended positioning during the leopard crawl and then to laterally flex the neck to sight/aim the weapon.

Research

8.3.7 Much of the research identified in relation to these CATTs pertained to the use of protective equipment such as knee and elbow pads. No information was located that outlined the impact of altered technique upon injury risk and injury incidence. Much of the information available on the efficacy of padding in reducing injury risk in a military environment has been sourced from letters to the editor of the journal Military Medicine. In a letter to the editor of *Military Medicine*, Caravelho (1992) expressed his opinion on the use of knee and elbow pads for Army Ranger training. He reported that he had experimented with traditional volleyball knee pads which wore out within three weeks but switched to the inline skater type of knee pad which consist of a hard plastic shield secured on to soft foam and nylon base. He reported that overall the pads used by in line skaters made ‘taking a knee’ during patrols a lot easier and he believed he performed individual movement techniques with greater mobility. He also stated that the life of the pads was seriously limited but he believed the benefits far outweighed the inconvenience or cost of replacing the pads. He believed that routine use of knee and elbow pads can significantly contribute to a decrease in the incidence of lower extremity soft tissue and musculoskeletal complaints. Caravalho (1992) went on to recommend that to improve the knee pads they should have: 1. a resilient plastic shield, 2. self-adhering straps long enough to be fastened over the front of the knee pad to avoid irritation of the popliteal area, 3. a soft base which allows quick drying and be resistant to water, and 4. a thin plastic shin guard which attaches to the inferior aspect of the pad and held in place with an additional mid-shaft strap. Caravelho’s proposal was supported in a further letter to the editor (Kragh, 1992) which again added personal and anecdotal support to the belief that those personnel who wore knee pads during training suffered fewer knee problems and that knee pads were an excellent preventive measure for contusions, infections and cellulitis. Observations made by Kragh (1992) also noted that those who used elbow pads did not suffer any elbow problems during training. Unfortunately, no research has been located that has used scientifically valid methods to investigate the efficacy of using knee and/or elbow pads in military training to reduce injury risk. However, anecdotal information suggests that knee and ankle padding have been used with varying degrees of success and frustration. Given the absence of scientifically valid data that can be used to gain a better understanding of the impact of protective equipment upon injury risk during the section attack, it is considered appropriate to explore data obtained from similar activities such as in line skating. Schieber et al (1996) examined the efficacy of protective equipment as a risk reduction strategy in in-line skating. They demonstrated that protective equipment is effective in preventing and reducing the severity of injuries to the wrist and elbows.

8.3.8 Research has been published which indicates that the use of helmet-mounted displays to alleviate the awkward positioning of the head in sighting weapons needs to be introduced with some caution. Adding weight to the helmet presents the risk of detrimental effects to the musculoskeletal system. Knight and Baber (2004) added weight to the front of the helmet (2 kg) to determine the musculoskeletal stress in different head positions and to determine if counterbalance was effective in reducing stress. EMG was recorded from neck extensors and sternocleidomastoid (SCM) muscles and pain levels were noted using the Borg-CR scale. The added load resulted in significant increases in EMG activity in the neck extensors and although the SCM showed little change due to increased load it increased significantly with head rotation. Therefore determining the effects of added weight to decrease stress from awkward head positioning requires knowledge of working head postures and the effects on musculature in a number of different working postures.

Options for Action

Logistics

8.3.9 No logistical solutions were identified that may be implemented to reduce the risk of injury from performing these CATTs.

Equipment

8.3.10 Given the inability to identify logistical solutions to the injury risks associated with the section attack, the risk mitigation strategies are largely focused upon the adoption of various forms of personal protective equipment. The incorporation of knee and elbow padding has been supported in the literature and has been shown to be effective in reducing arm and wrist injuries in activities such as in-line skating. Despite the somewhat obvious justification for the inclusion of such padding, concern remains about the practicalities of such equipment; especially in an operational environment. Therefore, as the extra protection might not be practical for operations, it may be considered for use in the training environment. Use of knee and elbow padding in training may not necessarily have a negative impact upon the ability of soldiers and airmen to perform the CATT in an operational setting.

8.3.11 The use of knee and elbow protection in training warrants investigation and research. Problems identified by Defence key informants with strap on styles of knee and elbow pads were that they tend to fall down and it was suggested that they be inserted into pockets sewn into pants and sleeves. Importantly, it was reported that American, Korean and Singaporean armies use these kinds of protective equipment in training; especially in urban areas. Information from these armies highlights the need for a kit to be adopted that is appropriate for the specific operational or training circumstances.

8.3.12 The risk of ankle injury for individuals who have previously experienced an ankle injury may also be reduced by taping the ankles or use of ankle bracing (Handoll et al., 2001), although newly designed boots now issued to soldiers include ankle area reinforcement. However, some military informants suggest that ankle strapping should be avoided because, unlike sports participants, soldiers/ADGs generally operate for hours on end without breaks to change or care for strapping. This may lead to skin irritation, skin removal/tearing, formation of constricting and irritating ridges in the strapping as they move, and loss of support of the strapping over time, making it much less effective than bracing. Further, even with bracing, care must be taken not to overbrace (hence increasing subtalar pronation and potentially leading to other overuse injuries) and to ensure a snug fit over the foot and within the footwear.

8.3.13 The Defence key informants reported that the strain placed on the neck during the leopard crawl and when aiming and firing a personal weapon has increased with the use of helmets as this task was previously undertaken while wearing a cloth bush hat. As stated above, the injury risk to the neck is largely associated with hyperextension and this is exacerbated by ill-fitting helmets that tend to cover the eyes. Although no solution was identified to reduce neck hyperextension during leopard crawling, the use of better fitting helmets via adopting individually tailored and correctly fitted foam inserts and offset sights such as those used by the British Army will have the effect of improving neck posture and reducing injury risk.

Methods and Training

8.3.14 The ‘going to ground technique’ varies considerably from a sideways slide, a direct fall onto the knees and a roll to ground similar to that used in a parachute fall. There is a need to determine the best technique to decrease the risk of injury in this critical task that must be performed regularly and in various types of terrain. A biomechanical analysis of the ‘going to ground technique’ could provide valuable information about the most appropriate technique to decrease the stress placed upon the knees, elbows and back. Such an analysis would need to consider if technique should be varied according to terrain.

8.3.15 In general, it was noted that the use of correct technique for the leopard crawl needs to be reinforced. Leopard crawling technique tends to vary between and within individuals depending on fatigue, injury and terrain. If there is a correct technique, this needs to be taught and adhered to during training. It is suggested that the emphasis may need to be placed more on technique and purpose than speed in order to decrease the risk of injury during leopard crawl training. However, the view was also expressed that there may be value in being able to adjust technique to compensate for weaknesses, fatigue, kit configuration etc, and so the risk of injury may be reduced if a variety of techniques can be employed, providing justifiably 'unsafe' techniques are avoided.

8.3.16 Physical preparation may be undertaken to improve strength and proprioception. Notwithstanding the recommendations made to reduce the stress placed upon the neck, specific strength training for the neck musculature would reduce the negative effects of the relative load upon the neck. In addition, as the leopard crawl and support position for firing are critical task requirements of the infantry and airmen, physical preparation should include exercises to improve shoulder and scapular stabilization, as well as training to improve the strength and endurance of the upper body musculature. Finally, training to increase proprioception may be incorporated into standard physical preparation regimens so as to improve ankle, knee and lower limb stability. This form of training has been shown to aid in protection against and rehabilitation of ankle and knee injuries (Prentice, 2004).

8.4 Urban Movement and Building Access

Tunnel crawl
Total load: 21.6 kg carried either fast [58 m covered in 3 min] or slow [58 min covered in 13 min].

Rope climb
Grappling climb with ballistic vest, helmet and webbing; 7.2 m wall scaled in approx. 70 s.

Star picket lift
Lifters risk – climber covered in wall climb.

Second storey drop
Variable time and distance depending upon technique and height of participant.

Ladder lift

Introduction

8.4.1 Australian Infantry soldiers and ADGs have traditionally been more likely to be engaged in operations located in bush or jungle environments. In recent times, the ADF have been engaged in a number of urban operations and therefore, the number of infantry and ADG CATTs that involve activities in urban terrain has been expanded significantly. These CATTs involve a range of actions; the most dominant include lift, climb, crawl and fall. The nature of the CATTs is dependent upon the type of urban terrain encountered. Given the recent advent of these CATTs, it is important to note that they are not as well embedded into infantry or ADG doctrine as some of the more 'traditional' CATTs. All of these tasks are undertaken while wearing body armour (minimum of helmet and ballistic vest) and therefore the soldiers/airmen carry a minimum of 21.6 kg throughout each of the CATTs.

Risks

8.4.2 As the actions that are involved in the various CATTs are somewhat discrete, the risks will be analysed for individual CATTs rather than by body part.

Tunnel Crawl

8.4.3 The technique used to execute the tunnel crawl appears to be very dependent on the physical size of the soldier compared to the diameter of the tunnel. This reflects a real life situation and therefore the risk of injury to various body parts will vary according to the technique imposed by the size of the soldier with respect to the size of the tunnel.

8.4.4 If the soldier chooses to crawl through the tunnel on hands and knees, the knees and one hand will take the majority of the load if the weapon needs to be carried. The circular surface of the tunnel will also influence leg and hip positioning and the impact load through the patella. The risk of injury to the knees, elbows and shoulders will be increased in a manner similar to that described for the section attack if the leopard crawl is adopted as the preferred movement pattern. Irrespective of whether the leopard crawl movement pattern is adopted, all of the observed tunnel crawl techniques required the soldier/airman to hyperextend his neck. Therefore, there is a need to minimise the risks associated with this neck posture by ensuring that the helmet is well fitted, offset sights are used and appropriate neck strengthening exercises are incorporated into the soldiers'/airmen's physical preparation regimen.

8.4.5 It was also observed that when the tunnel is large, some of the smaller soldiers adopted a crouching walk or 'duck waddle' position. This position place the knees at a very high risk for meniscal injury and this would be exacerbated by increasing the load (other than body weight).

Rope Climb

8.4.6 Correct technique for this CATT requires the use of the legs and feet to 'lock off' the rope and provide a base of support for the legs to be extended from a flexed position along with the arms to be used to pull the individual along the rope. Use of correct technique reduces the need for the soldier/airman to exert maximum levels of isometric and dynamic strength. Poor technique results in a significant reliance upon the arms to pull the individual up the rope. When good technique is used, risk of injury in minimized. When poor technique is used there is an increased risk of falling, upper body musculo-skeletal injury and hand injury due to rope burn.

Star Picket Lift

8.4.7 The members of the risk mitigation workshop considered the risk of injury to both the lifter and the soldier being lifted as being so great as to warrant this CATT being excluded from use. It was considered that there are safer and more operationally effective means of gaining entry to a building.

Second Storey Drop

8.4.8 The risk of injury during the balcony drop is dependent on the height of the drop, the height of the soldier completing the task, the landing surface and the skill and strength of the soldier undertaking the landing. A taller soldier is less likely to injure the lower limbs due to the decreased distance over which he needs to drop. Smaller, lighter soldiers may be at a greater risk of a landing injury not only due to the greater drop distance but also because of the relative increased load imposed by the webbing, weapon and helmet. Smaller, lighter soldiers may also be less able to control their landing with the added load of combat gear.

8.4.9 The CATT can be considered to consist of two sub tasks: preparation and landing. The preparation phase requires good upper limb strength and sustained grip strength to enable to soldier/airman to support their body weight along with the added weight of webbing, weapon and helmet. During the preparation phase the soldier/airman is at risk of injury to the elbows, shoulder and back due to the awkward methods used to achieve the 'ready' position for dropping from the balcony. The landing phase places the ankles, knees and back at a high risk of injury due to the landing impact forces and/or unbalanced landing on uneven surfaces.

Ladder Lift

8.4.10 The members of the risk mitigation workshop considered the risk of injury to both the lifter and the soldier being lifted as being so great as to warrant this CATT being excluded from use. It was considered that there are safer and more operationally effective means of gaining entry to a building.

Research

8.4.11 Research has been identified that has examined injuries sustained when individuals fall from a rope and the strategies used when landing after jumping from a height. Unfortunately, no studies were identified that examined the injury risk of crawling.

8.4.12 In a retrospective survey of fast roping injuries Kragh and Taylor (1996) found that injuries sustained were similar to parachute landing fall injuries but with a greater risk of ankle injuries (30% of all injuries). The mechanisms of injury were landing after a controlled descent and falls from a height when an individual loses control of the rope.

8.4.13 Individuals self-select landing strategies and this is primarily based on experience and training with different load distribution requirements and landing surfaces. Research has shown that there are marked differences between the landing strategies selected by experienced and novice jump personnel and this is reflected in differences in ground reaction forces and greater use of muscle power during the impact phase of landing (Hoffman, Leibermann and Gusis, 1997). Studies have also shown it is possible to decrease ground reaction forces of landing with instruction which relate to the kinematics of the knee and ankle joints and auditory cues, within one session (Prapavessis and McNair, 1999; McNair, Prapavessis and Callender, 2000; Onate, Guskiewicz and Sullivan, 2001).

Options for Action

Tunnels

Logistics

8.4.14 No logistical solutions were identified that may be implemented to reduce the risk of injury from performing this CATT.

Equipment

8.4.15 A range of simple suggestions were made to make movement through tunnels safer and more efficient during training and if appropriate also in operations. These included the use of wheels on chest plates or the use of trolleys for ‘rolling’ through the tunnel, use of ‘miners lights’ attached to the helmet or the back to assist in seeing where to go in the tunnel, and the introduction of gloves for hand protection.

8.4.16 It was also noted that the soldiers/airmen use a large range of webbing types (official and unofficial). It is apparent that there is a need for the soldiers/airmen to use one standard webbing type that can be adjusted to accommodate needs of the varying circumstances found during movement in tunnels.

Methods and Training

8.4.17 Training may be implemented to reduce injury risk for the entry to and exit from the tunnel. The size of the tunnel opening and height of the entrance of the tunnel compared to the stature of the individual soldier affects the manner in which safe movement techniques may be employed. Some soldiers had marked difficulty in entering the tunnel due to the combinations of height of the entry off the ground, diameter of the tunnel, the equipment being carried (especially the weapon), the configuration of the equipment attached to the webbing and the relative size of the soldier. When exiting the tunnels many soldiers display awkward exiting techniques and risked injury to the head, neck, hands, elbows, shoulders and back. For example many soldiers landed awkwardly on their head and one shoulder in an endeavour to hold the weapon in the ‘ready’ position. It is apparent that operationally appropriate and safe techniques for entering and exiting the tunnels need to be developed and taught in training.

Rope Climb

Logistics

8.4.18 No logistical solutions were identified that may be implemented to reduce the risk of injury from performing these CATTs.

Equipment

8.4.19 The equipment nominated for use in this CATT was a length of rope attached to a grappling hook. The members of the risk mitigation workshop were strongly of the view that a rope is not the preferred piece of equipment for this task. Instead, it was recommended that lightweight rope ladders are the preferred option, especially in training. Another suggestion put forward included an appropriate ladder that could be built out of extendable poles that are kept with the section kit.

Methods and Training

8.4.20 It was clear that many of the soldiers observed undertaking this CATT were not skilled in rope climbing and relied upon upper body strength to climb the rope and thereby placed themselves at a heightened risk of injury. If rope is to be used for assaulting a multistorey building, it is imperative that the soldiers and airmen be taught to climb using correct and safe technique. Likewise, if a lightweight rope ladder is used, it is also critical that the soldiers and airmen be taught the correct technique to ensure the stability of the ladder and appropriate foot placement (on opposite sides of the ladder) on the ladder. It was also noted that the width of the ladder appears to be too small for the majority of soldiers' boots and errors were made in placing the foot in the appropriate foot hold position. Widening the ladder may be a simple solution to decrease the risk of falling during the rope ladder climb. Enhanced training and practice may improve this aspect of the wall climb quite markedly.

Star Picket Lift

8.4.21 The star picket lift was considered to be an inherently dangerous activity for the soldiers performing the lift. The risk of injury during this task was deemed too high to allow task modification or training issues to be considered. The preference would be to adopt another method entirely to achieve the goal of gaining entry at a second story level. For example, telescopic poles may be used to make a climbing pole or ladder.

Notes on Star Pickets Generally

8.4.22 Two significant safety issues regarding the use of star pickets were noted. These both related to the potential to incur hand injuries from activities involving star pickets. Firstly the use of the 'dolly' to drive the star picket into the ground often sees the 'dolly' being lifted off the star picket and strike the hand of the soldier holding the picket. It was recommended that the task of holding the star picket while it is being driven into the ground be eliminated. A further concern regarding the star pickets for military use was that these pickets have notches in the side. There is a potential to severely injure a finger should a ring catch on a notch. It was recommended that soldiers/airmen refrain from wearing rings during military field training and operations.

Second Storey Drop

Logistics

8.4.23 No logistical solutions were identified that may be implemented to reduce the risk of injury from performing this CATT.

Equipment

8.4.24 It may be possible for the soldiers' webbing to have an attachment to permit a carabineer to be fitted and enable the use of abseiling technique during descent from a building. This would eliminate the need to perform the 'drop' and would enable the soldier to control the landing speed and technique.

Methods and Training

8.4.25 If the drop is to be maintained as a CATT, it is important for the soldiers/airmen to have sufficient grip strength to allow them to appropriately position their body and thereby perform the drop in as safe a manner as possible. Secondly, it is also important for the soldiers/airmen to be taught appropriate safe landing techniques. These techniques can be taught while landing on a shock absorbing surface in order to reduce the risk of injury and should not detract from the learning of the operational skill. There is, however, some debate as to the optimum landing surface for use in training. Examples of potential training landing surfaces include rubber matting, pebbles, sand and sprung boards. This type of modification would only be possible during training and correct landing technique needs to be ensured regardless of the landing surface used.

8.4.26 It was also noted that the soldiers/airmen need to be trained in the correct method of carrying their weapon during the CATT. It was observed that many soldiers/airmen were at risk of injury either from the weapon directly striking them or from attempts to control it during the landing phase of the drop. It is also suggested that a maximum drop height be established for training purposes.

Ladder Lift

8.4.27 It was suggested to eliminate the ladder lift task, which came from US Marines, as it is too dangerous due to the extreme effort by lifters, potential for fall from height, risk of the ladder breaking and impact of soldier hitting into the wall.

8.5 Population Protection and Control Drills

Population protection and control
Drills: total duration: approx 18 min.

Introduction

8.5.1 Population protection is a special ancillary CATT undertaken by Infantry soldiers and ADGs. It can be considered as being beyond the core set of tasks of the infantryman and ADG. The very nature of the CATT indicates that if deployed to undertake these duties, the soldiers/airmen would be engaged in a range of unpredictable activities that require specialist training in order for them to undertake the CATT in a safe manner.

Risks

8.5.2 The variability of this CATT carries an inherent risk because physical preparation and training alone may not be able to fully prepare for the inconsistent and unpredictable pressure loads. The need for sustained positioning through bracing also increases the risk of injury to the legs, back, shoulder and arms.

8.5.3 The use of water in the training environment increases the risk of injury from slipping and losing footing.

Options for Action

8.5.4 During the workshop discussion it was stated that the water cannon was used in an attempt to simulate crowd pressure. It was also acknowledged that crowds may use a variety of weapons available to them in any given situation. However it was deemed that this CATT was a specialist task not routinely undertaken by infantry. It was recognised that these tasks should be taught on a specialized course. It was acknowledged that the risk of injury is likely to come from the weapons used by a crowd. It was concluded that the equipment used in the training scenario observed was appropriate although soldiers/airmen should be required to wear eye protection when a water cannon is used in training.

8.6 Casualty Evacuation

Casualty evacuation (drag)
One man; over approximately 25 m in 60 s.

Casualty evacuation (carry)
Four person rotation; 4 km in 45 min.

Casualty evacuation (combined)
Two man (25 m drag, 200 m); carry on stretch while carriers are running, total time approx. 2 min.

Introduction

8.6.1 The CATTs associated with casualty evacuation range from 'emergency' evacuation undertaken in a battle environment to an evacuation undertaken in a less urgent environment behind the lines. The scenarios explored also involved a range of individuals from the single person drag to an evacuation involving an entire section carrying the injured soldier/airman in a rotational sequence.

Risks

One Man Drag

8.6.2 The most common technique used in the casualty evacuation drag (single person) was to generate the force required to drag the injured person by extending one leg at a time while lying on one side. There was also considerable isometric strength required of the hand, arm/shoulder and trunk to grasp and hold the webbing of the injured person. The soldiers often experienced significant fatigue and had difficulty in maintaining the required position and in dragging the casualty for the required distance. This caused many of the soldiers to alter their position in an attempt to find a technique that involved using less fatigued body parts such as moving to the alternate side of the injured person and using the non-fatigued leg and arm.

8.6.3 The soldier/airman performing the single person drag is placing their back at a high risk of injury. Qualitative analysis of the task revealed that the technique adopted required the soldiers/airmen to drag while assuming a posture that involved trunk flexion and rotation; a posture that is well known to increase the shear forces transmitted through the vertebrae to a level that exceeds safety limits and anatomical capacity (Waters et al., 1993).

8.6.4 In addition, the fact that the knee acts as the pivot for the load being dragged is likely to generate excessively high compressive forces through the knee risking meniscal and patella damage and twisting with load also risks ligament damage.

8.6.5 It is was noted that the fingers, wrists, arm, and shoulder are at risk from injury due to the static forces being transferred through these muscles and joints when pulling the casualty.

Two Man Drag

8.6.6 The two man drag is a much more rapid activity than the single man drag and was the battle field evacuation technique preferred by the Defence subject matter experts. The two man drag requires the rescuers to run in a crouched position while holding the injured soldier/airman by his webbing. This technique does place the rescuers at risk of injuring their back while the stresses placed through the hand, arm and shoulder are also likely to be very high.

Stretcher Lift and Carry

8.6.7 The initial task of bending and lifting the casualty to shoulder height has potential for injury to the back, arms and shoulders if not executed with appropriate lifting technique; particularly if the soldiers/airmen are in a fatigued state. This technique needs to be coordinated by all parties as does the positioning of soldiers/airmen within the four carrying positions. The sustained carrying forces also put the back and legs at further risk of overuse or fatigue injury. This is largely due to the excessive compressive forces experienced by the soldiers/airmen when carrying an injured person. It should also be noted that carrying the injured person at shoulder level (a height of approximately 1.65m) also places the injured person at risk of further injury should he be accidentally dropped.

Research

8.6.8 Knapik et al., (2000) studied effects on performance, human factors and cardiorespiratory responses of standard and alternative methods of stretcher carriage. Four different methods of stretcher carriage were investigated using 11 soldiers walking on a treadmill until volitional fatigue or for a maximum of 30 minutes. The different methods of carriage were: (1) hand carriage, (2) shoulder straps, (3) a specially designed hip-shoulder system (which allowed load shifting between the hip and shoulder), and (4) a clip fitted to the belt of each soldier's standard military load carrying equipment (LCE) which placed the weight predominantly on the hips. Hand carriage resulted in increased cardiorespiratory stress. Perceived exertion was less in the hip-shoulder and LCE systems. These two systems were also subjectively preferred with regard to comfort, ease of use and stability. This research suggests that the load should be supported either by the hips or shoulders or combination of both for improved performance and reduced stress.

Options for Action

Logistics

8.6.9 It is unlikely that logistical support can eliminate the need for battle field evacuation using the one or two man dragging technique. However, it is advocated that where possible air and land support should be accessed to eliminate the need for extended stretcher carrying.

Equipment

8.6.10 Much of the injury risk observed in the single person drag appeared to result from the need to adopt a 'high risk' posture in order to grasp hold of the injured person. It was recommended that a lower risk posture could be adopted if the soldier undertaking the evacuation could be somewhat removed from the injured soldier. This scenario could be accomplished if it were possible to connect a rope or baton/multipurpose extendable stick to the casualty's webbing during the drag.

8.6.11 It was also noted that in order to reduce the risk of hand injuries and to improve the efficiency of the evacuation, it is necessary to have a secure and safe grip on the casualty. This may require a review of each soldiers' webbing structure to provide a suitable 'handle'.

8.6.12 The review of the published literature identified that the US Army uses a hip carrying technique by using a clip attachment fitted to a belt. It is recommended that this method be investigated and trialled. One major benefit of this technique over the shoulder carry is the reduced risk of dropping the injured soldier from a height.

8.6.13 Given the potential injury risk to a soldier/airman playing the role of the injured person in the stretcher lift and carry due to a fall, it is recommended that an 80 kg dummy be used for this training task. This approach is used by numerous fire brigades to facilitate the safety of their rescue training.

Methods and Training

8.6.14 The infantry may need to consider advocating a two person drag be used wherever possible. This would decrease the risk of injury to the back and knees of the dragger in the single person drag. This may be the preferred option although it would still involve a risk of injury to the back. With the use of a rope/stick that could be hooked into the patient's webbing a two person drag would be easily performed by the rescuers in an upright posture. The modification of this technique may be limited by the need to maintain a low profile for safety in combat and therefore the technique needs to be reviewed in context of training and combat requirements.

8.6.15 It is recommended that the lift to shoulder level for the stretcher carry be performed by all available soldiers/airmen (6-8) in order to reduce the likelihood of a back injury being sustained during this task. Soldiers/airmen performing the stretcher carry are routinely rotated to reduce fatigue but this rotation must ensure that carriers are rotated through positions from the front (feet of casualty) to the rear (head of casualty) as the carrier located at the rear (head) position carries a greater load. This rotation should also include movement from left to right to allow even load carriage on both sides of the body of the carrier. During the carry the soldiers'/airmen's height should be matched side to side and an attempt made to maintain matching even with rotation of carriers. This is essential to balance the weight-bearing load for each carrier. Further, during the carrying component of this task, soldiers/airmen should attempt to keep in step to decrease uneven forces for the carrier and jolting the casualty.

8.6.16 Soldiers/airmen should be discouraged from running while carrying due to the increased impact load though the back and legs which may lead to overuse and fatigue injuries. If this is a necessary part of training to simulate operations then this aspect would require graded physical training. Soldiers/airmen will be required to run in operations but the risk of injury to the ankle, knee and back are considered unnecessary during training.

8.7 Bayonet Assault

Bayonet assault
Assault course approximately 4 min in duration.

Introduction

8.7.1 The bayonet assault is considered an important component of the infantry soldier and ADGs' skill set. In this study a simulated bayonet assault was observed at Tully in north Queensland. It is important to note that the simulated bayonet assault did not involve actual hand to hand combat and also it was not possible to reproduce the psychological environment that would normally surround an actual bayonet assault.

Risks

8.7.2 The simulated bayonet assault is a prolonged, high intensity activity that involves vigorous upper and lower body movements as well as movements through a challenging obstacle course. Given the challenging nature of the CATT, overall fatigue appears to be a major contributor to the risk of injury. In addition, poor technique displayed when negotiating the obstacle course component of the bayonet assault course also contributed to injury risk. A visual assessment indicated that the ankles, knees and back are at risk of acute injury during the run over rough ground and movement through obstacles. There is also a risk of tripping and falling and therefore sustaining injuries as a result of an impact with obstacles or the ground due to the nature of the course and the associated fatigue.

8.7.3 The actual bayonet strike involves a coordinated series of ballistic parry and thrust actions using a weapon weighing approximately 4 kg. The posture adopted during these actions is side on to the opponent with legs apart to brace the body (see photograph). These ballistic actions involve a risk of strain to muscles involved in both the dynamic and static activities.

Research

8.7.4 Little research was located that described or analysed the movements and risks associated with a simulated bayonet assault. One related paper was that published by Pope (2002) who explored the impact of obstacle course landing surface on knee injuries. Pope (2002) found that rubber matting used as a landing surface on obstacle courses increases the risk of anterior cruciate ligament ruptures especially if speed and rubber-soled footwear are involved. The subsequent removal of the rubber matting and replacement with concrete for take-off and raked river pebbles for landing minimized this risk. Therefore, this research underlines the fact that caution must be taken with simply placing a more compliant surface throughout the obstacle course for take-off and landing.

Options for Action

Logistics

8.7.5 No logistical supports were identified that could reduce the injury risk of the bayonet assault CATT.

Equipment

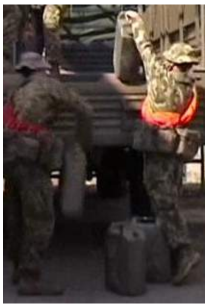
8.7.6 Integrated bayonet assault training that involves traversing an obstacle course includes many hazards. The risk of injury during performance on the obstacle course appeared to be increased with fatigue and it was noted that technique was negatively affected by repetition of the task. The Defence subject matter experts recommended that given the high risk of injury to the ankle and knee when traversing obstacle courses, the use of tyres as obstacles should be reviewed.

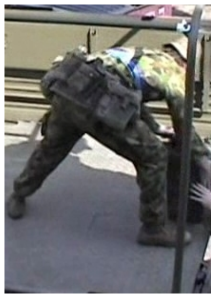
Training

8.7.7 Some of the other hazardous actions observed during the simulated bayonet assault included jumping into holes and scaling fences. It is therefore necessary to ensure appropriate landing techniques are taught and implemented to minimise risks when completing these actions during training.

8.8 Loading and Unloading Trucks

Loading and unloading a UNIMOG
Task was conducted over approx. 10 min and involved soldiers/airmen walking 100-150 m carrying loads up to 60 kg.





Introduction

8.8.1 Infantry soldiers and ADGs are regularly required to undertake a range of tasks that involve carrying a large range of equipment and manually loading and unloading this equipment onto vehicles. The most common vehicle loaded and unloaded is a UNIMOG, the tray of which is 1.5 m off the ground. These tasks are often completed in a rapid manner and are undertaken in both high and low combat risk environments.

Risks

8.8.2 The variability of the equipment and supplies being handled increases the need to continually adjust technique to accommodate changes in size, weight and shape. This increases the risk of injury during both the loading and unloading phase of this task. The soldiers/airmen also are required to continually make subjective decisions as to whether to lift, carry and load various pieces of equipment individually or as a team. A warm-up was not performed by the soldiers/airmen prior to the loading task.

8.8.3 Given the range of weight lifted and variable nature of the equipment and tasks, it is critical that an appropriate back posture and correct use of the legs is adopted to ensure safe lifting technique thereby minimizing the risk of injury.

8.8.4 The height of the lift (to the back of the vehicle) places the arms and shoulders at risk during the lift to waist height and then further with the lift over shoulder height. Controlling heavy equipment lifted from these heights during the unloading also carries risk of injury.

8.8.5 The soldiers and airmen who are positioned in the vehicle to receive the supplies must work in a bent position. This posture places the knees, back, shoulder and neck at risk due to the need to continually drag heavy objects on the truck tray using a range of lift, place, push, pull and twisting actions while in a bent posture.

Options for Action

Logistics and Equipment

8.8.6 Given that this CATT is often undertaken in a low threat ‘industry like’ setting, there are a number of opportunities to decrease the injury risk by employing lifting technology commonly used in civilian industry. Such technological innovations may range from the low technology tailgate loader to the use of pallets and fork lifts. It was also apparent that the use of loading bays would negate the need for much of the high lifting. The use of wheeled trolleys or pallets would reduce the risk of injury during both carry and loading phases. Also the use of racks for off-ground storage would reduce the need to lift equipment from the ground. Many storage facilities have improved capability using more modern methods of storage and better equipment that would reduce the time spent performing the loading and unloading tasks on the base considerably. This needs to be reviewed to ascertain the relevance to the military storage facilities. However these new storage and handling techniques may not be transferable to loading and unloading in the field and the two methods must be compatible. Where loading is conducted in the field and no technological aids are available, it is important to note that the soldier/airman located in the truck appears to be at greatest risk of injury due to the bent posture assumed when dragging or carrying the equipment into position. It is recommended that options for side loading of trucks be considered to reduce the distance over which the equipment needs to be moved once on the truck and thereby reduce the risk to the soldier/airman responsible for positioning the equipment on the truck.

Training

8.8.7 Assuming that even if the above recommendations are implemented, there will still be a need for manual loading during in-field settings, it is critical that the soldiers/airmen be instructed in 'safe' lifting techniques and conditioned with appropriate training loads. Officers and NCOs should be instructed to ensure that safe lifting techniques are implemented.

8.9 Digging

Shell scrape
Construct a hole large and deep enough for one person to lie in; construction to take up to 20 min.

Dig to Stage1
Construct a defensive position for 2-3 people to stand in approximately 1 m deep over 6 hr; construction to occur in rotated teams of 2-4 people.

Introduction

8.9.1 Digging is a very common defensive task undertaken by infantry soldiers and ADGs. In some situations such as the construction of a shell scrape, the digging is an individual task conducted at a rapid pace given that the person digging the shell scrape is potentially in immediate danger. In other situations such as the construction of a more robust defensive position (Stage 1, 2 or 3), the digging is undertaken at a more regular pace, in a team-based rotation over a prolonged period of time. It is important to note that the implements used for digging also vary. Shell scrapes are generally constructed using an entrenching tool, whereas construction of a defensive position to Stage 1, 2 or 3 is generally undertaken using picks, shovels and crow-bars.

Risks

8.9.2 A range of risks of musculo-skeletal injury were observed during the two digging activities. These risks were to the back, knees, fingers, wrists, arms, neck and shoulders.

8.9.3 During both digging activities, but exaggerated in the shell scrape, the back is in a sustained forward bending and twisted position which greatly increases the potential for disc injuries in the lower back.. The momentum developed in the swinging action of the pick and entrenching tool, combined with the sudden jarring when the digging implement contacts the ground, is also cause for concern for overuse injuries to the shoulder.

8.9.4 The crouching and kneeling position maintained in the shell scrape forces the knees to bear the full weight of the body and personal combat gear. The knees are also vulnerable to injury in the standing position assumed when digging to Stage 1 due to the need to straddle the hole and stand on uneven surfaces.

8.9.5 The construction of the Stage 1 defensive position often involves both carrying the digging equipment to the construction site as well as the digging activity per se. Carrying the digging equipment over variable distances and terrain may increase the risk of injury due to trips and falls as well as strain to the back, shoulder and arms. During the digging task the fingers, wrists arms and shoulders are at risk of repetitive strain injuries from swinging the pick and shovel and blisters from gripping the handle of the pick or shovel.

8.9.6 To view the digging process the neck is maintained in a forward flexed position and must also support the weight of the helmet. This sustained load would increase the risk of neck muscle strains and contribute to poor postural habits.

8.9.7 It should also be noted that the digging to Stage 1 CATT also involved a significant risk of the soldiers/airmen striking each other while digging with picks. Should an injury be sustained in this manner it may have potential life-threatening consequences.

Options for Action

Logistics and Equipment

8.9.8 Dependent upon the level of combat threat, mechanised equipment may be used to reduce the risk of injury when constructing the Stage 1 defensive position. Mechanised equipment may be used to transport the digging equipment to the construction site or, if available, to actually dig the defensive position (for example using a detachable trenching apparatus attached to a 'Bobcat').

8.9.9 It is recommended that an extendable digging tool for digging the shell scrape be developed. It was noted that the current tool use in the shell scrape has been used since WW1 and although serviceable, may have greater effectiveness and efficiency if the handle could be extended further. Routine use of gloves to avoid blisters and abrasion injuries during the shell scrape construction would help decrease minor but sometimes debilitating hand injuries. Also, the use of eye protection would reduce the risk of eye injury due to dirt and debris.

Methods and Training

8.9.10 Where tactically appropriate, the soldiers/airmen need to remove ballistic vest, webbing and helmet while digging to decrease the load carried and therefore early fatigue, to ensure freedom of movement of the arms, unencumbered vision and allow cooling during the task of digging. The weapon should also be removed whenever tactically appropriate during the digging tasks. The basic technique and principles of digging need to be taught, such as cutting down the face of the hole and advancing away, then cleaning out the hole. This is important as many of the digging styles employed by the soldiers/airmen showed haphazard methods that were inefficient and dangerous.

8.9.11 General construction safety issues also need to be addressed. For example, there should be only one person in pit at a time; while the one digger rests the other one digs. Also, during the construction of a shell scrape there needs to be some consideration of safety of other diggers and the proximity of the scrapes to one another so diggers do not interfere with each other.

8.10 Debussing

Debus
Debus from vehicle; total activity time approx. 10 sec over 20 m; airmen carried equipment weighing 21.6 kg.

Introduction

8.10.1 Swift exit from a vehicle is undertaken by ADG airmen as part of their rapid response strategy. As shown above, the debussing CATT involves jumping down from a small vehicle and rapid transition to a running action.

Risks

8.10.2 The techniques used in debussing from a vehicle appear to be varied and may be dependent on individual physical characteristics and personal skill and style. The need to debus with weapon at the ready also affects the safety of the landing by limiting the use of arms to assist the manoeuvre. The ankles, knees and back are at risk of injury due to the impact forces when landing after jumping from the truck. There is also potential for rotational injuries to the knee that may be incurred when the airman moves rapidly from a landing posture to running. The tasks associated with the run from the vehicle, 'going to ground', leopard crawling, and assuming the support position for firing are the same as for the combined section attack task. Therefore there is potential risk of injury to the ankles, knees, elbows, shoulders and neck.

Options for Action

Equipment

8.10.3 Modifications to the vehicles may be considered to decrease the landing impact forces experienced during debussing from the vehicle. These include engineering options such as suspension lowering similar to that seen in commercial buses, a flip out step along side the vehicle and a ramp to exit without jumping from the height of the vehicle. Another aspect of vehicle design that may need to be considered is to redesign the lip on the side of the vehicle to avoid a trip hazard when getting out. Anecdotally, this trip hazard is sometimes eliminated by raising the level of the floor with sandbags.

8.10.4 It will be important to assess the soon to be commissioned 'Bushmaster' vehicle to ensure that it facilitates safe and rapid debussing, should it be used in rapid deployment.

Methods and Training

8.10.5 Due to the considerable variety in debussing techniques, an investigation into which techniques are most appropriate for decreasing injuries during jumping and landing should be implemented. Following this investigation appropriate training in landing technique needs to be implemented.

8.10.6 The injury risks associated with the fall to ground issues are similar to going to ground for section attack.

8.11 General Issue

8.11.1 It appears in many tasks that individuals are left to develop their own technique perhaps taking into account their strength and size capabilities. In some instances, the techniques developed increase the risk of injury to the individual. Consideration needs to be given to the extent to which the technique used to complete a CATT may be customised given the potential injury implications.

PART C: CONCLUSION

9 RECOMMENDATIONS

9.1 Risk Register

9.1.1 This report has presented an overall assessment of risk for each task. However, the risk register (Annex 1) contains data based on an analysis of each subtask. It is recommended that the listing of subtasks in the register be maintained. It is the subtasks that have particular risk characteristics. It is these characteristics that need to be addressed through solutions. Whilst a solution might require changing the entire task, to understand the risks attention needs to be given to the detail of the subtasks. The risks should also be identified according to the body part as this helps identify the particular problem with the subtask.

9.1.2 To facilitate ongoing evaluation and review, it is recommended that the data in the risk register be used to establish a risk database. Individual entries in the database should be at the subtask level, but entries should also be linked to tasks so that all the hazards associated with a particular task can easily be identified and collated. There should be provision for recording details including a hazard description, part of the body affected, risk score, suggested actions and person/position responsible for risk reduction.

9.1.3 It is recommended that the risk register/database should be reviewed within the Australian Defence Force in line with other recent or contemporaneous risk assessments conducted in programs such as RAAFSAFE.

9.2 DPESP Criterion Tasks

9.2.1 With specific reference to the DPESP, it is recommended that in selecting Criterion Tasks on which to base Physical Employment Tests (PETs), account should be taken of the risk assessments in this report. If possible, PETs should be based on lower risk tasks. However, it is noted that most tasks, regardless of the overall level of risk, contain subtasks that present high risks to one or more body parts. Therefore, even if it is possible to utilise only lower risk tasks for the PETs, it is recommended that close consideration be given to the high-risk components of selected criterion tasks. Removal or modification of the high risk subtasks when developing the PET protocols would significantly reduce the overall risk of the PETs.

9.3 Risk Mitigation Strategies

9.3.1 It is recommended that the risk mitigation strategies proposed in Chapter 8 of this report should be considered for adoption. Many of these can be grouped into the following categories:

a. The helmet should be redesigned to ensure better fit and to reduce the stress on the neck.
b. Neck strengthening needs to form part of physical preparation activities for all soldiers and airmen and should be weighted to meet the strength and endurance requirements of wearing a helmet while performing combat tasks and duties.
c. The safest casualty evacuation techniques should be determined, subject to operational performance requirements, and these methods should be taught and used in relevant training activities.
d. Flexibility of function should be built into webbing design, such as a grip for the patient drag, a harness for balcony drop and a variety of attachment points.
e. Biomechanical analysis of ‘going to ground’ should be undertaken to assist in the development of the most appropriate technique (which may be terrain dependent) for decreasing risk of injury to the knees, back, neck and upper limbs.

f. There is a need to reconcile the appropriate use of full kit including body armour in training with the inherent associated risks (eg. heat injury), and to ensure that training is graded appropriately to fully prepare soldiers and airmen for combat.

g. Appropriate and consistent weapon slinging technique for specific tasks should be advised and adhered to, especially in training activities. If this varies in the combat situation then training should allow a gradual inclusion of the weapon in these tasks, from no weapon to correctly slung weapon, and finally to weapon ready.

9.3.2 It is also recommended that Defence should:

a. Prioritise the ideas put forward from the workshop.

b. Develop steps to advance these to the next developmental or implementation stage, including allocating responsibilities, determining agencies that should be involved and determining research needs for specific ideas (Defence Materiel Organisation, Defence Science and Technology Organisation, University of Ballarat).

c. Attempt to better understand the impact of the various CATTs on injury and disease costs. At present, it appears that costs of injury and disease are not able to be allocated in a way that makes a clear connection to a given CATT.

d. Communicate the ideas and solutions contained within this report to those responsible for allied projects such as Project Wundarra and Land 125 in order to ensure that appropriate solutions are incorporated into the design of new and emerging equipment.

e. Undertake research to better understand and define the impact of operations on safe long-term human performance. This could involve considering the applicability of manual handling models to the defence environment.

f. Review policy on injury and disease prevention by considering opportunities to strengthen policy to emphasise that good safety is essential to maximise operational capability.

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ANNEXES

Annex 1. Risk Register

Risk register Analysis Method key: B biomechanical R Rodgers (See Section 2.4)

Where the task was observed	Who performs the task	Sub task No.	Description	Analysis Method	Legs	Risk Score	Back	Risk Score	Neck	Risk Score	Shoulder	Risk Score	Arms	Risk Score	Average	Ancillary musculoskeletal risks that are not manual handling as such but are related – due to falls, trips, etc.	Notes, ideas for solutions, etc
ADG	Both		**Ammunition box carry** (subtask maximum)			**7.0**		**10.0**		**3.0**		**3.0**		**6.0**	**5.8**	**-**	.
ADG	Both		**Ammunition box carry** (average all subtasks)			**3.4**		**7.1**		**2.1**		**2.1**		**2.7**	**3.5**	**-**	.
ADG	Both	1	Lift large box to/from ground level	B	91%	4	5200 N	10		2	99%	2	100 %	1	3.8	-	Bend to ground level. Box=20kg.
ADG	Both	2	Lift large box to/from vehicle boot (~ mid thigh height)	B			3200 N	8		2	99%	2	95%	3	3.8	-	Half stoop with hands about mid thigh height and well forward of body. (Ankle load (72% capable) probably overestimated by model as thighs lean on boot lip - hence is not included)
ADG	Both	3	Hold large box at around waist height	B	99%	2	1600 N	4		2	99%	2	98%	3	2.6	-	Upright posture hands around hip height.
ADG	Both	4	Lift two small boxes to/from ground (not shown on video) hands at shin height	B	79%	7	3200 N	7		2	99%	2	99%	2	4.0	-	Stooped forward with hands about shin height, hands to side of body, handles on top of boxes, estimate weight 10kg each
ADG	Both	5	Lift two small boxes to/from vehicle boot	B			4000 N	9		1	99%	1	100 %	1	3.0	-	Hands about hip height (handles on top of box), hands well forward, estimate weight 10kg each. (Ankle load (72% capable) probably overestimated by model as thighs lean on boot lip - hence is not included). Increased potential for injury if straight legs are maintained and rotation occurs without moving feet when placing or removing boxes from back of car.
ADG	Both	6	Walk with one large box	R	113	2	222	6	122	3	122	3	222	6	4.0	-	Upright posture with hands hanging at side, estimate weight 10kg each
ADG	Both	7	Walk with two small boxes	R	113	2	222	6	122	3	122	3	122	3	3.4	-	.
Infantry	Both		**Bayonet assault** (subtask maximum)			**8.0**		**9.0**		**9.0**		**8.0**		**6.0**	**8.0**	**-**	Trip and fall hazards intentionally placed, strike hazard on star pickets (covered with caps). Jumping and landing over pits or into pits has high potential for ankle and knee sprains. Crawl under wire loading of elbows and shoulders. Trip and fall hazard of tyres increases likelihood of ankle and sprains. Hurdle sideways over low fence landing on one leg - executed well with landing but potential for ankle and knee sprains. Impact of upper body / bayonet strike appears to be self- limited on impact and strike which decrease potential for injury.
Infantry	Both		**Bayonet assault** (average all subtasks)			**4.8**		**5.2**		**5.0**		**4.5**		**4.3**	**4.8**	**-**	.
Infantry	Both	1	Crawl under wire (~6-8s)	R	313	8	321	9	321	9	313	8	213	6	8.0		.
Infantry	Both	2	Run through tyres	R	313	8	213	6	211	3	211	3	211	3	4.6	Risk of tripping and ankle injury. Tripping may cause a fall with potential for injuries to other body parts.	-

Risk register Analysis Method key: B biomechanical R Rodgers (See Section 2.4)

Where the task was observed	Who performs the task	Sub task No.	Description	Analysis Method	Legs	Risk Score	Back	Risk Score	Neck	Risk Score	Shoulder	Risk Score	Arms	Risk Score	Average	Ancillary musculoskeletal risks that are not manual handling as such but are related – due to falls, trips, etc.	Notes, ideas for solutions, etc
Infantry	Both	3	Jump into hole	R	311	4	311	4	211	3	211	3	211	3	3.4	Impact hazard for legs and back	-
Infantry	Both	4	Attack with weapon	R	211	3	311	4	211	3	311	4	311	4	3.6	-	High effort for short duration with upper body and back
Infantry	Both	5	Scale hurdles	R	311	4	311	4	211	3	211	3	311	4	3.6	Risk of ankle injury. Tripping may cause a fall with potential for injuries to other body parts.	.
Infantry	Both	6	Lie on ground and aim weapon	R	121	2	221	4	321	9	231	6	231	6	5.4	-	Sustained neck posture bent backwards and to the side
Infantry	Both		**Casualty evacuation - carry** (4 person) (subtask maximum)			**8.0**		**10.0**		**6.0**		**6.0**		**6.0**	**7.2**	**-**	Lift coordinated which decreases potential for injury. Resting load on packs increases load through spine and lower limbs. If load remains evenly distributed weight is borne by all four soldiers equally however load shifted to one side during evacuation. This may have occurred with changeover. Changeover decrease potential for long-term load injuries. One soldier allowed load to shift onto shoulders and adjusted posture to a forward flexed position rather than taking load on pack. Maintaining an even cadence when walking would assist in controlling forces of the load. If heights of soldiers are uneven shorter soldiers will bear more of a load.
Infantry	Both		**Casualty evacuation - carry** (4 person) (dominant subtask, no. 4)			**8.0**		**10.0**		**6.0**		**6.0**		**6.0**	**7.2**	**-**	.
Infantry	Both	1	Lift stretcher to shoulder height - initial	B	98%	3	4700 N	9		2	99%	2	99%	2	3.6	-	As for wall climb except load about 25kg total
Infantry	Both	2	Lift stretcher to shoulder height - at elbow height	B	98%	3	2200 N	5		2	99%	2	89%	5	3.4	-	.
Infantry	Both	3	Lift stretcher to shoulder height - hands at shoulder height	B	98%	3	1900 N	4		6	83%	6	100 %	1	4.0	-	.
Infantry	Both	4	Carry stretcher	R	313	8	331	10	231	6	231	6	231	6	7.2	**Risk of twisted ankle, trip or fall especially given the load and potential fatigue.**	Risks of casualty falling, as well as injuries to the carriers, are reduced with training the soldiers on coordinating their gait. Uneven load front to back. Slight forward stooping, non-uniform load (I.e. greater at the casualty's head end), also carrying jacket, helmet, webbing, weapon and pack), team carry resulting in variation in carry height, different position side-side (thus varying the load supported on each side).
ADG	Both		**Casualty evacuation – combined** (subtask maximum)			**8.0**		**10.0**		**6.0**		**10.0**		**10.0**	**8.8**	**-**	.
ADG	Both		**Casualty evacuation – combined** (average all subtasks)			**8.0**		**8.0**		**6.0**		**10.0**		**10.0**	**8.4**	**-**	.
ADG	Both	1	Drag casualty 50m - two person 20-30seconds)	R	313	8	331	10	231	6	331	10	331	10	8.8	-	Forward flexed spine with rotation and loaded with weight of body being dragged. Potential for disc injury and lower back strains.

Risk register Analysis Method key: B biomechanical R Rodgers (See Section 2.4)

Where the task was observed	Who performs the task	Sub task No.	Description	Analysis Method	Legs	Risk Score	Back	Risk Score	Neck	Risk Score	Shoulder	Risk Score	Arms	Risk Score	Average	Ancillary musculoskeletal risks that are not manual handling as such but are related – due to falls, trips, etc.	Notes, ideas for solutions, etc
ADG	Both	2	Stretcher carry 250m - four person	R	313	8	231	6	231	6	331	10	331	10	8.0	**Risk of twisted ankle, trip or fall especially given the load and potential fatigue.**	Running with stretcher could strain to shoulder due to load. Difficult to measure time - seemed to be about 30sec which would be less than 250m
Infantry	Both		**Casualty evacuation - drag** (subtask maximum)			**8.0**		**8.0**		**6.0**		**8.0**		**8.0**	**7.6**	**-**	Load through one knee which is maintained in a flexed position with body weight through joint. This is increased if soldier fully flexes knee. Groin strain of "pushing" leg with increased forces on medial aspect of knee (medial collateral ligament / meniscus). Shoulder has distraction forces caused by dragging casualty especially if using a straight arm drag position. Other technique used with bent over fully flexed trunk has high potential for disc injury or muscular strain or joint sprain of lower back - most soldiers who tried this technique could not or did not sustain it for long and did not appear to be effective. Guns seemed to pose a distraction / problem for this task and probably need to be secured. Casualty at risk of being kicked, eye injuries and neck strain whilst being dragged, easily solved by use of a dummy.
Infantry	Both		**Casualty evacuation - drag** (average all subtasks)			**8.0**		**8.0**		**6.0**		**8.0**		**8.0**	**7.6**	**-**	.
Infantry	Both	1	Drag casualty with one hand while keeping low to ground, ~ 1-2min	R	313	8	313	8	213	6	313	8	313	8	7.6	-	.
Infantry	Both		**Category 1 wiring** (subtask maximum)			**7.0**		**10.0**		**9.0**		**9.0**		**8.0**	**8.6**	**-**	Seven posts weigh 25kg (3.7kg each). Large wire roll weighs 20kg. Three large rolls plus one post weighs 64kg (carried by two people). Small roll of wire weighs 16kg. Two small rolls plus one post weighs 36kg (carried by two people). Lifting, carrying and placing down of wire needs to be coordinated between two carriers.
Infantry	Both		**Category 1 wiring** (average all subtasks)			**4.5**		**6.6**		**4.0**		**5.0**		**5.5**	**5.1**	**-**	.
Infantry	Both	1	Lift 7 post bundle from vertical to shoulder	B	93%	4	4700 N	9		2	98%	2	96%	3	4.0	-	Bend and lift from ground (if posts on ground). Seven posts = 25kg.
Infantry	Both	2	Lift wire rolls with post through centre with partner (hands just above knees)	B	97%	3	3500 N	9		2	99%	2	99%	2	3.6	-	32kg each person.
Infantry	Both	3	Lift wire rolls with post through centre with partner (hands at elbow height)	B	96%	3	2300 N	5		3	97%	3	69%	8	4.4	-	32kg each person.
Infantry	Both	4	Lift wire rolls with post through centre with partner (hands at shoulder height)	B	92%	4	2200 N	5		9	50%	9	97%	3	6.0	-	32kg each person.

Risk register Analysis Method key: B biomechanical R Rodgers (See Section 2.4)

Where the task was observed	Who performs the task	Sub task No.	Description	Analysis Method	Legs	Risk Score	Back	Risk Score	Neck	Risk Score	Shoulder	Risk Score	Arms	Risk Score	Average	Ancillary musculoskeletal risks that are not manual handling as such but are related – due to falls, trips, etc.	Notes, ideas for solutions, etc
Infantry	Both	5	Carry wire/posts on shoulder	R	131	3	131	3	131	3	231	6	231	6	4.2	Risk of twisted ankles and possibly subsequent falls while carrying the load depending on terrain	Bearing weight on the shoulder, some side bending of spine owing to load on one side, awkward and sustained posture of arm to restrain load. Sustained load on shoulder with star pickets or wire coil carry. Soft tissue injury to shoulder musculature (trapezius and supraspinatus) possible. Need to ensure load is well balanced on shoulder especially when carrying the wire coils between two people (otherwise load is unevenly distributed). Poor posture was demonstrated (forward flexion of the back and rounding of the shoulders) when load became uncomfortable/painful.
Infantry	Both	6	Drive posts	R	213	6	213	6	213	6	313	8	313	8	6.8	Very high risk of hand injury if an assistant's hand gets caught between driver and post.	Risk greatly reduced with training of technique, which is good in video. The posts shown appeared to be new or near new. Bent posts can jam inside the driver. A small part on top of the post designed to enable barbed wire to be slotted in to the top can also easily become bent - although this particular problem is more common when posts are driven with a sledgehammer. In either case the post can be very difficult to remove but this was not shown on the video.
Infantry	Both	7	Roll wire with hands along ground	R	231	6	231	6	131	3	213	6	213	6	5.4	-	This involves sustained bending and repeated effort at the shoulder to push the roll forward. Forward flexion of spine to roll out wire individually demonstrates sustained poor back posture. ADG personnel worked in pairs with a post through the roll to reduce bending. Perhaps a simple tool could be devised to roll out faster and without bending? The tool could be a handle that would slide through the roll to enable the roll to be rolled while standing upright.
Infantry	Both	8	Removing post from ground (not shown)	B	77%	7	5200 N	10		4	94%	4	67%	8	6.6	-	One post needed to be removed to be repositioned in ADG exercise. The post was pulled out by bending forward and gripping the post at about knee height. The force was not measured. Allow 25kg each hand. All would need to be removed at some point, A post removing tool would minimize risks to hands and back.
ADG	Both		**Category 1 wiring** (subtask maximum)			**7.0**		**10.0**		**6.0**		**8.0**		**8.0**	**7.8**	**-**	Different approach to task organization compared to infantry. Assistance being given with rolling out wire and striking star picket. Unwinding wire has forward bent posture but is not necessary if two people carrying wire between them. Note: Removing the wire and posts was not shown. Need eye protection
ADG	Both		**Category 1 wiring** (average all subtasks)			**4.6**		**5.5**		**3.7**		**4.6**		**5.9**	**4.8**	**-**	.
ADG	Both	1	Carry wire roll in pairs	R	213	6	221	4	121	2	221	4.0	221	4	4.0	Risk of twisted ankles and possibly subsequent falls while carrying the load depending on terrain	Carry one roll in pairs. Wire roll weight = 25kg. Back is leaning to one side while carrying.

Risk register

Analysis Method key: B biomechanical R Rodgers (See Section 2.4)

Where the task was observed	Who performs the task	Sub task No.	Description	Analysis Method	Legs	Risk Score	Back	Risk Score	Neck	Risk Score	Shoulder	Risk Score	Arms	Risk Score	Average	Ancillary musculoskeletal risks that are not manual handling as such but are related – due to falls, trips, etc.	Notes, ideas for solutions, etc
ADG	Both	2	Carry posts on shoulder	R	113	2	121	2	221	4	221	4	221	4	3.2	Risk of twisted ankles and possibly subsequent falls while carrying the load depending on terrain	Bearing weight on the shoulder, some side bending of spine owing to load on one side, awkward and sustained posture of arm to restrain load. Number of posts not known. Estimate 4 posts. Posts appear to be about 2.4m long. Posts infantry used appeared to be 1.8m and weighed 3.7kg. Assume therefore that 2.4m posts would weigh about 5kg. Seven posts weigh 25kg (3.7kg each). Large wire roll weighs 20kg. Three large rolls plus one post weighs 64kg (carried by two people). Small roll of wire weighs 16kg. Two small rolls plus one post weighs 36kg (carried by two people).
ADG	Both	3	Lift/jerk rolls of wire free from other rolls	R	212	4	312	7	212	4	212	4	212	4	4.6	-	Place something between rolls to avoid tangling?
ADG	Both	4	Drive posts	R	213	6	213	6	213	6	313	8	313	8	6.8	Very high risk of hand injury if an assistant's hand gets caught between driver and post.	Repeated lifting of 10kg driver. Driver has handles to assist with control and generating force using arms as well as trunk (abdominals).
ADG	Both	5	Crouch to hold posts	R	222	6	222	6	122	3	113	2	213	6	4.6	-	It is not really necessary to hold the post - the driver can keep the post vertical
ADG	Both	6	Roll out wire - 2 person using post through roll	R	222	6	222	6	122	3					5.0	-	Some tend to stoop while walking with the roll. These figures are based on stooping. Others walk in a less hazardous upright posture.
ADG	Both	7	Attach wire to posts - crouch/bend	R	222	6	222	6	122	3	113	2	213	6	4.6	-	Repeated bending
ADG	Both	8	Remove driver from post	R	112	1	212	4	212	4	312	7	312	7	4.6	-	Driver (10kg) overbalances when lifted off the top of the post as the soldier can only hold the bottom of the driver at that point. The overbalancing twists the wrists and possibly the shoulder,
ADG	Both	9	Spread large diameter wire loop	R	112	2	212	4	212	4	213	6	213	6	4.4	-	Some bending, frequent arm movements to untangle and spread the wire roll into a loose spiral
ADG	Both	10	Remove post from ground	B	77%	7	5200 N	10		4	94%	4	67%	8	6.6	-	One post needed to be removed to be repositioned. The post was pulled out by bending forward and gripping the post at about knee height. The force was not measured. Allow 25kg each hand. All would need to be removed at some point. Is the technique to pull the posts out by hand? Or are there tools available?
Infantry	Both		**Company Level replenishment** (subtask maximum)			**6.0**		**7.0**		**8.0**		**10.0**		**10.0**	**8.2**	**-**	Generally a lower risk task.
Infantry	Both		**Company Level replenishment** (average dominant subtasks 3&4)			**6.0**		**6.0**		**4.5**		**8.0**		**8.0**	**6.5**	**-**	.

Risk register Analysis Method key: B biomechanical R Rodgers (See Section 2.4)

Where the task was observed	Who performs the task	Sub task No.	Description	Analysis Method	Legs	Risk Score	Back	Risk Score	Neck	Risk Score	Shoulder	Risk Score	Arms	Risk Score	Average	Ancillary musculoskeletal risks that are not manual handling as such but are related – due to falls, trips, etc.	Notes, ideas for solutions, etc
Infantry	Both	1	Lift two jerry cans from ground (handles on top)	B	95%	3	3200 N	7		2	99%	2	100 %	1	3.0	-	25kg jerry can. On first appearances it seems that jerry cans could have wheels and a pull out handle along the lines of modern suitcases. The wheels would need to be larger and designed for outdoor use. The can could not be rolled in all terrain but where it minimizes effort and should also increase speed of travel. It is understood that attempts of this nature have been made. The search may thus be a fruitless one, but on the other hand technology is always changing and a new idea that improves the functionality and reliability of this type of idea may be available.
Infantry	Both	2	Lift jerry can, box, bag to shoulder	B	99%	2	1900 N	4		8	66%	8	89%	5	5.4	-	25kg jerry can.
Infantry	Both	3	Carry can at side in each hand	R	231	6	231	6	131	3	231	6	231	6	5.4	Risk of twisted ankles and possibly subsequent falls while carrying the load depending on terrain.	Two cans each 25kg. Sustained hook grip on jerry cans may cause strain of forearm flexors and supraspinatus strain due to constant distraction force.
Infantry	Both	4	Carry jerry can, box, bag on shoulder	R	231	6	231	6	231	6	331	10	331	10	7.6	-	One can at 25kg. If carrying in pairs, ammunition load needs to be balanced evenly between two carriers.
ADG	ADG		**Debus** (subtask maximum)			**8.0**		**9.0**		**9.0**		**8.0**		**6.0**	**8.0**	**-**	-
ADG	ADG		**Debus** (average all subtasks)			**4.7**		**5.7**		**7.3**		**5.7**		**5.0**	**5.7**	**-**	.
ADG	ADG	1	Jump from vehicle ~ 1m high	R	311	4	311	4	311	4	211	3	211	3	3.6	Landing forces has potential for ankle and knee sprains. Most demonstrated a two-foot landing position and used hands to assist which further decreased forces through lower limbs. Landing on one leg increases likelihood of landing unevenly and injuring ankle or knee.	Impact on legs and spine. Wearing helmet, webbing, jacket and carrying weapon.
ADG	ADG	2	Run/roll/crawl (as for section attack)	R	313	8	321	9	321	9	313	8	213	6	8.0	Risk of twisted ankles and possibly subsequent falls depending on terrain. Especially as run is fast and vision may be focused on other than the footings. ADG personnel seem to use a fall and roll technique. The fall and roll is not without its own risks. Perhaps thought could be given to the relative merits and the safest method determined?	.
ADG	ADG	3	Lie on stomach in readiness (as for section attack)	R	121	2	221	4	321	9	231	6	231	6	5.4	-	.

Risk register Analysis Method key: B biomechanical R Rodgers (See Section 2.4)

Where the task was observed	Who performs the task	Sub task No.	Description	Analysis Method	Legs	Risk Score	Back	Risk Score	Neck	Risk Score	Shoulder	Risk Score	Arms	Risk Score	Average	Ancillary musculoskeletal risks that are not manual handling as such but are related – due to falls, trips, etc.	Notes, ideas for solutions, etc
ADG	Both		**Dig to stage 1** (subtask maximum)			**6.0**		**10.0**		**10.0**		**8.0**		**8.0**	**8.4**	**-**	.
ADG	Both		**Dig to stage 1** (average all subtasks)			**6.0**		**10.0**		**10.0**		**8.0**		**8.0**	**8.4**	**-**	.
ADG	Both	1	Break ground with pick (~ 1min ~ 1blow each 2 seconds)	R	231	6	331	10	331	10	313	8	313	8	8.4	-	Repeated about 20 times alternating/resting with removing soil task. Stooped posture, some straightening between blows but posture is essentially sustained, additional effort on back to pull pick out each time it becomes lodged in the soil, neck is horizontal supporting the head. Digging to below ground/foot level increase forward flexed posture and forces on lumbar spine. Repeated back extension and forceful forward flexion with overhead pick action. A hole deepens reach must be further forward and below foot height.
ADG	Both	2	"Sweep" soil out with shovels (~ 30-60 seconds, ~1 movements/s)	R	231	6	331	10	331	10	313	8	313	8	8.4	-	Repeated about 20 times alternating/resting with breaking soil task. Stooped posture, sweep soil to one side. Scraping out is either on knees in half squat position or legs spread and forward bent to scrape between legs. Knee forces from body weight through flexed knees and lumbar loading with forward flexed position.
Infantry	Both		**Forced entry and stair climb** (subtask maximum)			**8.0**		**4.0**		**4.0**		**4.0**		**4.0**	**4.8**	**-**	.
Infantry	Both		**Forced entry and stair climb** (average all subtasks)			**5.5**		**3.5**		**4.0**		**4.0**		**4.0**	**4.2**	**-**	.
Infantry	Both	1	Strike door with large hammer	R	211	3	211	3	311	4	311	4	311	4	3.6	-	.
Infantry	Both	2	Run up stairs with hammer or with weapon drawn	R	313	8	221	4	221	4	221	4	221	4	4.8	Risk of tripping on stairs and falling forwards. Object in hands would hamper protecting the face against impact.	.
Infantry	Infantry		**Forced march** (subtask maximum)			**8.0**		**10.0**		**9.0**		**9.0**		**9.0**	**9.0**	**-**	Heat stress if conducted during day. Poor posture and pack fitment demonstrated. Fatiguing soldiers more at risk.
Infantry	Infantry		**Forced march** (dominant subtask 1)			**8.0**		**10.0**		**6.0**		**6.0**		**6.0**	**7.2**	**-**	.
Infantry	Infantry	1	March with large pack and weapon ready (some with two packs)	R	313	8	331	10	231	6	231	6	231	6	7.2	Risk of twisted ankles and possibly subsequent falls depending on terrain especially given the pack weight and with increasing fatigue.	Sustained slight forward stoop. Weight of pack increases impact forces of repeated footfall - increases likelihood of overuse injuries - "shin splints", stress fractures, mechanical or disc lower back injuries. This increased up to eight fold with jogging with pack. Some poor posture demonstrated with forward flexion of trunk - habitual hitching of pack. As march progressed increased flat footed gait increasing potential for lower limb and foot overuse injuries. Soldiers carrying two packs increasing potential for lower back and lower limb injuries especially when combined with jogging. Changing surfaces would also change impact of footfall and potential for tripping and ankle sprains.
Infantry	Infantry	2	Lift pack from ground.	B	80%	6	5700 N	10		2	99%	2	100 %	1	4.2	-	Allow pack = 40kg.

Risk register Analysis Method key: B biomechanical R Rodgers (See Section 2.4)

Where the task was observed	Who performs the task	Sub task No.	Description	Analysis Method	Legs	Risk Score	Back	Risk Score	Neck	Risk Score	Shoulder	Risk Score	Arms	Risk Score	Average	Ancillary musculoskeletal risks that are not manual handling as such but are related – due to falls, trips, etc.	Notes, ideas for solutions, etc
Infantry	Infantry	3	Lift pack in front of body at elbow height	B	96%	3	2900 N	6		4	90%	4	38%	9	5.2	-	Allow pack = 40kg.
Infantry	Infantry	4	Lift pack in front of body at head height	B	94%	4	3100 N	7		9	30%	9	99%	2	6.2	-	Allow pack = 40kg.
ADG	Both		**Jerry can carry** (subtask maximum)			**8.0**		**7.0**		**7.0**		**7.0**		**9.0**	**7.6**	**-**	.
ADG	Both		**Jerry can carry** (dominant subtask, no. 1)			**5.5**		**7.0**		**4.5**		**4.5**		**5.0**	**5.3**	**-**	.
ADG	Both	1	Walk with two jerry cans for about 1 minute	R	313	8	231	7	231	7	231	7	321	9	7.6	Risk of twisted ankles and possibly subsequent falls while carrying the load depending on terrain.	Arms hanging at side
ADG	Both	2	Lift cans	B	95%	3	3200 N	7		2	99%	2	100 %	1	3.0	-	Bend to pick up jerry cans, hands at knee height, allow 25kg each hand
Infantry	Both		**Ladder lift** (subtask maximum)			**9.0**		**9.0**		**4.0**		**9.0**		**9.0**	**8.0**	**-**	Extreme fall risk of person on top of ladder during the "flip". Hand injury could occur when ladder strikes wall. Two soldiers pulling ladder with back lateral flexion with load of ladder plus soldier. Strain of low back and trunk flexors. Three other soldiers using arms overhead bracing position resulting in high axial loading through upper limb and back.
Infantry	Both		**Ladder lift** (average all subtasks)			**6.8**		**5.3**		**3.5**		**7.3**		**7.3**	**6.0**	**-**	.
Infantry	Both	1	Ground personnel general	R	313	8	321	9	221	4	312	7	312	7	7.0	-	Multiple postures including on ground and on ladder.
Infantry	Both	2	Soldier squatting to brace ladder	R	321	9	221	4	221	4	321	9	321	9	7.0	-	One person bracing ladder from wall in forward leg split position and ankle/foot for bracing. Potential for slipping and straining adductors/groin.
Infantry	Both	3	Soldier on ladder	R	121	2	221	4	121	2	321	9	321	9	5.2	Risk of traumatic injury to all areas of body if fall occurs from height or suffers impact against the building.	Hang from ladder for ~ 6 seconds holding against accelerative forces, so that effective body weight varies during lift.
Infantry	Both	4	Ladder climb	R	313	8	221	4	221	4	221	4	221	4	4.8	Risk of traumatic injury to all areas of body if fall occurs from height.	Mainly high leg effort when climbing.
ADG	Both		**Load and unload UNIMOG** (subtask maximum)			**8.0**		**10.0**		**9.0**		**9.0**		**8.0**	**8.8**	**-**	Lift to shoulder height has potential to cause rotator cuff tendonitis / impingement if repeated consistently. This is increased with one person unloading from truck. Solutions - minimise bending. Store items to grasp without bending or reaching to shoulder height, use mechanical aids such as a tailgate lifter, park the truck closer to the store to minimize carrying, put wheels on jerry cans and other items, use trolleys to move large boxes, reduce the size of boxes unless items can not be broken down.
ADG	Both		**Load and unload UNIMOG** (average all subtasks)			**4.9**		**6.4**		**6.1**		**6.1**		**3.9**	**5.5**	**-**	.
ADG	Both	1	Lift cans	B	95%	3	3200 N	7		2	99%	2	100 %	1	3.0	-	Bend to pick up jerry cans, hands at knee height, allow 25kg each hand

Risk register Analysis Method key: B biomechanical R Rodgers (See Section 2.4)

Where the task was observed	Who performs the task	Sub task No.	Description	Analysis Method	Legs	Risk Score	Back	Risk Score	Neck	Risk Score	Shoulder	Risk Score	Arms	Risk Score	Average	Ancillary musculoskeletal risks that are not manual handling as such but are related – due to falls, trips, etc.	Notes, ideas for solutions, etc
ADG	Both	2	Lift jerry can to truck	B	99%	2	1900 N	4		8	66%	8	89%	5	5.4	-	.
ADG	Both	3	Lift net to head height - two person	B	97%	3	2100 N	5		8	64%	8	98%	3	5.4	-	Hands at about shoulder height, estimate 50kg total (25kg each).
ADG	Both	4	Lift long bag/box to elbow height - two person	B	92%	4	1600 N	4		3	97%	3	89%	5	3.8	-	.
ADG	Both	5	Lift long bag to truck - two person	B	85%	5	2300 N	5		9	49%	9	100 %	1	5.8	-	.
ADG	Both	6	Bend to lift various items	B	88%	5	5900 N	10		2	99%	2	99%	2	4.2	-	Bending forward hands at ankle height lifting 25kg with two hands. Loading in the back of the truck shows maintained forward flexed posture with the need to lift, carry or drag items within the back of the truck. Forward flexion with rotation increases risk of disc injury and increasing load while lifting or dragging further increases this potential. Need to use a bent knee (squat) position (not seated as demonstrated by one soldier) but this would be difficult to sustain for full loading period.
ADG	Both	7	Slide items from rear to front of truck	B	74%	8	3400 N	8		9	46%	9	92%	4	7.6	-	Bending forward and applying force to side, allow 25kg between two hands lateral
ADG	Both	8	Overall activity on ground (~15 sec carry, 1-2 per minute)	R	213	6	222	6	222	6	222	6	222	6	6.0	-	.
ADG	Both	9	Overal activity on truck (~ 10 movements/minute)	R	312	8	322	9	312	8	312	8	312	8	8.2	Potential fall from truck.	Bending sustained, repeated forces while bent with legs, spine, shoulders and arms
Infantry	Both		**Mortar route march** (subtask maximum)			**8.0**		**10.0**		**9.0**		**9.0**		**9.0**	**9.0**	**-**	.
Infantry	Both		**Mortar route march** (average dominant subtask 4)			**8.0**		**10.0**		**6.0**		**6.0**		**6.0**	**7.2**	**-**	.
Infantry	Both	1	Lift pack from ground	B	80%	6	5700 N	10		2	99%	2	100 %	1	4.2	-	Soldier lifts pack including barrel from ground level. Allow pack = 40kg.
Infantry	Both	2	Lift pack in front of body at elbow height	B	96%	3	2900 N	6		4	90%	4	38%	9	5.2	-	
Infantry	Both	3	Lift pack in front of body at head height	B	94%	4	3100 N	7		9	30%	9	99%	2	6.2	-	.
Infantry	Both	4	Walk 10km carrying large pack	R	313	8	331	10	231	6	231	6	231	6	7.2	Risk of twisted ankles and possibly subsequent falls while carrying the load depending on terrain.	Sustained partial stoop in order to keep balance given heavy backpack. More personalized packs will reduce risk, but their availability is lacking.
Infantry	Both		**Patrol in marching order** (subtask maximum)			**6.0**		**10.0**		**6.0**		**6.0**		**6.0**	**6.8**	**-**	.
Infantry	Both		**Patrol in marching order** (average all subtasks)			**6.0**		**10.0**		**6.0**		**6.0**		**6.0**	**6.8**	**-**	.

Risk register Analysis Method key: B biomechanical R Rodgers (See Section 2.4)

Where the task was observed	Who performs the task	Sub task No.	Description	Analysis Method	Legs	Risk Score	Back	Risk Score	Neck	Risk Score	Shoulder	Risk Score	Arms	Risk Score	Average	Ancillary musculoskeletal risks that are not manual handling as such but are related – due to falls, trips, etc.	Notes, ideas for solutions, etc
Infantry	Both	1	Walk slowl\y, weapon ready with pack (no helmet)	R	213	6	331	10	231	6	231	6	231	6	6.8	Unpredictable terrain increases likelihood of sprains of ankle or knee. Greater need for small jumps and landings over culverts and uneven areas also increases impact forces to lower limb.	Slower pace than march, more difficult terrain as shown.
Infantry	Both		**Patrol in patrol order** (subtask maximum)			**6.0**		**6.0**		**3.0**		**6.0**		**6.0**	**5.4**	-	Generally lower risk task.
Infantry	Both		**Patrol in patrol order** (average all subtasks)			**6.0**		**6.0**		**3.0**		**6.0**		**6.0**	**5.4**	-	.
Infantry	Both	1	Walk, weapon ready (no pack,no helmet)	R	213	6	231	6	131	3	231	6	231	6	5.4	Risk of twisted ankles and possibly subsequent falls depending on terrain. Irregular surfaces with potential for sprained ankles, trip or falls. Walking backward, turning on unsighted ground has potential to twist and sprain knee.	Slower pace than march, more difficult terrain as shown, no pack. Pivoting may increase ligament injury of knee.
Infantry	Both		**Population protection and control** (subtask maximum)			**9.0**		**9.0**		**6.0**		**9.0**		**9.0**	**8.4**	-	
Infantry	Both		**Population protection and control** (average all subtasks)			**6.0**		**6.3**		**4.0**		**6.0**		**5.7**	**5.7**	-	Generally lower risks
Infantry	Both	1	Walking, making formations, thrusting baton	R	113	2	122	3	122	3	212	4	212	4	3.2	-	Low potential for wrist, forearm and shoulder sprains and strains with use of batons and shield if twisting or wrenching movements occur. This increased at the shoulder in high arm position.
Infantry	Both	2	Walking, making formations, thrusting baton and brace/advance against water cannon	R	222	6	222	6	122	3	212	4	212	4	4.6	-	.
Infantry	Both	3	Arrest	R	312	7	312	7	212	4	312	7	312	7	6.4	Risk of falls while making arrest.	Unpredictable loads depending on detainee. Rocks could increase potential for ankle sprains and falling over.
Infantry	Both	4	Shield against vehicle mounted cannon/kicking	R	322	9	322	9	222	6	322	9	322	9	8.4	Risk of overbalance. Generally low impact as body is low to the ground at the outset.	Sustained effort with legs and back. With shield in low position arm/shoulder effort is lower with shield against body. Upper shield position or in formation or when advancing alone appears to involve high arm/shoulder effort. Kneeling position increases forces through knee (patella and meniscii).
ADG	ADG		**Pursuit** (subtask maximum)			**8.0**		**6.0**		**6.0**		**6.0**		**6.0**	**6.4**	-	-
ADG	ADG		**Pursuit** (average all subtasks)			**8.0**		**6.0**		**6.0**		**6.0**		**6.0**	**6.4**	-	.

Risk register Analysis Method key: B biomechanical R Rodgers (See Section 2.4)

Where the task was observed	Who performs the task	Sub task No.	Description	Analysis Method	Legs	Risk Score	Back	Risk Score	Neck	Risk Score	Shoulder	Risk Score	Arms	Risk Score	Average	Ancillary musculoskeletal risks that are not manual handling as such but are related – due to falls, trips, etc.	Notes, ideas for solutions, etc
ADG	Both	1	Jog with helmet, jacket, webbing, weapon ready	R	313	8	213	6	213	6	213	6	213	6	6.4	Variable terrain and surfaces increasing potential for ankle and knee sprains. Jogging increasing weight and forces through lower limb. Jogging unbalanced with arms holding weapon in front of body.	High risk of knee and back strains. Jogging effort greatly increases risks. Some extra equipment, mortars, etc
Infantry	Both		**Rope climb** (subtask maximum)			**8.0**		**6**		**6**		**10**		**10**	**8.0**	**-**	Shoulder strain, triceps and latissimus dorsi and forearm flexors and wrist extensors from gripping rope and pulling body weight. Adductor and groin strain if leg technique is used ineffectively. Variable quality techniques demonstrated. Injury could be sustained by falls, slips and loss of grip.
Infantry	Both		**Rope climb** (average all subtasks)			**8**		**6**		**6**		**10**		**10**	**8.0**	**-**	.
Infantry	Both	1	Climb with ballistic vest, helmet and webbing	R	313	8	231	6	231	6	331	10	331	10	8.0	Risk of traumatic injury to all areas of body if fall occurs from height.	.
ADG	Both		**Sandbagging** (subtask maximum)			**6.0**		**9.0**		**6.0**		**6.0**		**6.0**	**6.6**	**-**	High risk of back strain with sustained effort. Assume bag weighs 15kg, two handed lift to one side. Side lunge and thrust to lay sand bag. Load on groin and lower back.
ADG	Both		**Sandbagging** (average all subtasks)			**5.0**		**6.2**		**3.2**		**2.7**		**2.7**	**3.9**	**-**	.
ADG	Both	1	Bend and hold bag (~30-40 seconds)	R	131	3	231	6	231	6	131	3	131	3	4.2	-	One leg kneeling posture to shovel sand - loaded flexed knee. Soldier holding bag maintains a forward flexed back posture for prolonged period.
ADG	Both	2	Kneel and hold bag (~30-40 seconds)	R	231	6	131	3	131	3	131	3	131	3	3.6	-	.
ADG	Both	3	Kneel and shovel sand into bag (~15 shovels in ~ 30-40 sec)	R	231	6	313	8	213	6	213	6	213	6	6.4	-	.
ADG	Both	4	Lift/place bag (hands ~ ankle height)	B	80%	6	4700 N	9		1	99%	1	100 %	1	3.6	-	.
ADG	Both	5	Lift bag (hands ~ knee height)	B	80%	6	2600 N	6		2	99%	2	100 %	1	3.4	-	.
ADG	Both	6	Lift bag (hands ~ elbow height)	B	95%	3	2300 N	5		1	99%	1	98%	2	2.4	-	.
Infantry	Both		**Second storey drop** (subtask maximum)			**4.0**		**4.0**		**4.0**		**9.0**		**9.0**	**6.0**	**-**	Body should be completely still before drop. Too much padding on ground may increase the risk of ankle rolling. Coccyx injury. Potential for impact to ankles and knees - dependent on landing terrain. Most demonstrated good landing techniques with most forces being absorbed by legs in a correct manner. Potential shoulder and upper body injury could be incurred during positioning over balcony due to awkward preparation with railings or during hang if sustained. This was avoided by some by use of a ladder to gain hanging position on balcony.

Risk register Analysis Method key: B biomechanical R Rodgers (See Section 2.4)

Where the task was observed	Who performs the task	Sub task No.	Description	Analysis Method	Legs	Risk Score	Back	Risk Score	Neck	Risk Score	Shoulder	Risk Score	Arms	Risk Score	Average	Ancillary musculoskeletal risks that are not manual handling as such but are related – due to falls, trips, etc.	Notes, ideas for solutions, etc
Infantry	Both		**Second storey drop** (average all subtasks)			**4.0**		**4.0**		**4.0**		**9.0**		**9.0**	**6.0**	**-**	.
Infantry	Both	1	Second storey drop (sustained hold >6s on balcony)	R	311	4	311	4	221	4	321	9	321	9	6.0	Risk of traumatic injury to all areas of body if fall occurs from height.	Several seconds supporting upper body with load on shoulders, arms, neck. Impact on legs and back on landing (model probably underestimates impact effect).
Infantry	Infantry		**Section attack on oval** (subtask maximum)			**8.0**		**9.0**		**9.0**		**8.0**		**6.0**	**8.0**	**-**	Rough ground and slopes would complicate the task. With variable terrain ankles could be sprained on run component. Lumbar extension is increased in field due to decreased visual field.
Infantry	Infantry		**Section attack on oval** (average all subtasks)			**6.0**		**6.3**		**8.0**		**6.7**		**6.0**	**6.6**	**-**	.
Infantry	Infantry	1	Run (a few metres) and go to ground	R	313	8	222	6	213	6	222	6	222	6	6.4	Risk of twisted ankles and possibly subsequent falls depending on terrain. Especially as run is fast and vision may be focused on other than the footings. At the run/crawl transition there is a severe impact of knees on the ground. Braking force from knees transferred to lower back in whiplash mechanism. The ADG personnel seem to use a fall and roll technique. The fall and roll is not without its own risks. Perhaps thought could be given to the relative merits and the safest method determined? High risk of patella injury with poor technique in fall. ADG's roll method may also involve less patello-femoral strain when standing, as their momentum is already established with roll before standing.	-
Infantry	Infantry	2	Crawl fast (a few metres)	R	313	8	321	9	321	9	313	8	213	6	8.0	-	High effort on ankles, knees and hips, twisting and extension of spine, upper body load on elbows and shoulders, shoulder posture awkward with hands "above" shoulder, neck posture sustained.

Risk register Analysis Method key: B biomechanical R Rodgers (See Section 2.4)

Where the task was observed	Who performs the task	Sub task No.	Description	Analysis Method	Legs	Risk Score	Back	Risk Score	Neck	Risk Score	Shoulder	Risk Score	Arms	Risk Score	Average	Ancillary musculoskeletal risks that are not manual handling as such but are related – due to falls, trips, etc.	Notes, ideas for solutions, etc
Infantry	Infantry	3	Lie on stomach and aim weapon	R	121	2	221	4	321	9	231	6	231	6	5.4	-	Sustained backward bending of neck, twist neck to side to sight target. Sustained prone position with extension of lumbar spine, upper body weight through shoulders with commando crawl - irritation of rotator cuff muscles to stabilize shoulder in weight-bearing and repeated impact on elbows. Neck extensor strain from sustained postural extension. With regard to the neck position, perhaps alternative scope systems are available such that the neck posture is not so awkward?
Infantry	Infantry		**Section attack in bush** (subtask maximum)			**8.0**		**9.0**		**9.0**		**8.0**		**6.0**	**8.0**	**-**	As per section attack on oval.
Infantry	Infantry		**Section attack in bush** (average all subtasks)			**5.5**		**5.8**		**7.0**		**6.0**		**5.5**	**6.0**	**-**	.
Infantry	Infantry	1	Run (a few metres) and go to ground	R	313	8	222	6	213	6	222	6	222	6	6.4	Risk of twisted ankles and possibly subsequent falls depending on terrain. Especially as run is fast and vision may be focused on other than the footings. At the run/crawl transition there is a severe impact of knees on the ground. Braking force from knees transferred to lower back in whiplash mechanism. The ADG personnel seem to use a fall and roll technique. The fall and roll is not without its own risks. Perhaps thought could be given to the relative merits and the safest method determined? High risk of patella injury with poor technique in fall. ADG's roll method may also involve less patello-femoral strain when standing, as their momentum is already established with roll before standing.	.
Infantry	Infantry	2	Crawl fast (a few metres)	R	313	8	321	9	321	9	313	8	213	6	8.0	Crawling was minimal but did occur.	High effort on ankles, knees and hips, twisting and extension of spine, upper body load on elbows and shoulders, shoulder posture awkward with hands "above" shoulder, neck posture sustained.

Risk register Analysis Method key: B biomechanical R Rodgers (See Section 2.4)

Where the task was observed	Who performs the task	Sub task No.	Description	Analysis Method	Legs	Risk Score	Back	Risk Score	Neck	Risk Score	Shoulder	Risk Score	Arms	Risk Score	Average	Ancillary musculoskeletal risks that are not manual handling as such but are related – due to falls, trips, etc.	Notes, ideas for solutions, etc
Infantry	Infantry	3	Lie on stomach and aim weapon	R	121	2	221	4	321	9	231	6	231	6	5.4	-	Sustained backward bending of neck, twist neck to side to sight target. Sustained prone position with extension of lumbar spine, upper body weight through shoulders with commando crawl - irritation of rotator cuff muscles to stabilize shoulder in weight-bearing and repeated impact on elbows. Neck extensor strain from sustained postural extension. With regard to the neck position, perhaps alternative scope systems are available such that the neck posture is not so awkward?
Infantry	Infantry	4	Crouch, aim and fire weapon	R	221	4	221	4	221	4	221	4	221	4	4.0	This method of firing was not used in other section attack examples.	Repeated squatting and kneeling throughout to prepare for run - body weight through flexed knee increasing load on meniscii and patella.
ADG	ADG		**Section attack with roll on oval** (subtask maximum)			**8.0**		**9.0**		**9.0**		**8.0**		**6.0**	**8.0**	**-**	-
ADG	ADG		**Section attack with roll on oval** (average all subtasks)			**6.0**		**6.3**		**8.0**		**6.7**		**6.0**	**6.6**	**-**	.
ADG	ADG	1	Run (a few metres) and go to ground with a roll	R	313	8	222	6	213	6	222	6	222	6	6.4	Risk of twisted ankles and possibly subsequent falls depending on terrain. Especially as run is fast and vision may be focused on other than the footings. Trip and fall, stepping in holes. Uneven terrain increasing potential for trips and falls especially while turning, walking sideways or backwards. ADG personnel seem to use a fall and roll technique. The fall and roll is not without its own risks. Perhaps thought could be given to the relative merits and the safest method determined?	As for section attack on oval. But terrain more difficult. Crawl on knees or one foot and one knee increase impact forces through knee and loading through flexed knee.
ADG	ADG	2	Lie on stomach and aim weapon	R	313	8	321	9	321	9	313	8	213	6	8.0	-	.
ADG	ADG	3	Crawl fast (a few metres)	R	121	2	221	4	321	9	231	6	231	6	5.4		High effort on ankles, knees and hips, twisting and extension of spine, upper body load on elbows and shoulders, shoulder posture awkward with hands "above" shoulder, neck posture sustained.
ADG	ADG		**Section attack with roll in bush** (subtask maximum)			**8.0**		**9.0**		**9.0**		**8.0**		**8.0**	**8.4**	**-**	.
ADG	ADG		**Section attack with roll in bush** (average all subtasks)			**6.5**		**7.0**		**8.3**		**7.0**		**6.5**	**7.1**	**-**	.

Risk register Analysis Method key: B biomechanical R Rodgers (See Section 2.4)

Where the task was observed	Who performs the task	Sub task No.	Description	Analysis Method	Legs	Risk Score	Back	Risk Score	Neck	Risk Score	Shoulder	Risk Score	Arms	Risk Score	Average	Ancillary musculoskeletal risks that are not manual handling as such but are related – due to falls, trips, etc.	Notes, ideas for solutions, etc
ADG	ADG	1	Run (a few metres) and go to ground with a roll	R	313	8	222	6	213	6	222	6	222	6	6.4	Risk of twisted ankles and possibly subsequent falls depending on terrain. Especially as run is fast and vision may be focused on other than the footings. Trip and fall, stepping in holes, trip on stumps, rocks, etc. Uneven terrain increasing potential for trips and falls especially while turning, walking sideways or backwards. ADG personnel seem to use a fall and roll technique. The fall and roll is not without its own risks. Perhaps thought could be given to the relative merits and the safest method determined?	As for section attack on oval. But terrain more difficult. Crawl on knees or one foot and one knee increase impact forces through knee and loading through flexed knee.
ADG	ADG	2	Lie on stomach and aim weapon	R	121	2	221	4	321	9	231	6	231	6	5.4	-	.
ADG	ADG	3	Crawl fast (a few metres)	R	313	8	321	9	321	9	313	8	213	6	8.0		High effort on ankles, knees and hips, twisting and extension of spine, upper body load on elbows and shoulders, shoulder posture awkward with hands "above" shoulder, neck posture sustained.
ADG	ADG	4	Crawl and carry machine gun	R	313	8	321	9	321	9	313	8	313	8	8.4	Machine gun used in this example seemed much more substantial that weapons/replica weapons in other section attack examples.	Crawl while supporting upper body with one arm, carry machine gun with other arm
ADG	Both		**Shell scrape** (subtask maximum)			**6.0**		**10.0**		**10.0**		**8.0**		**8.0**	**8.4**	**-**	.
ADG	Both		**Shell scrape** (average all subtasks)			**6.0**		**10.0**		**10.0**		**8.0**		**8.0**	**8.4**	**-**	.
ADG	Both	1	Use shovel to pick and sweep soil, ~15min average ~ 30-40 / min	R	231	6	331	10	331	10	313	8	313	8	8.4	-	Working at maximum pace, fatigue and back discomfort from bending becomes obvious after about 5min. Kneeling with full body weight through flexed knees increases potential for meniscus injury. Method of scraping out sideways increases rotational forces through spine that is in a flexed position. This increases load on discs.
Infantry	Both		**Star picket lift** (subtask maximum)			**5.0**		**10.0**		**10.0**		**10.0**		**10.0**	**9.0**	-	.
Infantry	Both		**Star picket lift** (average all subtasks)			**4.3**		**8.0**		**6.7**		**6.7**		**5.3**	**6.2**	-	Allow 100kg for soldier, clothing, weapon, webbing, picket - I.e. 50kg each side.

Risk register Analysis Method key: B biomechanical R Rodgers (See Section 2.4)

Where the task was observed	Who performs the task	Sub task No.	Description	Analysis Method	Legs	Risk Score	Back	Risk Score	Neck	Risk Score	Shoulder	Risk Score	Arms	Risk Score	Average	Ancillary musculoskeletal risks that are not manual handling as such but are related – due to falls, trips, etc.	Notes, ideas for solutions, etc
Infantry	Both	1	Star picket lift - initial	B	94%	4	6100 N	10		4	99%	4	99%	5	5.4	-	Stoop to provide initial lift. Lower back (disc, muscle, joint) injury exacerbated by technique (those shown on video showed good technique at this stage). Hand injury risk on sharp picket edges. Reduced by wrapping with sand bag.
Infantry	Both	2	Star picket lift - elbow height	B	93%	4	3300 N	7		6	81%	6	8%	10	6.6	Risk of falling from picket. Risk of traumatic injury to all parts of body.	High load on elbow at elbow height lift (forearms horizontal).
Infantry	Both	3	Star picket lift - shoulder height	B	88%	5	3100 N	7		10	9%	10	99%	1	6.6	Risk of falling from picket. Risk of traumatic injury to all parts of body.	Movement replicates the "clean and jerk" technique but lifters fail to move body under load when lift is above shoulder height - potential for tearing shoulder and elbow joints and musculature and damaging rotator cuff or dislocating shoulder with weight of soldier being borne anterior to lifters body position.
ADG	ADG		**Sustained patrol** (subtask maximum)			**8.0**		**10.0**		**9.0**		**9.0**		**9.0**	**9.0**	**-**	Heat stress effects as conducted during day by Airfield Defence Guards. Poor posture and pack fitment demonstrated. Fatiguing soldiers more at risk.
ADG	ADG		**Sustained patrol** (dominant subtask, no.1)			**8.0**		**10.0**		**6.0**		**6.0**		**6.0**	**7.2**	**-**	.
ADG	ADG	1	March 10km with webbing, pack and weapon in hand.	R	313	8	331	10	231	6	231	6	231	6	7.2	Risk of twisted ankles and possibly subsequent falls depending on terrain especially given the pack weight and with increasing fatigue.	As for Infantry forced march. Some individual personal characteristics may be noted - flat-footed gait increases potential for overuse injuries. Short uneven cadence on stride length and forward leaning posture have potential for increasing injury due to poor absorption of forces.
ADG	ADG	2	Lift pack from ground (as for Infantry forced march)	B	94%	4	3100 N	7		5	88%	5	39%	9	6.0	-	Allow pack = 40kg.
ADG	ADG	3	Lift pack in front of body at elbow height (as for Infantry forced march)	B	93%	4	3200 N	7		9	30%	9	99%	2	6.2	-	Allow pack = 40kg.
ADG	ADG	4	Lift pack in front of body at head height (as for Infantry forced march)	R	313	8	331	10	231	4.2	231	6	231	6	6.8	-	Allow pack = 40kg.
Infantry	Both		**Tunnel crawl** (subtask maximum)			**10.0**		**10.0**		**10.0**		**6.0**		**6.0**	**8.4**	**-**	.
Infantry	Both		**Tunnel crawl** (average all subtasks)			**7.3**		**7.3**		**7.3**		**6.0**		**6.0**	**6.8**	**-**	.
Infantry	Both	1	Crawl through short tunnel with small pack ~ 30 seconds	R	213	6	213	6	231	6	213	6	213	6	6.0	-	Can look down periodically. Sustained body weight through shoulders and elbows to crawl forward - rotator cuff and shoulder stabilisers. Head first drop -landing and impact on hands and full body weight through arms/shoulders
Infantry	Both	2	Tactical tunnel crawl with weapon ~ 2min	R	213	6	213	6	331	10	213	6	213	6	6.8	-	Crawling on all fours impact to knees (patella). Duck walking technique (walking in full squat position) increases likelihood of meniscal injury with full body weight through fully flexed knee, increased strain on anterior cruciate ligament (leg risk higher for this technique). Slower than regular tunnel crawl

Risk register Analysis Method key: B biomechanical R Rodgers (See Section 2.4)

Where the task was observed	Who performs the task	Sub task No.	Description	Analysis Method	Legs	Risk Score	Back	Risk Score	Neck	Risk Score	Shoulder	Risk Score	Arms	Risk Score	Average	Ancillary musculoskeletal risks that are not manual handling as such but are related – due to falls, trips, etc.	Notes, ideas for solutions, etc
Infantry	Both	3	Tunnel exit? - crouch walk	R	331	10	331	10	231	6	231	6	231	6	7.6	-	Sustained effort of legs in crouch position, sustained forward bending of back, sustained horizontal head position but not sustained looking forward (note some crawl on knees). Tunnel exit has risk of head, tibia, and knee hyperextension injury if foot gets caught on tunnel roof.
Infantry	Both		**Urban patrol** (subtask maximum)			**6.0**		**6.0**		**3.0**		**6.0**		**6.0**	**5.4**	**-**	.
Infantry	Both		**Urban patrol** (average all subtasks)			**4.7**		**4.7**		**2.7**		**4.0**		**4.0**	**4.0**	**-**	.
Infantry	Both	1	Run short distances (~10s) with weapon ready	R	213	6	222	6	122	3	222	6	222	6	5.4	Risk of twisted ankles and possibly subsequent falls depending on terrain.	Carrying webbing, effort with legs and back, impact on legs and back while running, holding weapon at readiness.
Infantry	Both	2	Kneel/crouch with weapon	R	221	4	221	4	121	2	121	2	121	2	2.8	-	Resting on one knee, resting weapon on knee. Repeated squatting on one knee - impacting patella and placing force on meniscii. Getting up from this position using quadriceps and again loads patellofemoral complex.
Infantry	Both	3	Scale/roll over fences ~ 1.6m	R	311	4	311	4	211	3	311	4	311	4	3.8	Risk impact injuries when falling from the fence.	Fence climb usually favoring one side on all fence clearances. Technique of rolling over fence decreases forces on spine - other rotating and flipping with combined flexion, rotation and lateral flexion. Landing easily on two feet decreases impact and shares load evenly between legs. Mistimed or awkward landings increases likelihood of lower limb injuries. Tend to use legs to propel over fence. Some use one arm.
Infantry	Both		**Wall climb** (subtask maximum)			**5.0**		**10.0**		**10.0**		**10.0**		**10.0**	**9.0**	**-**	Landing appeared to be in good form for those that took the time to land equally on two feet and absorbed force correctly with legs. Other that were hurried on landing, landed on one leg or various unstable and unpredictable techniques. Climber has potential risks involved in 6 and 8 foot climbs but appears to a more difficult press to execute without the momentum of run.
Infantry	Both		**Wall climb** (average all subtasks)			**4.3**		**6.0**		**5.5**		**5.7**		**4.8**	**5.3**	**-**	.
Infantry	Both	1	6-foot wall climb	R	311	4	311	4	211	3	311	4	311	4	3.8	Risk of leg or spine impact injuries when falling/jumping from the wall.	Leg effort to run and propel elbows to wall height, arm and shoulder effort to lift body to wall height (<6s), twisting of back, impact on landing. Biomechanical model for elbow: 45kg push down each hand. 6 and 8 foot wall climb relies on soldier's upper body strength to weight ratio to lift body to support position on top of wall. Strong force from shoulders and elbows extensors - triceps, latissimus dorsi, pectorals. Relies on stable shoulder position to support body weight and depress through shoulders. Potential groin strain (adductors) for those swinging one leg over wall to assist in raising body over wall.
Infantry	Both	2	8 foot wall climb - pull up to top of wall (hands around head height)	B			2900 N	6		10	4%	10	99%	2	7.0	Risk of leg or spine impact injuries when falling/jumping from the wall.	.

Risk register Analysis Method key: B biomechanical R Rodgers (See Section 2.4)

Where the task was observed	Who performs the task	Sub task No.	Description	Analysis Method	Legs	Risk Score	Back	Risk Score	Neck	Risk Score	Shoulder	Risk Score	Arms	Risk Score	Average	Ancillary musculoskeletal risks that are not manual handling as such but are related – due to falls, trips, etc.	Notes, ideas for solutions, etc
Infantry	Both	3	8 foot wall climb - overbalance at top of wall - hands on top of wall	B			500	2		2	99%	2	6%	10	4.0	Risk of leg or spine impact injuries when falling/jumping from the wall.	.
Infantry	Both	4	12 foot wall climb - "lifters" initial position	B	94%	4	6300 N	10		2	99%	2	99%	2	4.0	-	As for star picket lift. 12 foot climb showed 4 soldiers assisting with lifting one. Lift from ground potentially high risk of low back and knee injury by the two main lifters - mostly good technique was demonstrated on these lifts. At times the lifted soldier stood on heads of lifters - high potential for neck injury. Alternated positioning with lifts which decreases repeated risk of injury. Need to ensure that the two lifters are of approximately equal height to ensure an even lift. Distraction forces through shoulder and high load on wrist flexors in elbow height position. Overhead pressing action places strain on shoulder flexors and elbow extensors.
Infantry	Both	5	12 foot wall climb - "lifters" hands at elbow height	B	93%	4	3300 N	7		6	81%	6	8%	10	6.6	Risk of traumatic injury to all areas of body if fall occurs from height.	.
Infantry	Both	6	12 foot wall climb - "lifters" hands at head height	B	88%	5	3100 N	7		10	9%	10	99%	1	6.6	Risk of traumatic injury to all areas of body if fall occurs from height.	.