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STRATEGIC DIRECTION AND ADVICE FOR INCREASING SAFE PARTICIPATION IN PHYSICAL ACTIVITY IN THE AUSTRALIAN DEFENCE FORCE:

A report for the Defence Health Service

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Title and sub-title:

Strategic direction and advice for increasing safe participation in physical activity in the Australian Defence Force: A report to the Defence Health Service

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Abstract:

Background: In the context of the Australian Defence Force (ADF) requirement for a trained, fit and deployable workforce, injury resulting from physical training and sporting activity poses major manpower losses and substantial and rising costs. The ADF approached Monash University Accident Research Centre to provide strategic direction and advice to reduce the adverse effects of ADF personnel participating in physical activity, whilst optimising participation rates and the physical and mental health benefits of such participation.

Method: Literature from on-line library databases, relevant unclassified military reports, and other reports was critically analysed for evidence-based information for the following: benefits of, and barriers to, participation in physical activity; interventions to increase safe participation; countermeasures for reducing injury during physical training and sporting activities; and strategic research to advance injury prevention in the ADF.

Results: The physical benefits of sustained participation in physical activity include a reduction in all-cause mortality, heart disease, stroke, type 2 diabetes, and hip fracture. Although participation in physical activity can reduce anxiety and depression in clinical populations, the evidence for an effect on cognitive performance is equivocal. Interventions to increase participation in physical activity such as behavioural management and health promotion in the workplace tend to have small and relatively short-lived effects. Injury associated with physical activity depends on the type of activity and its duration, intensity, and frequency. DEFCARE data shows that participation in physical training and sports (touch, rugby, soccer and running/jogging) are strongly associated with injury. Despite injury being the most common adverse effect of participation in physical activity in the ADF, the expected benefits of personnel increasing safe participation in sports include an estimated reduction in injuries of 25% per annum.

Conclusions: The ADF should devise, implement and evaluate a detailed strategy to increase safe participation in fitness-producing physical activity based on the recommendations in this report. Substantial research is needed for the following: to study the primary modifiable risk factors for injury such as intensity, frequency and duration of training activities and dose-response effects on injury; to determine levels of activity to maintain fitness after basic training; to promote physical activity for health gain; to evaluate interventions for injury prevention; and to reduce barriers to participation in physical activity. Evaluation should employ a randomised controlled design wherever possible.

Key Words:

Disclaimer

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Contents

Figures

Tables

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EXECUTIVE SUMMARY

BACKGROUND

The Australian Defence Force (ADF) has a requirement for a trained, fit and deployable workforce. Fitness and sports activities are actively encouraged. However, injuries resulting from participation in such activities are associated with the highest number of working days lost, hospitalisation days, sick days and light duty days. Further, most invalidity retirements and compensation costs are largely due to musculoskeletal system disorders related to injuries. These costs are increasing substantially.

The major cause of injury associated with physical activity in ADF personnel is physical training which accounts for more than three times the number of casualties than other specific activities. Further, the strong, competitive sports culture in the ADF sometimes results in unsafe participation in sport with resulting injuries particularly for rugby, touch and soccer.

In April 2001, the ADF approached Monash University Accident Research Centre to provide strategic direction and advice to help address this problem.

AIM

The study aimed to provide evidence-based strategic direction and advice to the ADF for the purpose of reducing the adverse effects of participation in physical activity, whilst optimising participation rates and the physical and mental health benefits of such participation.

METHOD

Literature from on-line library databases, relevant unclassified military reports, and other reports was critically analysed for the following evidence-based information:

1. Physical and mental health benefits of participation in physical activity.

2. Barriers to, and interventions for, increasing participation in physical activity.

3. Adverse effects of participation in physical activity.

4. Countermeasures for reducing injury during military training, physical training and sports.

5. Strategic research necessary to advance the prevention of injury associated with physical activity and to improve safe participation rates in physical activity in the ADF.

MAJOR FINDINGS

The physical activity levels of ADF personnel appear to be similar to those of the Australian civilian population with crude estimates of 20% largely inactive, 60% engaging in 3 episodes of physical activity per week and 20% undertaking higher levels of more vigorous activity. Rates of participation decline with age to 59 years. Overweight and obesity are about 10% lower in prevalence than the civilian population but also increase with age. More accurate measures of ADF participation in physical activity would better inform physical training and injury prevention programs.

The findings are documented according to the five areas described in the Method.

Physical benefits of participation in physical activity

- Physical activity decreases all-cause mortality. It benefits the cardiovascular and musculoskeletal systems, the control of weight, reduction in cancer risk, the functioning of the endocrine, metabolic and immune systems, and mental health. Regular sustained physical activity reduces the risk for type 2 diabetes and is beneficial in its management.

- Sufficient physical activity for health benefit is based on a duration of 150 minutes of walking and/or moderate-intensity activity and/or vigorous-intensity activity per week. Measurement of physical activity for health benefit incorporates several parameters (intensity, frequency, duration, type) settings (transport, leisure, sport, occupational) and forms of activity (energy expenditure, fitness, strength, flexibility).

- Increasing the level of physical activity from sedentary to a sustained relatively moderate level could result in substantial reductions in heart disease, stroke, diabetes, and hip fracture.

- Many of the beneficial effects of exercise training diminish within 2 weeks if physical activity is substantially reduced and effects disappear within 2-8 months if physical activity is not resumed.

- Research is needed to establish the intensities and patterns of exercise necessary to positively influence health outcomes. Standardised measures and methods of assessing physical activity and energy expenditure are needed before a systematic evaluation and interpretation of dose-response characteristics between physical activity and specific health-related outcomes can be achieved.

Mental health and cognitive performance benefits of participation in physical activity

Benefits to mental health from participation in physical activity

- The general hypothesis is that people who are physically active or have higher levels of cardiorespiratory fitness have enhanced mood, greater self-esteem, and higher levels of cognitive functioning than people who are less physically fit.

- The evidence for benefits of exercise to mental health in both the short and long-term in non-clinical populations is, however, weak. Exercise interventions in clinical populations to reduce anxiety and depression are generally more successful than for non-clinical populations.

Benefits to cognitive performance from participation in physical activity

- The evidence for the improvement in cognitive task performance following exercise is equivocal. There is no clear consensus as to whether exercise affects performance in the short-term, either in a positive or negative manner. There is even more limited evidence for a positive association between physical activity and performance in the longer-term. Further, any dose-response relationship between the intensity of physical activity and subsequent effects on cognitive performance remain to be elucidated.

Other aspects of physical activity

Safe and unsafe behaviour

- There are a number of intrapersonal factors that contribute to risk-taking behaviour. Behavioural tendencies such as sensation seeking (thrill seeking), impulsiveness, aggression, and emotional instability are linked with risk and injury. Over confidence is another critical issue that is linked with risk taking behaviours.

- While there do not appear to be any documented examples where Cognitive Behavioural Therapy (CBT) has been used to modify risk behaviours in the military context, there are examples of CBT being used successfully to modify other forms of risky behaviour, and so this approach may be the most appropriate for the military.

The effects of anxiety and stressful situations on performance

- There are many stressful situations that are likely to be encountered by military personnel. Some of the stressors include heat, cold, noise, and fatigue. Generally speaking, if performance on tasks such as complex reaction time, vigilance, and other psychomotor tasks is impaired then it is reasonable to assume that more general processes such as information processing and decision-making are also disrupted to an extent. There is the potential for disruption of these processes to influence the prevalence of safe and unsafe behaviours in specific situations.

Expected benefits of increased sports participation for the ADF

- Increased participation in sports would likely result in a number of improved outcomes to the ADF, but collaterally, an increase in injuries. The effects of increased sports activity were modelled and the results derived. Data for the model were derived from the *ADF Health Status Report*, with some assumptions. Predicted outcome measures include fitness for deployment, Working Days Lost, injury incidence, casualties, retirements due to injury, and the outcome for deployed forces in terms of casualties per 10,000 personnel per week. Model runs suggest considerable benefits to the ADF from increased physical activity, particularly when coupled with an increase in safe involvement in physical activities.

Psychological barriers to, and interventions for, participation in physical activity

- There are many known determinants of physical activity in the general community. It is not known to what extent these are determinants of physical activity in the military context. A number of theories have been described in the literature to explain how some of the above factors influence participation in physical activity.

- The differing psychological theories are used to accommodate different types of interventions. CBT, incorporating cognitive and behavioural methods, appears to be the most appropriate and effective intervention for the military context.

Public health and other interventions to increase participation in physical activity

- Intervention to increase participation in physical activity include behavioural management approaches, interventions in health care settings, health promotion interventions, worksite interventions and communications strategies. Overall, controlled interventions in these settings have been positive but effects tend to be small (5-10%) and short lived. Further research to determine optimal ways for selection of intervention components, settings, population groups, and maintenance of effect is essential to inform programs for promoting increased physical activity for health gain.

Adverse effects of participation in physical activity

- Injury is the most common adverse effect of participation in physical activity. The most serious but much rarer risks associated with physical activity are myocardial infarction and sudden death.

- The risk for injury associated with physical activity increases with increased intensity, frequency, and duration of activity and depends on the type of activity.

- Injury can interfere with the enjoyment of physical activity and sport and reduce the expected health gain in long term chronic disease risk reduction from participation in these activities.

- Internationally, non-combatant injuries are the leading cause of death, disabilities, hospitalisations, outpatient visits, and manpower losses among all branches of the military services. Training injuries, sports, falls, and motor vehicle crashes are among the most important causes of morbidity. Basic military training results in high injury rates mainly due to overuse. Rates vary with the type of unit and type and amount of training. Rates for injury and medical discharge are frequently higher for females. There is a lack of emphasis on strength training. Useful comparison of studies of injury across military and civilian settings is limited by a lack of standardisation of injury definition, data collection and classification methods, training programs, and differential access of personnel to medical care.

- Risk factors for injury during military training include higher age, female gender, greater amounts of running, low levels of physical activity/sedentary lifestyle, low levels of aerobic fitness/performance, previous injury history, high and low degrees of flexibility, high arches of feet, cigarette smoking, smokeless tobacco use, and cold weather. Special, highly rigorous training incurs increased injury risk.

- Approximately half the total casualties for injury in physical activity are related to physical training (PT) and sports. PT is the leading casualty-producing physical activity accounting for 14.3% of total casualties among full-time ADF personnel. Three sports –rugby union/league, touch and soccer– rank among the ten leading causes of casualties [and Work Days Lost (WDL)] accounting for 3.9%, 3.2% and 3.1% of all casualties respectively. Other sports that are prominent in the ranked list of casualty-producing physical activities (and associated with significant proportions of WDL) are: running/jogging (2.0% of all casualties); Australian football (1.9%); and basketball/netball (1.8%). Volleyball is ranked among the 'top 15' physical activities associated with WDL but did not rank in the 'top 15' for casualties.

- Across the highest ranked physical activities for WDL (physical training, touch, rugby, soccer, running/jogging), the most common injuries are strains and sprains followed by disorders of muscles/tendons/soft tissues, except for rugby and soccer where fractures are more common than muscles/tendons/soft tissue injury. The lower limb is much more commonly injured than the upper limb, trunk or head, except in the case of rugby where upper and lower limbs are injured equally. The major injury sites are the knee , ankle and shoulder.

- Injuries during physical training account for the highest loss of working days, days of hospitalisation, sick days, and light duty days, and predict attrition from training. Most moderate or severe injuries tend to occur during the first 2 weeks of training.

- The ADF culture of strong competitiveness in sport results in a substantial loss of personnel working capacity due to injury.

- Recommendations for injury coding and surveillance systems include the use of 'cause of injury' codes as for the civilian population to better inform injury prevention and allow comparative studies. This would entail coding hospital admissions according to the International Classification of Diseases, 10^{th} Revision, Australian Modification (ICD-10-AM) Second edition (July 2000).

Interventions to prevent adverse side effects of physical training in the ADF

- Interventions to prevent adverse side effects of physical activity in the ADF should ideally address protection through individual and collective evidence-based countermeasures. These countermeasures should not discourage active participation in physical activity since the indicators of low physical activity levels, such as overweight, hypertension, and high cholesterol, are risk factors for cardiovascular disease and psychopathology.

- Interventions to reduce injury in military training should address modifiable primary risk factors including the level and amount of training intensity, levels of fitness, and possibly equipment as demonstrated in the ADF Army Recruit Training Intervention Study. Safe participation programs could impact optimal fitness of the ADF and associated long term health gains with consequent cost reduction in treatment and retirement benefits due to injury, disability and chronic health problems.

- The most likely effective method of improving physical fitness levels while minimising injury risk to recruits may be to modify basic training to a gradual increase in duration, frequency, and intensity of training activities over the training period. This approach has been found to result in reduction of overuse and stress fracture injury while achieving the desired recruit fitness levels.

- The reduction of running distance and substitution of other fitness activities shows promise and randomised controlled trial are needed to confirm the findings of cohort and observational studies. Deep water running can achieve the required aerobic fitness while reducing injury risk and is an important strategy for maintaining fitness in injured personnel.

- Shock-absorbent boot insoles can reduce the total number of stress fractures and stress reactions in military recruits and may be warranted for recruits at high risk for stress fractures. Further research is needed to investigate the types of insoles and footwear to prevent injury while incorporating the important characteristics of good support and shock absorption, and protection from heat, cold and water.

- The US experience of preventing injury to military parachutists by the use of outside-the-boot ankle braces may require testing under Australian conditions should they differ substantially from US conditions. If implemented more widely, evaluation and monitoring for on-going effectiveness would be necessary.

- It is important that thresholds of optimal training be identified for individuals of different fitness and performance levels so that the high risk due to overtraining can be avoided while still maintaining physical fitness.

- Other changes found to be promising for reducing injury to females include reducing route marches, running on softer surfaces, step length individualised for marching and interval-running replacing middle distance runs.

Interventions to prevent injury in physical training and sports

- Two approaches to the literature were utilised to identify countermeasures to reduce the burden and cost of physical activity injury in PT and sport. First, the literature on the prevention of ankle, knee and shoulder injuries was accessed because DEFCARE data showed that these were the most-injured body sites in sports associated with high injury frequencies and WDL. Second, potential strategies and countermeasures to injury in the three sports most associated with WDL in the ADF (touch, rugby and soccer) were investigated to exemplify the evidence-based approach to the selection of preventive strategies and countermeasures to sports injury.

Prevention of knee, ankle and shoulder injuries

Knee injuries

- Knee injuries were the most frequently occurring injury in the five leading physical activities related to WDL due to injury and illness in the ADF in 1997/8 (PT, touch, rugby, soccer and running/jogging).

- Overall, the evidence supporting the effectiveness of interventions to reduce acute and overuse knee ligament injuries is weak. Prevention programs designed to increase balance and neuromuscular control, such as balance board and plyometric (jump) training, appear to be promising interventions for the reduction of serious non-contact knee ligament injuries. Plyometric training should only be trialled in teams that have suitably qualified coaches and trainers, but balance board training is more accessible to community level teams. Laboratory and epidemiological studies in a range of sports suggest that the risk of ACL injuries may be reduced by the introduction of improved playing techniques, particularly bent knee landing. The shoe, surface and the shoe-surface interface all appear to play a role in knee ligament injury but the relationship is complex and not well researched. Several authors recommend that preventive programs for overuse injuries (predominantly jumper's knee/tendinitis) should concentrate on adjustment of training regimes and techniques, careful choice of floor surfaces for training and playing, and early treatment (when symptoms first appear).

Ankle injuries

- Ankle injuries (mostly sprains) were the second-most frequently occurring injury (behind knee injury) across the five leading physical activities related to WDL due to injury and illness in the ADF.

- Randomised controlled trials show that both ankle tape and semi-rigid bracing reduce the incidence and severity of ankle sprains particularly in, but not confined to, players with previously injured ankles. Bracing is more effective, cost effective and convenient. Ankle disc (balance board) training appears a promising preventive measure for lower limb injury but confirmation in well-designed trials is required before widespread implementation. Although evidence indicates that footwear and the playing surface contribute to ankle ligament injury, a complete understanding of the complex interactions between the lower extremity, the foot, footwear, playing surface and the shoe-surface interface in injury has not been achieved. More research is needed to underpin guidelines for footwear and surface choice for specific sports. The effectiveness of orthosis for the prevention of ankle overuse injury is not yet established.

Shoulder injuries

- Of the five leading physical activities related to WDL due to injury and illness in the ADF, shoulder injuries most frequently occurred in rugby and touch.

- The two countermeasures to acute shoulder injuries suggested in the literature (but not subjected to well-designed trials) are coaching of players to adopt proper landing and tackling techniques and the wearing of shoulder pads. The real protective benefit of the available and allowable rugby shoulder padding is debatable; laboratory and field trials are required to develop protective padding that is effective and acceptable to rugby peak sports bodies and players. There is sparse advice on prevention of shoulder overuse injuries in the literature. Exercise programs are recommended to prevent and correct the imbalances and lack of flexibility that appear to characterise the dominant shoulder of players in sports with high risk profile for shoulder overuse injuries. Authors also recommend that coaches, knowledgeable in the biomechanics of the particular sport, work with players to develop techniques that minimise stress on the shoulder. None of these conditioning programs has been systematically trialed (in groups of athletes with and without shoulder pain) and evaluated for injury prevention effects.

Preventing injuries in touch, rugby and soccer

Touch

- According to DEFCARE data, touch is the second-highest ranked physical activity associated with WDL in the ADF, behind physical training. Injuries to the lower limb, predominantly to the ankle and knee, are most common. Sprains and strains are the most frequently reported injury type but fractures and dislocations are also common.

- Because of the shortcomings of available data, the ADF is advised to conduct a prospective study of injuries in touch prior to instituting prevention measures specific to the sport. Data are needed to establish whether the apparent high frequency of injuries (and severe injuries) in touch in the ADF reflects high participation rates and hours of play or other player-related and environmental factors such as the rules, conditions and intensity of the game as played by ADF personnel (especially informal and 'scratch' games).

- There are no established risk factors for injury in touch. The suggested countermeasures to touch injury are drawn from other sports.

Rugby Union/League

- According to DEFCARE data, rugby is the third-highest ranked cause of WDL associated with physical activity in the ADF, behind physical training and touch. Most injuries occurred to the upper and lower limbs, each of these body regions accounting for approximately one-third of all injuries. The shoulder, knee, head and face and ankle are the most frequently injured body sites. Sprains and strains are the most common type of injury followed by fractures and dislocations.

- The strongest independent risk factors for rugby injury reported in the literature are grade (players from high grades reported higher incidence rates than players from lower grades) and previous injury (beginning the season with an injury). Robust independent risk factors for rugby injury that cause missed playing time (a proxy for injury severity) are: previous injury experience (being injured at the time of pre-season examination), hours of strenuous physical activity per week (only for the group that engaged in 39 hours or more per week), cigarette smoking status (current and past), low body mass index (BMI <23) and number of pushups (poor performance was shown to be protective). Foul play has been found to be associated with 13-33% of rugby union injuries.

- A 5-year systematic rugby injury research and prevention program currently underway in New Zealand, reports injury (insurance claims) reductions. The prevention arm includes injury prevention workshops for coaches, referee training, supply of pre- and off- season training guides for players and compulsory wearing of mouthguards. Other promising countermeasures to rugby injury rely on evidence from trials in other sports (for example ankle bracing, ankle disc training, shoulder padding) or require evaluation in well-designed trials (for example pre-season assessment and rehabilitation, pre-season impact drills, warm-up and cool-down, stricter enforcement of rules governing tackling and rough play).

Soccer

- According to DEFCARE data, soccer is the fourth-highest ranked cause of WDL associated with physical activity, behind physical training, touch and rugby. Lower limb injuries, mostly to the knee, ankle and lower leg, accounted for more than two-thirds of the soccer injuries. Sprains and strains were the most frequently occurring type of injury, accounting for approximately half of all injuries, followed by fractures and dislocations. The most common mechanisms of injury were being hit by moving object or person and falls trips and slips.

- Given that soccer is not a full contact sport, the relatively strong association of soccer with casualties and WDL warrants further investigation. Data are required to establish whether the comparatively high frequency of injuries (and severe injuries) in soccer is related to exposure or other player-related and environmental factors.

- Predisposing factors for soccer injury supported by strong evidence are failure to use ankle support (taping or bracing) and failure to wear shin guards. Other factors that appear to be associated with injury (but for which evidence is weaker or conflicting) are: level of play and position on field; duration of training; warm-up; shoe-surface interface; type and quality of footwear; pitch conditions; and foul tackles.

- Interventions for soccer injury prevention that are supported by randomised controlled trials (albeit of varying quality) are: a multifactorial intervention (that included warm-up, wearing of shinguards and appropriate shoes for weather/ground conditions, ankle taping, supervised rehabilitation, exclusion of players with knee instability, and player and coach education on fair play and injury prevention); free substitution of players in matches; balance board training (but evidence is conflicting); and semi-rigid ankle bracing. Other suggested countermeasures require evaluation in well-designed studies.

Framework for selecting countermeasures to injuries in PT and sports

Potential countermeasures to injury in the three sports were slotted into an injury prevention framework that covered primary (pre-event), secondary (event) and tertiary (post event) prevention measures along with an assessment of current evidence on the effectiveness of the measures from the sports injury prevention literature.

<u>Pre-event (primary prevention) prevention measures</u>

- measures to reduce exposure (restrictions on participation, increased team sizes, reduced playing time and free substitution)

- pre-participation assessment (incorporated into the medical assessment of all recruits along with tailored fitness and conditioning programs)

- pre-season assessment and tailored rehabilitation with controlled re-entry to play in new season

- pre-season and in-season conditioning including trials of balance board training (to prevent ankle sprains) and plyometric training (to prevent knee ligament injury)

- physical impact drills in pre-season training sessions (for rugby)

- specific skills training

- checks on overtraining

- training of coaches and referees and education of players on injury prevention and fair play

- routine warm-up and cool-down before and after all training sessions and games

<u>Event (secondary prevention) measures</u>

- use of prophylactic and rehabilitative ankle bracing (under trial conditions)

- compulsory wearing of shin guards and mouthguards (for soccer and rugby)

- wearing of other personal protective equipment, for example chest, thigh and shoulder pads (for rugby only, under trial conditions)

- supply of footwear appropriate to the condition of the surface being played on

- improvements to playing surface and ground conditions, for example pre-game ground/pitch inspections, padding of goalposts and safe anchoring of moveable soccer goal posts

- strict enforcement of rules especially in relation to tackles and rough play

Post event (tertiary prevention) measures

- best practice first aid, treatment and rehabilitation

- development and strict enforcement of return-to-play rules

Organisational change

- An organisational culture is that set of rules, regulations, common understandings, and general practices accepted by most members of an organisation. These elements govern, and allow the organisation to function. Cultural change within organisations involves the organisation at several levels. Consequently, as a pre-condition for successful cultural change, all levels of the organisation must adopt their share of the change. Due to the nature of organisational change, evidence pertaining to change is largely anecdotal with some limited case study material available. Unfortunately, little evidence of successful change within organisations is actually published for a number of reasons. Thus, work in this field has only been evaluated by case study.

- One further problem that complicates assessment of successful organisational change models is that of unfounded theoretical bias. Many practitioners in the field hold assumptions that colour their approach to organisations. Over the past 50 years several psychological factors and theories have been proposed as being important to cultural change. Many psychological theories that have excellent explanatory validity (ie. they adequately explain some behaviour or its absence), but have poor predictive validity (ie: the measured presence or absence of some factor prior to some behaviour predicts the outcome). Factors that have been regarded as important in organisational cultural change in the past have included moral obligations, stated intentions, planned actions, self-efficacy, and expectancies. Unfortunately, the evidence suggests most of these as unsuitable models upon which to base organisational change. One practitioner in the field, Lewin, developed a model, Action Research, which is atheoretical, and widely applicable. As such, Action Research has been widely applied with considerable success, and is founded on the scientific method, for which the evidence is abundant. Action research postulates that information should be gathered by means such as questionnaire, observation, or direct measurement. Thereafter, analysis of the data is undertaken, which is reported back to the organisation, most particularly to the targeted employees of the change, the change is then implemented, and results evaluated.

RECOMMENDATIONS

Recommendations for injury prevention during physical activity and for increasing participation in physical activity in the ADF encompass the following broad areas.

Injury surveillance

- There is a need for detailed data collection and analysis of personnel activity-specific participation rates and exposure levels for physical activities with high injury frequency and high WDL. These data can be used to generate specific injury rates based on exposure and mechanisms to inform priorities for injury prevention.

- Refinement of current injury surveillance systems to improve information about the cause and circumstances of injury and for use in comparative studies with other populations. This enhanced system should also provide a powerful monitoring device for tracking injury trends and the evaluation of interventions.

General strategies for research

- A focus on high-risk populations and environments in the military with the largest impact on readiness. A strategic research approach to include more than basic training, infantry and special forces

- Evaluation research to concentrate on primary modifiable risk factors for injury using randomised controlled trials wherever possible

- A prospective cohort study in military training, PT and selected sports (with high injury frequencies associated with WDL) to determine the incidence and relative risks of injury in these physical activities and the risk and protective factors for injury. This study should also collect data on the cost of injury.

- Evaluation of short term and long term effectiveness of intervention programs and strategies and countermeasures

- Research programs for maintenance of fitness after basic training

- Cost effectiveness studies for injury prevention programs

Injury prevention implementation and evaluation

Trials of modified military (basic) training to incorporate smooth progression in intensity, duration and frequency of training. Modifications to basic training could include trials of:

- pre-selection screening of recruits for injury risk factors and assignment to modified training where needed.

- interval training versus continuous training

- modified risk factors for female recruit training

- equipment design and use

- strength training and effects on injury reduction

- deep water running as a substitute for running

Trials of interventions to reduce injury in physical training and sports including:

- pre-season assessment and tailored rehabilitation with strictly controlled return to play
- pre-season and in-season conditioning under trained supervision including balance board training (to prevent ankle sprains), plyometric training (to prevent knee ligament injury) and physical impact drills in the pre-season for rugby.
- prophylactic and rehabilitation ankle bracing
- compulsory wearing of shinguards and mouthguards for football codes
- chest, thigh and shoulder pads for rugby players
- coach, player and referee training/education to reduce foul play especially in relation to tackles

Research for increasing participation in physical activity

- Design, implement and evaluate programs to increase participation in physical activity by the identification and reduction of barriers to participation.
- Establish processes for promoting, developing, maintaining and evaluating healthier habits of physical activity in military personnel by focusing on interventions with the greatest health gain and cost-effectiveness

Recommended organisational change process

- Identification of the problem and the solution through focus groups addressing both the problem and solutions with measurable outcomes
- Commitment to, and acceptance of, the change through contrasting solutions to the ADF's mission within focus groups
- Change implementation through decision to adopt solutions conveyed to all members, and the removal of institutional barriers, followed by assessment of commitment to change
- Shared activity toward the change that is objectively measurable, with success of goals being reported openly
- Institutionalisation of the changes by ensuring all institutional rules that impede the change are removed, and relevant rules and regulations function to enhance the change, with continual monitoring.
- Process reporting of the nature of the problem, possible solutions, the adopted solution, and reasons for this, outcomes, rule changes, regulation changes

ADF Action Plan (prioritisation plan)

This report presents a substantial number of evidence-based interventions with good potential to achieve both an increase in the physical fitness of ADF personnel and a committment to decrease injuries associated with physical activity. It also provides modeling of outcomes based on these two parameters using measures identified by the ADF. This action plan provides a recommended means for the prioritisation of action and timely progress towards implementation.

<u>Step 1</u>

Set targets for physical fitness and injuries prevented, as measured by injury rates, sick days, light duty days, injury retirement rates and compensation costs based on the models on ‘Expected benefits to the ADF of increased sports participation’ presented in Chapter 2 of this report.

<u>Step 2</u>

Develop, implement and evaluate a Physical Fitness and Safety strategy that combines system-wide and local initiatives to increase lifelong participation in fitness activities and reduce related injury in ADF personnel.

<u>Step 3</u>

Select simple to implement, high impact, low cost measures from the menus provided (e.g. under specific sports) for immediate implementation.

<u>Step 4</u>

Enhance the utility of current injury surveillance in the ADF, in order to provide an excellent monitoring and evaluation tool and a mechanism for identifying ongoing and emerging injury trends.

<u>Step 5</u>

Initiate steps to implement the necessary cultural change throughout the organisation to ensure a positive approach to implementation of interventions and further research and development. Wide-spread implementation (*reach)* of interventions will be essential to achieving the desired outcome targets.

(Note: steps 2-5 to be implemented in the same time frame.)

<u>Step 6</u>

Conduct a prospective cohort study in military training, PT and selected sports (with a high frequency of injury associated with WDL) to determine the incidence and relative risks of injury in these physical activities and the risk and protective factors for injury.

<u>Step 7</u>

Further develop, pilot and implement factorial designed randomised controlled trials to evaluate the effectiveness of important selected countermeasures to training injuries, employing measures for which there is an evidence base in the literature.

<u>Step 8</u>

Undertake similar randomised intervention trials for physical training and selected sports injuries.

Step 9

Undertake or commission research studies to produce new knowledge on important questions raised in this review, for which current knowledge is inadequate.

CONCLUSION

This report sought to document the physical and mental health benefits of physical activity in the military, barriers to and interventions for participation in physical activity, adverse effects of physical activity particularly injury, countermeasures for the prevention of injury, and approaches to changing organisational culture to promote and maintain safe physical activity.

The project findings indicate two major issues which the ADF may consider addressing to progress the understanding and resolution of current injury problems associated with physical activity. The first relates to optimising the quality and utility of the newly established ADF injury surveillance system and the DEFCARE database to better identify specific injury patterns and mechanisms to inform priorities for injury prevention. The second issue relates to future possible research areas with the potential to progress the understanding of dose-response health benefits of participation in physical activity, personnel participation rates/exposure levels to specific physical activity, injury causation, scientifically rigorous trials of potential countermeasures for injury prevention, and cost benefit analyses.

1. BACKGROUND

The Department of Defence is responsible for the provision or procurement of health and health-related services to promote, establish and maintain the health and well being of Australian Defence Force (ADF) personnel and other eligible persons. This function is carried out through the Defence Health Service.

Within the ADF there is a strong, competitive physical culture. This culture sometimes results in over-enthusiastic and unsafe participation in physical activity by some members of the ADF, with resulting injuries. The ADF approached Monash University Accident Research Centre (MUARC) in April 2001 to provide evidence-based strategic direction and advice for the purpose of reducing the adverse effects of participation in physical activity, whilst optimising participation rates and the positive physical and mental health benefits of such participation.

1.1 AIM

This study will provide strategic direction and advice to the ADF for the purpose of reducing the adverse effects of participation in physical activity, whilst optimising participation rates and the physical and mental effects of such participation.

1.2 OBJECTIVES

To review relevant literature on the topic of safe participation in physical activity, including sports, for defence personnel in the 17 to 55 year age range; and to include literature on the patterns and prevention of sport and active recreation-related injuries in the civilian population because of its relevance to the military context.

Issues included are:

1. The benefits, to physical and mental health and to physical and cognitive performance capability, of participation in physical activity, threshold levels of participation required to achieve these benefits, mechanisms by which benefits occur, ceiling effects, dose-response (quantified) relationships, and variability in individual responses. Benefits of participation for prevention of injury as well as illness are included.

2. The expected, quantified benefits to the ADF institution (eg. operational, health, compensation, training successes) if participation rates were significantly increased. Where no information is available, it will be assumed that participation rates in the ADF reflect general community rates of participation for the same age-group.

3. Potential adverse side-effects (individual physical and mental health, injury, performance (physical & cognitive; short & long term), operational etc.) of participation in physical activity in the military context, their causes and mechanisms, threshold levels of participation required to cause these effects, ceiling effects, floor effects, dose-response (quantified) relationships and variability in individual responses.

4. Evidence-based interventions or practices (especially social and behavioural) that decrease the incidence of these adverse side-effects.

5. Social, psychological, resource and other potential barriers to participation in physical activity in the military context.

6. Evidence-based interventions or practices which overcome these barriers. Social, psychological and other influences on safe (non-injuring, non-morbidity-causing) and unsafe (foolish risk-taking, uncontrolled aggression or violence) behaviours and practices (habits, traditions etc.) during participation in physical activity in the military context.

7. Evidence-based interventions or practices, which will increase safe behaviour and decrease unsafe behaviour including:

   - the effects of anxiety, negative life events and stressful situations -eg heat, military threats, life stresses - on peripheral vision, reaction times, distractibility and injury risk;

   - interventions to change cultural norms toward safe behaviours and practices in the military context, and away from unsafe behaviours and practices.

   - antecedents and consequences for safe and unsafe behaviour, application to development of interventions for safe behaviour and to counter unsafe behaviour, and the relative merits of each.

   - Evidence based recommendations on reducing adverse effects of participation in physical activity while optimising participation and positive outcomes

   - An ADF research agenda on important issues for which there is no adequate research base

1.3 METHODS

On line searches of library databases including Medline, PsycINFO, EBM Reviews of Best Evidence, Cochrane Database of Systematic Reviews, AusportMed, and Current Contents were undertaken .

Searches were also conducted of 1) relevant unclassified military reports and other publications requested from ADF libraries and 2) relevant MUARC and other reports.

For the purposes of this report, physical activity includes personnel training, group training, sport, adventure training activities, and recreational activities such as bicycling, walking, running, and hiking.

The literature gathered for this review was critically assessed to determine the extent to which the various countermeasures had been fully evaluated and demonstrated to be effective in preventing injuries. A scale for the strength of the evidence presented in the identified literature was developed (Table 1).

Table 1.1 Grading scale for assessing the quality of research evidence

<table>
<tr><th>Relative strength</th><th>TYPES OF EPIDEMIOLOGIC STUDIES</th></tr>
<tr><td>Weaker</td><td> DESCRIPTIVE STUDIES (case series and cross sectional)
Case series (small, special registry and population-based)
Case series studies identify, define and describe injury problems and patterns. They classify injury cases into homogenous (like) subsets, count them, measure their severity and may specify their concentrations in specific population groups.
Strengths and weaknesses: Case series can be a rich source of information on injury, especially special registry studies. If the injury hazard from the case series is obvious there may be little need to carry out more extensive research. However, case series cannot be used to specify causes of injury. Also, the sample of cases may be biased (particularly when drawn from small and registry-based collections) and not representative of all cases, which precludes the calculation of injury rates and trends over time.
Cross sectional studies (surveys)
These studies determine the status quo of a condition during a specified period of time, for example, a survey of injuries among a representative sample of army recruits. Most surveys are cross sectional.
Strengths and weaknesses: Cross sectional studies examine the relationship between the condition (for example, injury) and other variables of interest (for example, age, sex, skill level, use of protective equipment) by comparing the prevalence of the condition in different population subgroups and between those with or without the condition, according to the presence or absence of the variables. They examine a condition at one point in time so cannot determine cause and effect. </td></tr>
<tr><td>Stronger</td><td> ANALYTIC (OBSERVATIONAL) STUDIES (case control and cohort)
These studies test hypotheses (suppositions/conjectures) about the influences which determine that one person is injured while another is not i.e., they provide strong evidence on the causes, risk and contributory factors to injury.
Case-control studies
The researcher assembles a group of persons with the injury of interest (cases) and a comparison group without the injury under investigation (controls), for example, army recruits with and without knee injury, and investigates the history of past (retrospective) exposure of one or more potential risk factors for the injury (for example, running history, age).
Strengths and weaknesses: Case control studies generally require a comparatively short study period, are relatively inexpensive and have the ability to examine association of several risk factors for the given injury. However, the choice and recruitment of appropriate controls can be difficult. Because case control studies investigate retrospectively from the injury event they are subject to recall and other biases which may affect the results and weaken evidence of cause and effect. </td></tr>
</table>

Stronger cont'd

- **Cohort studies**

The investigator begins with a group of persons exposed to the factor of interest and a group of persons not exposed (for example, male and female recruits if training injury was the factor of interest) and the researcher follows up the cohort and observes the association between exposure (training) and outcome (injury) over a specified period.

- **Strengths and weaknesses**: Because they are generally prospective (forward-looking) the likelihood of collecting reliable and valid data is greater. Consequently, results from a well-designed cohort study carry more weight in establishing a cause than results from a case control study. However, cohort studies often involve large numbers (especially if the factor of interest is rare) and/or a long study period, and are therefore expensive. A substantial problem in cohort studies can be the dropout rate ('loss to follow-up') which can result in biased data.

Strongest

EXPERIMENTAL STUDIES (Randomised controlled trial and community trial)

In experimental epidemiological studies, the investigator controls the conditions under which the study is to be conducted by assigning subjects (preferably randomly) to either an experimental (treatment) group which receives the intervention or a control group that does not receive it.

- **Randomised controlled trial** (RCT)

In a RCT the investigator randomly allocates similar persons to the treatment and control groups. For example, in a RCT to test whether or not ankle guards prevent ankle injuries subjects would be recruited into the trial and randomly allocated to treatment (ankle guard wearing) and control (non-ankle guard wearing) groups and followed up over time under otherwise similar conditions.

- **Community trial** (quasi-experimental)

In a community trial the group as a whole is collectively studied. The investigator selects two similar communities. The incidence of the disease or condition of interest (for example, ankle injury among trainee recruits) and prevalence of suspected risk factor/s (for example, running) for which an intervention has been developed are surveyed in both. The intervention (for example, compulsory wearing of ankle guards) is then carried out in one community and the other does not receive it. The intervention stops and the communities are surveyed again, the net difference in the incidence of the condition and prevalence of the risk factor/s is thereby associated with the intervention.

Strengths and weaknesses: Well-conducted controlled trials, where the assignment of subjects or communities to the experimental or comparison group is random, are regarded as the strongest epidemiological studies and provide the greatest justification for concluding causation. Obstacles to their use include their great expense and long-time period.

Sources: (Dawson & Trapp, 1990; Lilienfeld & Stolley, 1994; Robertson, 1992).

1.4 PREVALENCE OF PHYSICAL ACTIVITY

All ADF personnel are required to maintain their level of physical fitness to ensure they meet single Service requirements (Defence Health Service Branch, 2000). The RAAF and Australian Regular Army (ARA) personnel undergo regular physical fitness testing and the RAN trialed formal physical fitness testing in 1998. There are no data on the amount and type of physical activity engaged in by ADF personnel. Anecdotal evidence suggests that approximately 60% of personnel engage in 3 episodes of physical activity per week, 20% undertake higher levels of more vigorous activity, 20% are largely inactive, and participation in physical activity declines with age (Rodney Pope, personal communication). These activity levels tend to reflect those found for the general Australian population (Armstrong, Bauman, & Davies, 2000). More accurate measures of ADF participation in physical activity would better inform training and injury prevention programs.

Overweight and obesity in the ADF are about 10% lower in prevalence than the general Australian population but nevertheless reflect the same increasing trends by age group (Defence Health Service Branch, 2000). Levels of smoking and total serum cholesterol by age group are similar to the Australian community. Although the causes of mortality are similar for the ADF and the Australian community, the incidence differs. Non-age standardised mortality rates suggest ADF male suicide rates are approximately half, and Australian Regular Army motor vehicle deaths are higher, than the general male population.

The Australian National Physical Activity Survey (Armstrong et al., 2000) conducted in 1999 shows current activity patterns and national trends over 2 years for the Australian population. Survey findings indicate that, although a large (88%) and growing proportion of Australians agree with the health benefits of physical activity, participation in physical activity is declining. The survey found that the proportion of people reporting being physically inactive in the previous week increased from 12% in 1997 to 17% in 1999 (Armstrong et al., 2000). Those achieving sufficient levels of physical activity for a health benefit (150 minutes of moderate intensity activity per week) declined over the two years (62% to 57%) particularly for those aged 30-44 years (64% to 54%) with similar results for males and females. Participation in vigorous intensity activity declined from 24% to 19%. These general population participation rates are similar to estimates for the ADF.

In the National Survey, the participation rate for sufficient levels of physical activity increased with educational attainment being greatest for those aged 18-29 years (69%), particularly among males (74%), and lowest among those aged 45-59 years (50%) (Armstrong et al., 2000). The National Health and Medical Research Council (NHMRC) publication ‘Acting on Australia’s Weight’ (National Health and Medical Research Council, 1997a) reports that among adults aged under 25 years, 22% participate in jogging, 24% in aerobics and 20% in cycling. These vigorous activities decline substantially by age 55 and over, to a prevalence of 1%, 3% and 4% respectively. The National Survey found obese Australians were 50% less likely than other adults to reach a sufficient level of activity compared with those of healthy weight. The survey results indicated that one third of Australian adults in 1999 intended to become more physically active in the next month and 29% in the next six months. The five most common activities were walking, swimming, aerobics/fitness, golf, and tennis (Australian Bureau of Statistics, 2000).

In the US, approximately 15% of adults engage regularly (3 times a week for at least 20 minutes) in vigorous physical activity during leisure time. It is interesting to note that compared with the Australian rate of 57%, only approximately 22% of US adults engage regularly (5 times a week for at least 30 minutes) in sustained physical activity of any intensity during leisure time. This difference may be related to greater ethnic diversity (US Department of Health and Human Services, 1996) other demographic factors, differences in survey methods or a true difference in activity levels (US Department of Health and Human Services, 1996). About 25% of US adults report no physical activity at all in leisure time (17% in Australia). Reported physical inactivity is more prevalent among women than men, among blacks and Hispanics than whites, among older than younger adults and among the less rather than the more affluent. Walking, gardening and yard work are the most common activities. Males are more likely than females to participate in vigorous physical activity, strengthening activities, and walking or bicycling.

It is evident that there are substantial proportions of the ADF and the general Australian and US populations engaging in insufficient physical activity for health gain and maintenance. The general guidelines for increasing physical activity levels for the Australian and US populations are also applicable to the ADF (Bauman & Owen, 1999; Armstrong et al., 2000; US Department of Health and Human Services, 1996). The greatest health gains are likely to be demonstrated in those over 30 years and for those with a more sedentary lifestyle.

2. PHYSICAL BENEFITS OF PARTICIPATION IN PHYSICAL ACTIVITY

The effects of physical activity on reducing all-cause mortality are strong and consistent across studies and populations (Blair et al., 1996; Lee & Paffenbarger, 1997; Villeneuve, Morrison, Craig, & Schaubel, 1998). Those who participate in moderate to vigorous levels of physical activity and/or who have high levels of cardio-respiratory fitness have a lower mortality rate that those with a sedentary lifestyle or low cardio-respiratory fitness (Armstrong et al., 2000; Lee & Skerrett, 2001; Oja, 2001). Participation in more vigorous physical activity confers greater benefits in reducing overall mortality risk (Fries, Singh, & Morfeld, 1994; Lee & Paffenbarger, 2000). Physical activity in people of all ages benefits the cardiovascular and musculoskeletal systems, the control of weight, and the functioning of metabolic, endocrine and immune systems (Shephard, 2001; Thompson et al., 2001; US Department of Health and Human Services, 1996). Regular activity prevents or delays the development of hypertension and exercise will reduce hypertension (Fagard, 1995).

2.1 CORONARY HEART DISEASE

Epidemiologic, clinical and experimental evidence have established an association between coronary heart disease and physical activity (US Department of Health and Human Services, 1993). Mild to moderate levels of physical activity are protective for coronary heart disease and there is a substantial inverse relation between physical activity and coronary heart disease (Kohl, 2001). Data, mainly from cohort studies of white males, indicate that regular physical activity and higher cardio-respiratory fitness not only decreases overall mortality, but reduces risk for cardiovascular disease and coronary heart disease in a dose response relationship (Blair et al., 1995; Sandvik et al., 1993). There is also some evidence that overweight and obese persons who are physically active have a lower early mortality risk than normal weight but sedentary individuals (Blair & Brodney, 1999). Among obese men, low cardiovascular fitness is as important a predictor of all-cause mortality as high cholesterol, type 2 diabetes, smoking, and hypertension (Wei et al., 1999). Nevertheless, recent research suggests health risks increase with weight increases, even within the ‘healthy’ range (Liu & Manson, 2001).

A recent meta-analysis of 23 cohort studies of physical activity or cardiorespiratory fitness and cardiovascular disease end-points showed that combined coronary heart disease and cardiovascular disease risk decreased linearly with increasing percentiles of physical activity (Williams, 2001). This dose-response relationship suggests that promotional effort to increase exercise for health benefit should apply across all activity levels. In sharp contrast, the risk for heart disease dropped precipitously before the 25^{th} percentile of the physical fitness distribution, indicating that being unfit may be a separate risk factor from inactivity. Although some methodological issues have been raised about this analysis, further investigation of this association is needed to clarify the findings (Blair & Jackson, 2001).

Randomised controlled trials are needed to confirm observational studies showing (1) that higher levels of physical activity can attenuate the increased health risk observed with overweight or obese individuals, (2) that obese active people have a lower morbidity and mortality risk than normal weight sedentary persons, and (3) that inactivity and poor fitness are as important predictors of mortality as overweight or obesity (Blair & Brodney, 1999). Valid non-invasive measures of subclinical disease processes and activity would be required for these trials.

A review of evidence for the blood pressure lowering effects of exercise training involved 36 studies including 21 RCTs and 15 controlled trials (Fagard, 1995). Blood pressure decreased in all studies and the smallest decrease occurred in the more rigorous studies, RCTs and controlled trials. Hypertensive subjects experienced the greatest blood pressure reduction. Greater gains in fitness were associated with greater decreases in blood pressure. As a result of these findings the World Hypertension League recommended dynamic exercise (walking, running, cycling, swimming, cross country skiing, calisthenics) with the frequency, duration and intensity tailored to individual needs.

If all Australians became moderately physically active, more than 9000 premature deaths from coronary heart disease could be prevented (Commonwealth of Australia, 1995). More realistically, up to 1000 premature deaths could be prevented if there was a 3-5% increase in physical activity.

2.2 CANCER

Benefits from exercise in reducing risk for cancer have been shown for colon cancer (Colditz, Cannuscio, & Frazier, 1997; Neugut et al., 1996; Slattery et al., 1997) but not for rectal, endometrial, ovarian and testicular cancers (US Department of Health and Human Services, 1996) and results are variable for breast (Gammon, John, & Britten, 1998; Thune, Brenn, & Lund, 1997; Verloop, Rookus, van der Kooy, & van Leeuwen, 2000), prostate (Giovannucci et al., 1998; Liu et al., 2000) and lung cancer (Lee & Paffenbarger, 2000; Thune & Lund, 1997). The complex nature of the physical activity variable, together with the lack of knowledge regarding possible biological mechanisms linking activity levels and cancer warrant further studies using RCTs (Thune & Furberg, 2001).

2.3 DIABETES

More than 90% of all persons with diabetes have non-insulin dependent diabetes mellitus or type 2 diabetes (US Department of Health and Human Services, 1996). Regular exercise reduces the risk for non-insulin dependent diabetes (Helmrich, Ragland, Leung, & Paffenbarger, 1991; Manson et al., 1992). Physical activity is also beneficial in the treatment of this form of diabetes (Ivy, Zderic, & Fogt, 1999). The benefits for prevention and treatment occur only from regular sustained physical activity patterns (Arciero, Vukovich, Holloszy, Racette, & Kohrt, 1999).

2.4 MUSCULOSKELETAL HEALTH AND FUNCTION

Regular exercise maintains normal structure and function for muscle and joints (Brill, Macera, Davis, Blair, & Gordon, 2000) and appears to be beneficial for osteoarthritis (Armstrong et al., 2000; Vuori, 2001). There is no evidence for association with joint damage or osteoarthritis at recommended levels. Competitive athletics may be associated with the development of osteoarthritis later in life, but sport-related injuries are the likely underlying cause (Kujala, Kaprio, & Sarns, 1994). Long term recreational running has not been shown to increase risk of osteoarthritis (Lane, 1995) but athletes in competitive sports including running, soccer, football and weight lifting, have a risk of developing osteoarthritis of the joints of the lower extremity (Kujala et al., 1994). These observations are based on small sample sizes and larger studies are needed to confirm findings.

Former elite male endurance, track and field, and team sports internationally competitive athletes (N=1321) who represented Finland between 1920 and 1965 reported less hip disability than controls (N= 814) drawn from the general population (Kuttunen, Kujala, Kaprio, Koskenvuo, & Sarna, 2001). However, team sports that involved a high risk for knee injury were likely to lead to pain, disability, and osteoarthritis (OR 1.76, CI 1.03-3.02).

Participation in physical activity, aerobic fitness and muscular strength benefit bone density (Gutin & Kasper, 1992). Bone strength can be improved in women around menopause by moderate weight bearing exercise (Zhang, Feldblum, & Fortney, 1992). Physical activity may favourably affect body fat distribution (Grundy, Pasternak, Greenland, Smith, & Fuster, 1999) and weight loss (Rippe & Hess, 1998). Lifespan participation in physical activity can increase and maintain musculoskeletal health with advancing age (Brill et al., 2000). A large study of 3495 men and 1175 women showed a protective effect of physical fitness and physical activity on functional limitation not only among older adults but also among middle-aged men and women (Huang et al., 1997). Objectively measured physical fitness models were more accurate in quantifying the association than self-reported physical activity. The study suggests that sustained physical fitness and physical activity might be necessary for a long-term effect on functional health. Indeed, a cohort of 451older persons in a runners club who undertook vigorous running had both a lower reported mortality and slower development of disability at 8 years follow-up than 330 community controls (Fries et al., 1994). Regular exercise, especially resistance and high-impact activities, reduces the risk for fractures by contributing to the development of high peak bone mass and possibly by reducing risk of falls in older persons (NIH Consensus Development Panel on Osteoporosis Prevention Diagnosis and Therapy, 2001).

2.5 BENEFITS OF INCREASED PARTICIPATION IN PHYSICAL ACTIVITY

The Commonwealth Government has identified six National Health Priority Areas (cardiovascular disease, cancer, injury prevention and control, mental health, type 2 diabetes and asthma) (Commonwealth Department of Health and Family Services and Australian Institute of Health and Welfare, 1998). Prevention strategies for cardiovascular disease include increased participation in physical activity.

Using 1985 data, the Australian Sports Commission (Australian Sports Commission, 1997) estimated that a 5% reduction in heart disease risk and a potential saving of $103.75 million could be achieved for every additional 10% of the national population undertaking appropriate physical activity. Further, if an additional 40% of Australians undertook regular, moderate and effective exercise, a net benefit of $6.5 million/day could accrue because of reduced costs associated with heart disease, low back pain, absenteeism and lowered work productivity.

Reductions in risk for heart disease, stroke, type 2 diabetes and hip fracture could be achieved for those who move from a sedentary lifestyle to one of appropriate exercise (Nicholl, Coleman, & Williams, 1991; Nicholl, Coleman, & Williams, 1995). Further, there is evidence for benefits of increased stamina, suppleness and strength for those over 60 years in terms of mobility and self-reliance through improved balance with implication for injury reduction (Ball, 1998b; Spirduso & Cronin, 2001). Indeed, the maintenance of these fitness characteristics may extend independent living in old age by as much as 8 or 9 years.

Although there is no absolute threshold for health benefit, the number of episodes of physical activity recommended for health depends on the frequency, intensity and/or duration of the activity (Armstrong et al., 2000; US Department of Health and Human Services, 1996). Higher intensity or longer duration activity could be performed approximately three times weekly and achieve cardiovascular benefits, but low-intensity or shorter duration activities should be performed more often to achieve similar benefits.

The National Physical Activity Guidelines for Australians (Commonwealth Department of Health and Aged Care, 1999) recommend that the 'accumulation of 30 minutes of moderate physical activity on most days of the week' is beneficial for health. Armstrong et al (2000) define 'sufficient' physical activity for health benefit based on a duration of greater than or equal to 150 minutes of walking and/or moderate-intensity activity and/or vigorous-intensity activity per week. Preference for type of activity and ability to sustain the activity are essential determinants for maintenance of activity levels (US Department of Health and Human Services, 1996). Developing muscular strength and joint flexibility are important to improve ability to perform tasks and reduce potential for injury. Upper extremity and resistance (strength) training can improve muscular function and there may be cardiovascular benefits, but further research and guidelines are needed to assess benefits (US Department of Health and Human Services, 1996).

In a cohort study to assess the associations of light, moderate and vigorous intensity physical activity with longevity of 13,485 Harvard Alumni (average age 57.5 in 1977), energy expenditure was summed over walking, stair climbing and sport/recreation to give 5 categories (range <4,200 to >=16,800 kJ/week) (Lee & Paffenbarger, 1999). Reported distance walked and storeys climbed independently predicted longevity (p, trend=0.004 and <0.001 respectively). There was a dose-response relationship with increasing energy expenditure. Although the optimal intensity of activity for longevity is unknown, these results support the current recommendations for moderate and vigorous activities where not contraindicated because of underlying health problems.

Research studies are urgently required to determine the intensities and different patterns of exercise needed to positively influence health outcomes (Blair, Cheng, & Holder, 2001; Hardman, 2001). These studies should address priorities for health outcomes, the relationship of dose-response for biological variables to dose response for clinical outcomes, the basis for differences between individuals in response to exercise dose, and the health-risk benefit relationship for various doses of exercise (Haskell, 2001). Importantly, the development of standard measures and methods of assessing physical activity and energy expenditure are needed before a systematic evaluation and interpretation of dose-response characteristics between physical activity and specific health–related outcomes can be achieved (Howley, 2001; Lamonte & Ainsworth, 2001). Addressing these issues will inform the development of evidence-based guidelines for the use of exercise in promoting health.

While a number of studies indicate reductions in the rate of falls in older persons associated with strength and balance exercises, little research has been identified that examines any associated increased injury risk due to increased exposure.

2.6 EXPECTED BENEFITS TO THE ADF OF INCREASED SPORTS PARTICIPATION

Increased participation in sports would result in a number of improved outcomes to the ADF, and collaterally, in increased injuries. The effects of increased sports activity were modelled and the results derived. Data for the model were derived from the *ADF health status report* (Defense Health Service Branch, 2000), with some assumptions.

In order to model a change in sports participation, it is first necessary to have some baseline measure from which to speculate. Sports participation rates for the ADF are not available. It might be suggested that participation rates for sports from the general community would be applicable. However, the ADF does not reflect the general community on a number of important parameters. For instance, the ADF does not employ physically disabled persons, and given the ADF's nature it will tend to attract a high proportion of persons interested in a physical, sport-centered lifestyle, and a low proportion of persons who view such a lifestyle adversely. Consequently, the ADF modal attitude to sport will not reflect the general population's modal attitude to sport – there will be a strong bias. Therefore, a surrogate measure of participation was sought.

The *ADF health status report* (Defense Health Service Branch, 2000) makes the point that fitness is related to sporting activity. Additionally, the report gives a measure of fitness, standardised across all arms, and independent of fitness to deploy (a variable used as an outcome measure). Consequently, for the purposes of this exercise it was assumed that fitness is a surrogate measure of sports participation. Therefore, if fitness is increased, it will have done so in part through increased sports participation.

As one proposed outcome measure was availability to deployment, it was necessary to assume that increased fitness increases the likelihood of a person to become deployable. The effect of increased fitness was modelled on the probability of improvement based upon a Poisson distribution.

Injuries resulting from sporting activities was also included as an outcome measure. If only those injuries reported within Table 1-3 of the *ADF health status report* (Defense Health Service Branch, 2000) were used for this analysis, it is likely the true incidence of injury would be underestimated. Considerable numbers of injuries would have been included under the items "All other activities" and "Unknown". Consequently, the proportions of sporting and non-sporting injuries, exclusive of the items "All other activities" and "Unknown", were applied to these items, deriving an estimate of injuries resulting from "All other activities" and "Unknown" sporting activities. This assumption may overstate the level of sporting related injury resulting from changes to fitness levels, however, it was considered prudent to make the model more conservative, than to understate these injuries, rendering the model liberal.

Three scenarios were assessed across the model, assessing for "Improvement in ADF deployment status", "Casualties", and "Sport Injuries while Deployed". The scenarios included improvement in forces fitness to 95%, a goal indicated by Paragraph 4.34 of the *ADF health status report* (Defense Health Service Branch, 2000), an increase in safe sports behaviour to 100% (thereby eliminating sports related injuries), and a combination of both.

Model 1: Assuming increased sporting participation to the desired level of 95%. (Appendix 1 Model 1)

Results from Model 1 reveal that as sporting activity increases an increase in personnel classified as "Fit for Deployment" will result. Overall, it would be expected that 1,983 additional personnel became available (ARA: 625; RAAF: 368; RAN: 408; ARA reserves: 582). However, for full-time forces this would result in 934 more Working Days Lost (WDL), 144 additional casualties, and 1 additional retirement due to injury. For part-time forces, this would result in 77 WDL (full-time equivalent), and 31 additional casualties. If outcomes for deployed forces were considered, there would be an increase of 5 casualties per 10,000 personnel each week, approximately 2.5% increase in casualties per annum.

Model 2: Assuming no increased sporting participation but safe sporting behaviour increased to 100%. (Appendix 2. Model 2)

Results from Model 2 reveal that as safe sporting activities increase to 100%, without increasing sporting activity, numbers of personnel classified as "Fit for Deployment" will increase by 20 full-time personnel, and 14 part-time personnel. There would be a reduction of 21,259 WDLs among full-time personnel, and 1,746 WDLs among part-time personnel. Additionally, there would be 3,281 fewer full-time casualties and 685 fewer part-time casualties, and 12 fewer retirements due to injury. Among deployed forces, there would be a decrease of 108 casualties per 10,000 personnel each week, approximately 56.2% decrease in casualties per annum.

Model 3: Assuming increased sporting participation to the desired level of 95%, and safe sporting behaviour increased to 100%. (Appendix 3. Model 3)

Results from Model 3 reveal that as both safe sporting activities increase to 100%, and fitness is increased to 95%, increasing sporting activity, numbers of personnel classified as "Fit for Deployment" will increase by 1,423 full-time personnel, and 597 part-time personnel. There would be a reduction of 21,259 WDLs among full-time personnel, and 1,746 WDLs among part-time personnel. Additionally, there would be 3,281 fewer full-time casualties and 685 fewer part-time casualties, and 12 fewer retirements due to injury. Among deployed forces, there would be a decrease of 108 casualties per 10,000 personnel each week, approximately 56.2% decrease in casualties per annum.

Model 4: Assuming increased sporting participation to the desired level of 95%, and safe sporting behaviour increased to 50%. (Appendix 4. Model 4)

Results from Model 4 reveal that as both safe sporting activities increase to 50%, and fitness is increased to 95%, increasing sporting activity, numbers of personnel classified as "Fit for Deployment" will increase by 1,412 full-time personnel, and 591 part-time personnel. There would be a reduction of 10,162 WDLs among full-time personnel, and 834 WDLs among part-time personnel. Additionally, there would be 1,568 fewer full-time casualties and 332 fewer part-time casualties, and 5 fewer retirements due to injury. Among deployed forces, there would be a decrease of 51.6 casualties per 10,000 personnel each week, approximately 26.8% decrease in casualties per annum.

3. MENTAL HEALTH AND COGNITIVE PERFORMANCE BENEFITS OF PARTICIPATION IN PHYSICAL ACTIVITY

3.1 BENEFITS TO MENTAL HEALTH

Health is a condition with physical, social, and psychological dimensions, each characterised on a continuum with positive and negative poles (Bouchard & Shephard, 1994). Psychological contributions to the study of exercise and fitness deal with the processes underlying thoughts, feelings, and behaviours related to exercise. These contributions are focused on the determinants of exercise behaviour or the psychological outcomes associated with involvement in exercise, and the role of exercise in health compared to other lifestyle behaviours. Psychological research in exercise therefore draws upon research in the fields of medicine, epidemiology, and health (Gauvin & Spence, 1995). Physical activity has been examined either as a determinant of health or as an outcome of a health intervention.

While the role of exercise in the reduction in risk of mortality due to coronary heart disease and other illnesses is widely accepted, health and medical professionals are now increasingly interested in the role of exercise in the prevention and treatment of mental disorders such as depression and anxiety, and also in the improvement of the levels of well-being in the general population. Improved self-esteem is frequently offered as a key mechanism in this context (Fox, 2000). However in a review of the literature, Fox (Fox, 2000) found that improvements in self-esteem were evident in only approximately half of the studies. This is perhaps not surprising given that a recent meta-analysis found a weak but significant effect size for the effect of exercise on self-esteem (Spence & Poon, 1997). Improvements in self-esteem would therefore seem not to be an automatic consequence of exercise, but rather can occur with some exercise regimes for some people. While exercise has a much stronger effect on physical self-perceptions than self-esteem, there is evidence that physical self-perceptions are directly linked to mental well-being, and so the effects of exercise on self-perceptions is likely to continue to be of practical and clinical importance (Fox, 2000).

The relationships outlined above are based on an Exercise and Self-Esteem Model (EXsEM) developed by Sonstroem and colleagues (Sonstroem, 1997; Sonstroem, Harlow, & Josephs, 1994). This model assumes that exercise first influences physical self-concept such that people develop greater physical competence and acceptance, which then leads to increased feelings of self-esteem. While exercise is nearly always associated with improved physical self-concept, it is not always associated with improved self-esteem (Alfermann & Stoll, 2000).

There have been many studies that have investigated the effects of physical activity on mental health. The most commonly studied outcomes include mood, particularly depression and anxiety, self-esteem, self-efficacy, and cognitive functioning (Biddle, 1995). According to a recent report to the US Surgeon General (US Department of Health and Human Services, 1993) the general hypothesis is that people who are physically active or have higher levels of cardiorespiratory fitness have enhanced mood, greater self-esteem, and higher levels of cognitive functioning than people who are less physically fit.

There are other factors that can influence the effectiveness of the effects of physical activity on self-efficacy. Consistent with social cognitive theory (Bandura, 1986), it can be argued that changes in self-efficacy may mediate changes that are found in mood and other feeling states following physical activity (Turner, Rejeski, & Brawley, 1997). Given that social persuasion can augment beliefs of self-efficacy (Bandura, 1986), it is reasonable to suggest that people who lead groups of physical activity could have a powerful social influence on the participants within the exercise program. There is indeed some evidence from McAuley and Jacobson (1991) showing that instructors can contribute significantly to changes in self-efficacy that occur during physical activity. In a later study, Turner et al (1997) manipulated leadership behaviour to create a socially enriching or bland learning environment within an exercise program. Their research showed that the social environment created by an activity leader can influence positive mental health outcomes associated with physical activity. This research adds to the belief that the variables determining the psychosocial benefits of physical activity are not exclusively physiological (McAuley, 1994; Turner et al., 1997).

3.1.1 Physical activity and depression

Non-clinical populations

In general, people who are inactive are twice as likely to have symptoms of depression than are more active people (US Department of Health and Human Services, 1993). Physical activity helps to improve the mental health of both clinical and non-clinical populations. Interventions involving exercise have been found to benefit non-clinical populations who report mood disturbance, including symptoms of anxiety and depression (Morgan, Roberts, Brand, & Feinerman, 1970; Steptoe, Edwards, Moses, & Mathews, 1989).

The psychological benefits of regular exercise for people who have relatively good physical and mental health are not as clear as for people who do report mood disturbances. Some benefits of exercise that have been reported for people without serious psychological problems include increases in general well-being (Cramer, Nieman, & Lee, 1991), reductions in tension and confusion (Moses, Steptoe, Mathews, & Edwards, 1989), and perceived anxiety and stress (King, Taylor, & Haskell, 1993).

There are, however, also numerous studies that have shown little or no positive effects of exercise interventions on mental health (Brown et al., 1995b; Hughes, Casal, & Leon, 1986; Lennox, Bedell, & Stone, 1990). There are several possible reasons for these findings, which include the small sample sizes used, and the reduced opportunity for the participants to show improvements on standardised measures of mental health given that their baseline scores were already within the normal range. It is important to note that in many studies the participants reported improved psychological and physical well-being after participating in regular physical activity even though no objective improvement in mental health was documented (Blumenthal, Emery, Madden, & George, 1989; King et al., 1993).

Improvements in mood, such as reduced anxiety, are often reported after a single session of physical activity. Reduced levels of anxiety have been found to persist for between two and six hours after exercise (Landers & Petruzzello, 1994; Raglin & Morgan, 1987). Regular exercise would be necessary over a longer period of time to achieve these calming effects on an ongoing basis.

A number of cross-sectional population studies in the US and Canada have shown an association between physical activity and mental health. That is, people who spend more time participating in exercise, sports, or other physical activity had fewer symptoms of anxiety and depression (Ross & Hayes, 1988), and higher positive mood and general well-being (Stephens, 1988). These associations were similar for men and women and for younger and older adults. One of the Canadian surveys reported by Stephens (1988) did show higher ratings of positive affect for women when their energy expenditure scores were based on recreational activities rather than a combination of recreational and household activities. As such, the benefits of physical activity for mental health may in part be dependent on the type of setting in which the activity occurs. A positive association between physical activity and mental health however does not necessarily indicate a causal relationship between the two. It is possible that people who have good mental health are more likely to be active, or that mental health and physical activity vary together (O'Neal, Dunn, & Martinsen, 2000).

Cohort studies provide more insight into the relationship between physical activity and mental health (O'Neal et al., 2000). In 1,900 US adults, there was an association at baseline between depressive symptoms and little or no physical activity (Farmer et al., 1988). Eight years later, little or no physical activity was a significant predictor of increased depressive symptoms for people with few depressive symptoms at baseline. There have been two substantial studies that sampled approximately 7,000 and 10,000 US residents, although baseline data was collected in the 1960s in both studies (Camacho, Roberts, Lazarus, Kaplan, & Cohen, 1991; Paffenbarger, Lee, & Leung, 1994). People with low levels of physical activity in 1965 were at a greater risk for having a higher number of depressive symptoms in 1975 than more active people (Camacho et al., 1991). Similarly the level of physical activity reported in the 1960s was inversely related to the self-reported levels of physician-diagnosed depression in 1988 (Paffenbarger et al., 1994). The latter study suggests that there is a dose-response relationship between activity and depressive symptoms. The people who reported weekly sports play more than three times per week (at baseline) were 27% less likely to develop depression than the least active group.

The effects of physical activity on mental health and psychological well-being are less thoroughly studied than those related to biological health (Glenister, 1996). Outcomes for mental health depend strongly on individual and circumstantial factors, and are therefore less predictable than biological effects (Vuori, 1998). Nonetheless, for many reasons it is important to promote health-enhancing physical activity.

While there is limited evidence for a dose-response relationship, it is important to note that increased anxiety, fatigue, and feelings of depression have been found to be associated with over-training in elite athletes (Morgan, Brown, Raglin, O'Connor, & Ellickson, 1987). It is therefore conceivable that over-training may also lead to negative effects on mental health for the general population. It is not known at this point what threshold or optimal frequency, duration, or intensity of physical activity is necessary to improve mental health (US Department of Health and Human Services, 1993).

There is a large amount of evidence showing that self-ratings of anxiety are reduced within 20 minutes after a continuous bout (more than 20 minutes) of large muscle low resistance exercise such as swimming, cycling, or running in normal people (Petruzzello, Landers, Hatfield, Kubitz, & Salazar, 1991). Reductions in anxiety following high resistance exercise such as weight lifting often do not appear until more than 60 minutes after exercise (Focht & Koltyn, 1999), and persist for up to three hours post-exercise (Focht, Koltyn, & Bouchard, 2000). The vast majority of the research conducted has involved normal (non-clinical) samples with relatively normal anxiety levels. Given that there is little room for anxiety scores to improve from baseline in ‘normals’ it is surprising that anxiety reductions following acute exercise have been consistently observed (O'Connor, Raglin, & Martinsen, 2000).

Research has also addressed the benefits of exercise in ‘high anxious’ normals, that is, people who do not experience a clinical anxiety disorder but who are more anxious than others. In regard to state (situational) anxiety scores, the benefits of 20 minutes of cycling were found to be almost double for high anxiety compared to low anxiety normals (Breus & O'Connor, 1998).

It has been hypothesised that anxiety levels are reduced following exercise because it provides the individual with a break from their normal activities and worries (Bahrke & Morgan, 1978). Anxiety levels were not reduced in people who were forced to study during exercise, providing some additional support for the hypothesis that anxiety reductions following exercise occur because the exercise provides the person time out from daily activities (Breus & O'Connor, 1998). Exercise can also significantly reduce anxiety levels in normal people when pre-exercise anxiety levels are artificially elevated (Bartholomew & Linder, 1998; Youngstedt, O'Connor, Crabbe, & Dishman, 1998).

Clinical populations

As reviewed by O’Conner (2000), intense exercise over eight week periods has been found to reduce symptoms of anxiety in inpatients with anxiety disorders (Martinsen, Sandvik, & Kolbjornsrud, 1989; Meyer, Broocks, Bandelow, Hillmer-Vogel, & Ruther, 1998). Exercise interventions for the treatment of depression have also focussed on aerobic exercise. For example, it has been found that nine weeks of aerobic exercise amongst psychiatric inpatients had a significantly greater impact in reducing symptoms of depression compared to a control group who received psychotherapy and pharmacotherapy treatment (Martinsen, Medhus, & Sandvik, 1985). Non-aerobic forms of exercise have also been used successfully to treat depression. Reductions in depressive symptoms were also reported after eight weeks of chronic exercise (running or weight lifting) in young adult females diagnosed with depression (Doyne, Ossip-Klein, Bowman, & Osborn, 1987). However for people with self-reported symptoms of mild to moderate depression, chronic exercise (over 10 weeks) was found to reduce symptoms of depression to a similar extent as traditional pharmacotherapy (anti-depressant) treatments (Fremont & Craighead, 1987).

Exercise has also been used as a clinical intervention for people diagnosed with depression, but this area of research has been reviewed elsewhere and will only be discussed briefly here. A meta-analysis of 80 studies that examined the effects of exercise training on depression by North et al. (1990) found that, on average, people in the exercise conditions exhibited 50 per cent greater decrease in depressive symptoms than those in comparison groups. The North study was not restricted to clinically depressed people. A more recent meta-analysis (Craft & Landers, 1998) only included studies limited to clinically depressed people. The effect size here was greater than in the North study, and again found that exercise tended to reduce symptoms of depression, this time in clinical populations.

In conclusion, results from experimental studies suggest that exercise is associated with improvements in depression in depressed individuals. However many studies reported in the literature have methodological issues (Ojanen, 1994; O'Neal et al., 2000).

3.1.2 Physical activity and other measures of mental health

Some research has documented an association between physical activity and psychological well-being, including self-concept, self-esteem, and mood. A number of reviews have been published by McAuley. The first review found a positive association between physical activity and self-esteem in young adults (McAuley, 1994). The strength of this association increased when physical activity was personally valued, and when the measures of psychological well-being were specific rather than general. This association was observed after both long-term effects of exercise and short-term effects of a single activity.

In a review of middle-aged participants, McAuley and Rudolph (1995) found similar associations between physical activity and psychological well-being to those documented for young adults. This review of 38 studies states that the majority of studies reported positive associations between physical activity and psychological well-being. The strength of the relationship was directly related to the period of time that participants had been involved in programs of physical activity. Further studies and improved methodologies would clarify the parameters of this association. It is interesting to note that improvements in psychological well-being were not necessarily correlated with improvements in cardiovascular fitness.

There does appear to be an association between physical activity and psychological well-being. However physical activity seems to be particularly beneficial in improving the psychological well-being and physical function of people with chronic diseases than for healthy people. People with lower levels of mental and physical health have more room to improve their health status than those already possessing good health.

3.1.3 Summary

The general hypothesis is that people who are physically active or have higher levels of cardiorespiratory fitness have enhanced mood, greater self-esteem, and higher levels of cognitive functioning than people who are less physically fit. Improved self-esteem is frequently offered as a key mechanism for the improvement in the levels of well-being in the general population. It can be argued that changes in self-efficacy may mediate changes that are found in mood and other feeling states following physical activity.

The evidence for benefits of exercise to mental health in both the short and long-term in non-clinical populations is weak. Exercise interventions in clinical populations to reduce anxiety and depression are generally more successful than for non-clinical populations.

3.2 BENEFITS TO COGNITIVE PERFORMANCE OF PARTICIPATION IN PHYSICAL ACTIVITY

There have been two impressive reviews of the effects of exercise on cognitive performance (McMorris & Graydon, 2000; Tomporowski & Ellis, 1986) (Table 3.1). Studies conducted in this area are often difficult to interpret because there are many factors that are often not taken into consideration in study methodology. In their review, Tomporowski and Ellis (1986) identified some key factors that should be kept in mind when evaluating studies of the effects of exercise on cognition. While there are other variables that would also influence interpretation of results (eg: participant age), some variables will be mentioned briefly here.

Baseline physical fitness and the extent to which the investigators attempted to measure the physical fitness of participants prior to any about of exercise or exercise intervention are issues often not considered. This is critical because it has been suggested that physiological functioning would depend upon the level of physical fitness (Weingarten, 1973), and physiological functioning, specifically physical arousal, is linked to task performance (theories covering the link between arousal and performance are discussed shortly). Exercise intensity and duration are highly variable, and intensity, in particular, is often not clearly defined, which is an issue because variations in these variables produces different physiological, and perhaps psychological, states.

3.2.1 Immediate short-term effects of physical activity on performance

Discussions here focus on the performance both during and very shortly after a bout of physical activity. The following section then considers some of the theories that attempt to account for these effects. Finally, the benefits on exercise in the longer term are considered.

As highlighted below, the evidence for the improvement in cognitive task performance following exercise is equivocal (McMorris & Graydon, 2000; Tomporowski & Ellis, 1986).

Table 3.1 Summary of some studies that examined the effects of exercise on performance

Study	**Subject group**	**Form of exercise**	**Performance tasks**	**Time of testing**	**Outcome**
Tomporowski et al., (1987)	2 groups of 24 college students (17-33 yrs)	Treadmill running until voluntary exhaustion	Word recall tasks	Before and after exercise	No effect of exercise
Tomporowski et al., (1987)	12 fit people (19-23 yrs) & 12 controls (17-29 yrs)	Treadmill running until voluntary exhaustion	Word recall tasks	Before and after exercise	No effect of exercise
McGlynn et al (1977)	14 male college students	12 minutes treadmill running (increasing grade every 3 minutes)	Visual discrimination task	Before and during running and 30 seconds after	Increased intensity resulted in increased speed, but not accuracy
Gupta et al (1974)	50 male college students (19-21 yrs)	Step-up tests, either 2, 5, 10, or 15 mins duration	Mental arithmetic	Before and after exercise	Improved performance for 2 & 5 min, but degraded for 10 & 15 min exercise.
LeDuc et al (2000)	12 pilots (who attended 1 sleep loss and 1 control session)	10 mins treadmill running at 70% capacity, during 40 hours of sleep loss	Psychomotor and cognitive performance	Before and after exercise	Exercise increased alertness, but no effect on performance. Exercise also increased sleepiness (EEG) for 60 mins.
Levitt & Gutin (1971)	Not mentioned in secondary citation	Treadmill walking for 6 mins (at intensities up to 175 beats/min)	Choice reaction time	Before and for 6 mins after exercise	RT was improved at low intensity but deteriorated at high intensity.
Sparrow & Wright (1993)	50 men (mean age 25 yrs)	Step-ups at 3 different intensities.	Cognitive tasks (matrices & arithmetic tasks)	Before and after exercise	No effect of exercise compared to a non-active control group
Weingarten (1970)	13 fit and 9 unfit male undergraduates	Treadmill running for 10 mins at 60% capacity	Raven's progressive matrices	Before and during exercise	Performance of unfit group deteriorated during exercise.
Sjoberg (1980)	24 men of average and lot levels of fitness	Cycling for 12 mins at differing intensities	Short term memory, paired-associate learning &	During and after exercise	No difference between the 2 groups during and after exercise. The group with higher fitness performed better after than during

			multiplication tasks		exercise.
Tsorbatzoudis (1998)	12 fit cyclists & 46 unfit university students	Cyclists & 23 students did 30 mins moderate intensity exercise. 23 students did only 5 mins of exercise	Reaction time and continuous attention	Before and after exercise	No effect of fitness, but performance improved after exercise across all subjects.
Hogervorst (1996)	15 endurance athletes	Cycling for 1 hour at 75% capacity	Stroop test, reaction time, and finger tapping	Before and after exercise	Exercise improved performance, particularly speed.

3.2.2 Short-duration, high-intensity anaerobic exercise

The majority of studies have used tasks that require the participants to exert high levels of power, such as cycling and running. Exercise is generally continued to the point that the participant experiences fatigue, either self-reported fatigue or as observed by the experimenters. Typically this can be achieved within 15 minutes (Tomporowski, Ellis, & Stephens, 1987).

McGlynn and colleagues (1977) examined the effects of a 12 minute treadmill run on discrimination task performance of fit men, as defined by their VO_2max. Intensity was increased every three minutes via increased speed and steeper incline. The visual discrimination task was presented during the run and 30 seconds after. The speed of discrimination increased linearly with increasing task intensity, but then decreased when the exercise had finished. Accuracy remained constant at all times.

Another study examined the effects of exercise on simple arithmetic performance (Gupta, Sharma, & Jaspal, 1974). Arithmetic performance was measured after participants completed a step-up test for 2, 5, 10, or 15 minutes. While performance improved after the short durations of intensity (2 & 5 minutes), significant deteriorations were observed after 10 and 15 minutes of exercise.

LeDuc, Caldwell, and Ruyak (2000) examined the effects of exercise as a countermeasure to fatigue in sleep-deprived aviators. The twelve pilots engaged in 10 minute bouts of treadmill running (at 70% VO_2max) during 40 hours of sleep deprivation, and also attended a control condition involving the same amount of sleep loss but without the bouts of exercise. The pilots felt more alert immediately following exercise (than without exercise). However, EEG data showed increased signs of slow-wave activity about an hour following exercise. Exercise had no effect on psychomotor and cognitive performance. So, while exercise improved subjective alertness immediately following physical activity, it did not delay performance decrements during sleep loss, and actually led to increased levels of objective sleepiness approximately one hour following exercise.

Generally speaking there are three approaches to the study of exercise and performance in this category. There are studies that have attempted to examine the benefits of increased arousal on performance, studies that have examined the deleterious effects of exercise-induced fatigue on performance, and studies that have attempted to examine whether intense exercise has a more detrimental effect on people who are less fit compared to people who are very fit. Research to date has not been able to address any of these three issues with any degree of certainty, due to methodological constraints and limitations referred to earlier.

3.2.3 Short duration moderate intensity

Levitt and Gutin (1971) examined the effects of six minutes of treadmill walking on choice reaction time. Participants used the treadmill at heart rates of 115, 145, or 175 beats per minute. Following the six minutes of treadmill walking, performance was measured for six minutes while participants continued walking on the treadmill. While reaction time performance improved relative to baseline at low intensity (115 beats/min), performance remained stable at 145 beats/min and deteriorated at 175 beats/min. Movement time latencies decreased as heart rate increased.

Sparrow and Wright (1993) examined the effects of six minutes of exercise (step-up task) on Raven's Progressive Matrices and arithmetic tasks for 50 men (mean age approximately 25 years). Aerobic fitness, as measured by VO_2max, was constant across the five groups. Three exercise groups had mean stepping outputs of 47, 75, or 120 Watts. One control group played bingo and another had no activity. Exercise did not influence performance for these cognitive tasks. It was suggested that perhaps the physical effects of fatigue were overriding the benefits gained from increased arousal levels – a position that is also held by others to explain the lack of effect of exercise on performance (Tomporowski et al., 1987).

An interesting issue is whether or not people who are more physically fit perform at more optimal levels compared to less fit people. In one study a group of extremely fit and moderately fit men performed the Ravens Progressive Matrices test before and during 10 minutes of treadmill running (Weingarten & Alexander, 1970). Fitness was again measured by VO_2 max, and intensity during exercise was set at 60% of VO_2max. While performance of the extremely fit group did not differ between baseline and during exercise, the performance of the moderately fit group did deteriorate during exercise.

A similar study was conducted by Sjoberg (1980) which compared the performance of 24 men of average and low levels of fitness on three tests of mental ability. Participants cycled for 12 minutes at 25%, 50%, or 75% of their VO_2max. There were no differences between the groups for performance on short term memory and paired-associate learning tasks during and post exercise. The group of average fitness did however perform better on a multiplication task immediately after the bout of exercise, suggesting that this group were better able to resist the deleterious effects of exercise-induced fatigue.

Weingarten (1973) reported on a number of unpublished studies and provided support for the hypothesis that highly fit individuals perform cognitive tasks more efficiently than less fit individuals during periods of high physical activity. On the basis of their review, Tomporowski and Ellis (1986) concluded that the majority of the studies that have used moderate levels of exercise do provide some evidence that cognitive performance is facilitated by an increase in physical arousal, and that physically fit individuals are more able to perform cognitive tasks while under stress (such as exercise) than less fit individuals. On the basis of the literature available we feel that further evidence is needed before such conclusions can be made.

A later study examined the effects of exercise on the performance of 12 top level cyclists and 46 university students who were not participating in any form of exercise (Tsorbatzoudis, Barkoukis, Danis, & Grouios, 1998). The cyclists and half of the students completed 30 minutes of moderate intensity exercise, while the other half of the students did five minutes of high intensity exercise on a bicycle ergometer. Performance on reaction time and continuous attention tasks was measured before and after exercise. While there were no differences in performance between aerobically fit and unfit participants, performance on both tasks was improved after exercise. The authors attributed this effect to a practice effect, and concluded that neither previous aerobic activity nor the intensity or duration of physical activity significantly influenced cognitive functioning (Tsorbatzoudis et al., 1998).

3.2.4 Long duration aerobic exercise

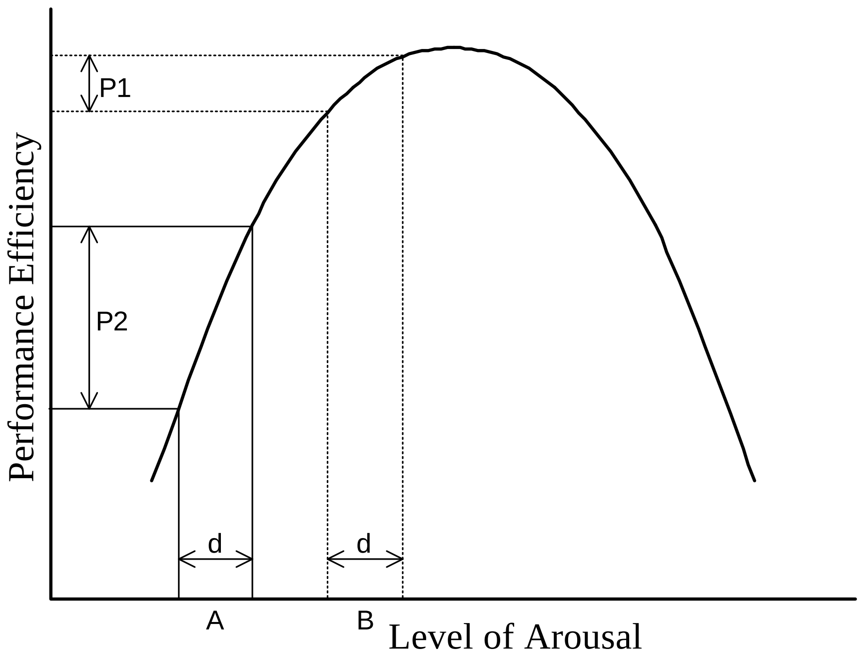
Very little information appears to be available concerning the effects of longer duration physical activity on cognitive performance. Tomporowski and colleagues (1987) studied 24 college students of average fitness who ran on a treadmill at 80% of their VO_2max until exhaustion, which took, on average, about 28 minutes. Immediately following exercise the participants completed 12 free-recall tasks (memory tests) over a one hour period. Compared to a non-exercise control group, the performance of the exercise group improved slightly (but not significantly) up to 30 minutes post exercise. The performance of 12 highly trained athletes was also compared with the performance on the 12 most unfit students, however there was no difference in the performance of these two groups.

Other studies have examined the effects of exercise in more highly trained people. Fifteen endurance athletes performed an ergometer endurance test at 75% of their maximal work capacity for approximately one hour (Hogervorst, Riedel, Jeukendrup, & Jolles, 1996). Performance on the stroop colour-wood test, choice reaction time, and finger tapping tests was measured before and after the bout of exercise. In this study exercise was found to improve performance, particularly speed of performance. It was suggested that the improved performance reflected a general increase in activation (arousal) resulting from the endurance exercise. These authors concede the potential role of expectancy in the improved performance of these athletes.

3.2.5 Hypotheses linking physical activity with cognitive performance

One hypothesis to explain any performance improvements from exercise is the inverted-U hypothesis that describes the interactive relation between exercise induced arousal and cognitive performance (Tomporowski & Ellis, 1986). Briefly, the inverted-U function represents an extension of the Yerkes-Dodson law, as described by Yerkes and Dodson (1908). This function predicts that a given change in arousal level will have a greater effect on performance when the overall level of arousal is relatively low (for example, in the case of sleep deprivation) than when arousal is at more optimal levels (Colquhoun, 1971). Davey (1973) was the first to use this theory to make the link between arousal and exercise and therefore subsequent performance. This is illustrated in Figure 1.2 by considering the arousal difference (d) at points A and B, and the resulting performance differences, P1 and P2. This function also predicts that performance will improve until a critical level of arousal is reached, and will then decrease.

Figure 3.1 An inverted-U function describing the relationship between arousal and performance (from Lenné (1998)).



A critical point is that performance on more complex tasks peaks at a lower level of arousal, whereas optimal performance on more simple tasks requires a higher level of arousal (Kahneman, 1973).

Easterbrook (1959) proposed a theory in an attempt to explain the findings that performance decreased after arousal had increased beyond a certain point, and that this point occurred at lower levels of arousal for more complex tasks. The main thrust of this theory was that increases in arousal led to increases in attentional selectivity. In other words, as arousal increases there is a progressive reduction in the range of cues utilised. At lower levels of arousal, selectivity of processing is low, and hence irrelevant cues would also be processed. As arousal increases to approach a critical point, selectivity of processing is increased, and hence performance improves because irrelevant stimuli are now excluded. However, beyond a critical level of arousal, further increases in arousal produce continued increases in selectivity, until the range of cues utilised is so restricted that relevant stimuli would also be ignored, and therefore not processed. There was a further assumption that the range of cues necessary for optimal performance was narrower for more simple tasks and wider for complex tasks. Complex tasks often require attention to a wider range of cues, and hence performance is poor when the range of cues is restricted at higher levels of arousal.

In the literature examining the relationship between physical exercise and performance there is a basic assumption that physical arousal associated with exercise leads to a narrowing of attentional focus (Brisswalter, Arcelin, Audiffren, & Delignieres, 1997; Cote, Salmela, & Papathanasopoulu, 1992; McMorris & Colenso, 1996; Salmela & Ndoye, 1986). Therefore, according to Easterbrook's (1959) cue-utilisation theory, it would be expected that moderate exercise would improve performance whereas intense exercise would have a negative effect on cognitive performance.

There has been some support for the relationship between arousal and performance (Brisswalter et al., 1997; Brisswalter, Durand, Delignieres, & Legros, 1995; Salmela & Ndoye, 1986). For example, in one study participants were required to cycle on an ergometer at 20, 40, 60, and 80% of their aerobic capacity (Brisswalter et al., 1997). Performance on a reaction time task was measured before, during, and after exercise. While there were no differences in performance pre and post exercise, performance did deteriorate during exercise, although the group of middle distance runners performed better than the group who had no regular physical activity. Performance tended to be more impaired when working at 60 and 80% capacity, particularly in the no activity group. These findings lend some support to the theory that higher levels of arousal have a negative impact on performance, assuming that the results were not confounded by the effects of physical fatigue.

The Inverted-U hypothesis is perhaps somewhat simplistic, yet it is often cited in the literature despite a lack of laboratory evidence to support it (Folkard, 1983; Wiener, Curry, & Faustina, 1984). A major issue is that it is difficult to estimate whether an individual is under-aroused or over-aroused prior to any experimental manipulations, and to determine exactly what effect arousal altering stimuli may have (Wiener et al., 1984). Providing evidence for the causal relationship between arousal and performance would be easier if a valid and reliable physiological measure of arousal was available (Parasuraman, 1983).

A similar theory was put forward by Gutin (1973). This position also states that different levels of arousal differentially affect performance on various task types. Similar to the inverted-U hypothesis, Gutin (1973) stated that lower levels of activation were optimal for performance on tasks requiring a great deal of information processing.

In summary, there is no clear consensus as to whether or not exercise affects performance at all, or in a positive or negative manner. While there are a number of researchers who claim that physical activity strongly influences information processing, there are many others whose findings do not support this position (Tomporowski & Ellis, 1986; Travlos & Marisi, 1995; Zervas, 1990; Zervas, Danis, & Klissouras, 1991). Given the lack of consensus about whether or not exercise affects cognitive performance, there is no convincing evidence of a dose-response relationship between the intensity of physical activity and cognitive performance.

3.2.6. Longer-term effects of physical activity on performance

There is even less evidence suggesting a positive association between physical activity and performance in the longer term. The effects of a 10 month exercise program was assessed in 36 men and women with a mean age of 36.4 years, and a control group of 21 people (mean age 30 years) (Paas, Adam, Janssen, Vrencken, et al., 1994). Subjects did not participate in any sport that involved running or jogging and engaged in less than one hour of recreational sports per week. The training program involved one supervised and three unsupervised training programs per week for 10 months. Long-distance running, sprinting, and interval training formed the bulk of each training session, which lasted between 30 and 90 minutes. Performance was measured on a number of tasks before and after the 10 month program, including simple and choice reaction time, and a letter-recognition task. While aerobic fitness improved in the experimental group, the effects of four aerobic exercise sessions per week for 10 months did not have any impact at all on the performance of any task.

Van Boxtel et al. (1997) reviewed the evidence concerning the link between aerobic fitness and cognitive performance, and concluded that no clear consensus could be drawn from the earlier studies about what effects of aerobic fitness on cognitive performance could be expected in a normal ageing population. In their study Van Boxtel et al (1997) examined the link between aerobic fitness and cognitive performance in 132 men and women between 24 and 72 years of age. Aerobic fitness was measured by calculating the VO_2 max during a cycle ergometer test. Cognitive performance was measured on a battery of tests, including tests of memory, psychomotor speed, and information processing speed. While aerobic fitness tended to decrease with age, only two measures of information processing speed were found to have a positive association with aerobic fitness.

A number of studies have examined the benefits of exercise over a period of time. Brown et al. (1995a) examined the benefits of low, moderate, and mindful exercise in 135 sedentary people with a mean age around 50 years. The mindful exercise involved a Tai-Chi like program. The greatest benefits were found with the mindful exercise program. Women in this group reported reductions in mood disturbances, including tension, depression, anger, confusion, and total mood disturbance. The moderate exercise was associated with increased positive affect for men. No other differences were found for mood or self-esteem. These authors concluded that exercise that incorporates cognitive strategy may be more effective than exercise programs that lack a structured cognitive component in promoting psychological benefits.

3.2.7 Summary

The evidence for the improvement in cognitive task performance following exercise is equivocal. There is no clear consensus as to whether or not exercise does affect performance at all in the short-term, either in a positive or negative manner. Given this lack of consensus, there is no convincing evidence of dose-response relationship between the intensity of physical activity and the subsequent effects on cognitive performance. There is even more limited evidence for a positive association between physical activity and performance in the longer-term.

4. OTHER ASPECTS OF PHYSICAL ACTIVITY

4.1 SAFE AND UNSAFE BEHAVIOUR

4.1.1 Social, psychological and other influences on safe and unsafe behaviour

We have the understanding that a small proportion of defence personnel engage in high levels of risky behaviour, particularly sports-related behaviours. It is critical therefore to gain an understanding of the antecedents for safe and risky behaviours before considering interventions that might reduce the incidence of risky behaviours.

There has been much research and many text books that address the concept of risk and risk taking behaviours (Hewitt, Elliot, & Shanahan, 1995; Lipsitt & Mitnick, 1991; National Health and Medical Research Council, 1997a; National Health and Medical Research Council, 1997b; Trimpop, 1994; Yates, 1992). Some key concepts will be addressed here.

A number of motivational models of behaviour appear in the literature. The most prominent of these is Risk Homeostasis Theory, described by Wilde (1982; 1988). This theory suggests that individuals have a target level of objective risk, and they try and maintain risk at that level. The theory is based on compensating actions which are triggered by a perceived discrepancy between the observed and desired levels of risk. A person's utility of action alternatives determines the target level of risk, and the perceptual skills determine the perceived level of risk. Through a series of adjustments a homeostatic level of risk is maintained over time, while continuously fluctuating to compensate for environmental changes. Any externally introduced measures to reduce injury risk will only be effective until the reduced risks are perceived by the individual. Lowering the perceived level of risk serves to increase the expected utility of risk-taking behaviour. The increases in risk-taking behaviour may offset any reduction in injury risk produced by the original improvement. In particular, this theory has been successfully used to account for risk-taking behaviours in the road safety context.

Another prominent theory is conflict theory. This theory is a general model of decision making that is relevant to the analysis of stress and other affective responses in risky behaviour (Janis & Mann, 1977; Mann, 1992). The crux of the theory is an analysis of five basic coping patterns which are used to deal with conflict and stress. In the fact of any given situation, the first issues are whether or not the risks are serious if current behaviour is and is not changed. Conflict occurs when there are serious risks in both cases.

The theory proposes three coping strategies used to deal with conflict, which involve distinct modes of information processing that are associated with tendencies toward extreme risk taking behaviour (hypervigilance) or tendencies towards calm and deliberate choice (vigilance). Defensive avoidance is when no action is taken because there are serious risks both if behaviour is changed and is not changed, and when no solution can be found. Each of these three coping strategies is associated with a distinct level of stress. The stress associated with defensive avoidance is variable (from low to high), extremely high for hypervigilance, and moderate for the vigilance coping strategy. Stress has a facilitative or detrimental effect on quality of information processing, and therefore influences risk taking (Yates, 1992).

4.1.2 Factors that contribute to risk behaviour

Two major reviews have outlined the range of factors that influence risk taking behaviours with particular emphasis on youth (under 30 years of age) (Hewitt et al., 1995; National Health and Medical Research Council, 1997a; National Health and Medical Research Council, 1997b). The following section is drawn from these sources and the reader is directed to these reviews for further detail. Younger people do engage in more risk-taking activities than older people, score higher on risk taking questionnaires, perceive lower risk for themselves in identical situations, and are also over-represented in accident and injury data (Trimpop, 1994), and so form the focus of discussions here.

There are a number of intrapersonal factors that contribute to risk-taking behaviour. Behavioural tendencies such as sensation seeking (thrill seeking), impulsiveness, aggression, and emotional instability are linked with risk and injury. Sensation seeking, in particular, has a more profound influence on the propensity to engage in risky behaviours. Levels of sensation seeking peak in the early 20s and then decline, and are higher in males than females. Higher levels of sensation seeking are also linked with other consequences of risky behaviour such as erratic driving and substance abuse, but these people also have confidence in their abilities to deal with and survive these risky behaviours. Sensation seeking can be measured by the Sensation Seeking Scale (Zuckerman, 1984). Risk taking may also be an outlet for mood states such as stress and aggression, and is also influenced by self-esteem, particularly in relation to drug use.

Over confidence is a critical issue that is linked with risk taking behaviours. The bulk of research addressing this issue has been in the context of driving, and there have been many studies that have shown that younger drivers consider themselves to be more skilful and safer than other drivers (Finn & Bragg, 1986; Jonah, 1986). However there is also research showing that over confidence is not restricted to younger people. Job (1990) found that over-confidence was a problem with drivers of all ages, as over half of drivers aged 17 to 69 years believed that their driving ability was greater than for the average driver. It was also found that drivers aged 25 to 49 years appeared to be more confident than drivers aged between 17 and 24 years. Over-confidence may therefore be a factor that contributes to the increased risk-taking of younger but also middle aged people.

Over confidence is also apparent in behaviours other than driving. It has been reported that young skiers also consider themselves to be more competent than their more experienced counterparts. In relation to sports injury, there are other factors such as the culture of risk and injury acceptance, that contribute to risk of injury in sport (National Health and Medical Research Council, 1997b). Distorted risk perception and the acceptance of risk in sport is common, again particularly for younger people. Knowledge of the inherent dangers involved in a particular sport does not necessarily change a person's perception of risks involved. Injury is often attributed to errors of judgement and skill. Danger neutralisation is the term used to describe 'victim blaming' and is used to help justify participation in high risk sports.

In terms of interpersonal factors, peer pressure, parents (as key role models), social norms, and gender norms all influence risk behaviour.

4.1.3 Interventions to promote safe behaviour and decrease unsafe behaviour

There is again a huge psychological literature devoted to cognitive and behavioural modification in relation to risk taking behaviours, eg: Beauvoois & Joule, 1996; Kendall, 1982; Kwee, 1990; Lipsitt & Mitnick, 1991; Wicklund & Brehm, 1976). There are many approaches to changing different forms of behaviour, and some of the more well known and supported include Adlerian Psycotherapy, Analytical Psychotherapy, Person-Centered Therapy, Rational Emotive Behaviour Therapy, Behaviour Therapy, and Cognitive Therapy (Corsini & Wedding, 1995). Without going into each of these theories in detail, discussions here will focus on Cognitive Behavioural Therapy (CBT), which appears the most appropriate approach for reducing unsafe behaviours as it encompasses the benefits of both cognitive and behavioural therapies.

CBT is established as a major form of psychological therapy. A basic assumption is that it is a person's interpretation of an experience, rather than the experience itself, that produces psychological disturbance. Both cognitive and behavioural methods are used to modify perceptions and interpretations of life events, and hence it is common to refer to CBT instead of behaviour therapy. In a broad sense CBT is psychotherapy that is primarily based on the social-cognitive theory and also encompasses a range of cognitive principles and procedures (Corsini & Wedding, 1995).

Reiterating briefly, the social-cognitive approach relies on the theory that behaviour is based on three separate but interacting regulatory processes, being external stimulus events, external reinforcement, and cognitive mediational processes (Bandura, 1986). The influence of environmental events on behaviour is largely determined by cognitive processes governing how these events are perceived and interpreted. This theory puts forward that the individual is the agent of change and emphasises the human capacity for self-directed behaviour change.

A number of techniques are available within CBT, which include guided imagery (systematic desensitisation), role playing, physiological recording, self-monitoring, behavioural observation, and psychological testing (Corsini & Wedding, 1995). CBT emphasises the need to tailor the treatment methods and principles of social-cognitive theory to each individual unique problem. The therapist must use clinical judgement to select the most appropriate treatment methods.

While we were unable to find specific documented examples where CBT has been used to modify risk behaviours in the military context, there are examples of CBT being used successfully to modify other forms of risky behaviour. For example, there are a number of behaviours that increase the risk of cardiovascular disease, and modifying these behaviours is likely to reduce cardiovascular problems. Some of the behaviours that have been targeted in CBT programs include cigarette smoking, obesity, lack of exercise, stress, and alcohol consumption.

Self-control procedures are used most successfully for substance abuse and obesity problems. Self-monitoring is fundamental to the success of self-regulation of behaviour, and involves setting goals and standards that guide behaviour (Corsini & Wedding, 1995). In the treatment of obesity, mutually selected daily calorie intakes would be set as goals. Research has shown that treatment is more successful when treatment goals are highly specific, unambiguous, and short-term, and so a fixed number of calories per day would be defined. The individual would be asked to self-monitor their caloric intake, the extent to which they engaged in planned physical activities, and the conditions under which they ate. In the military context standards and self-monitoring could perhaps be used to guide individuals toward safe behaviour.

4.1.4 Summary

There are a number of motivational models of behaviour that appear in the literature to account for why some people are more likely to engage in risky behaviours. The most prominent of these is Risk Homeostasis Theory, which has the central concept that individuals have a target level of objective risk, and they try to maintain risk at that level. There are a number of intrapersonal factors that contribute to risk-taking behaviour. Behavioural tendencies such as sensation seeking (thrill seeking), impulsiveness, aggression, and emotional instability are linked with risk and injury. Over confidence is another critical issue that is linked with risk taking behaviours.

While there do not appear to be any documented examples where CBT has been used to modify risk behaviours in the military context, there are examples of CBT being used successfully to modify other forms of risky behaviour, and so this approach may be the most appropriate for the military.

4.2 THE EFFECTS OF ANXIETY AND STRESSFUL SITUATIONS ON PERFORMANCE

Similar to other areas reviewed in this report, there is a substantial literature concerned with a range of environmental factors that have been shown to affect performance. These and other factors can be referred to as modifier variables and have differential effects on performance. Much research has been directed toward examining the effects of such variables on performance. These variables include noise (Smith & Jones, 1992b), vibration (Griffin, 1992), effects of toxic solvents (Stollery, 1992b), performance in hyperbaric environments (Brooke & Ellis, 1992b), heat (Hygge, 1992), cold (Brooke & Ellis, 1992a) and electric fields (Stollery, 1992a), amongst others. All of these factors might be encountered by military personnel in certain situations. It is not feasible to review the effects of each of these variables on performance in any detail here, and so brief mention is made.

Two of the more pertinent factors for military performance would be heat and cold. There have been several hundred studies that have examined the effects of heat and cold on a range of performance indices such as simple and complex reaction time, manual performance, tracking, vigilance, time sharing, cognitive and mental tasks, and social behaviour (see Brooke & Ellis, 1992a; Hygge, 1992 for reviews). Reaction time, vigilance, and cognitive abilities are likely to be more relevant for military performance. Simple reaction time seems to remain relatively stable in temperatures ranging from approximately 20 to 50 degrees Celsius. Complex reaction however is more variable, and tends to improve approaching temperatures of about 32 degrees Celsius, but then deteriorate beyond that point (Hygge, 1992). Several reviews have concluded that 27 to 32 degrees Celsius is the optimal range for vigilance performance (Hygge, 1992; Ramsey, 1983). If the external conditions do not alter core body temperature then effects on performance are minimal. Thermal stress that causes core body temperature to rise (and that cannot be counteracted by compensatory mechanisms) does impair vigilance (Hancock, 1986). Hancock (1986) argues that stress (in this case in the form of thermal stress) drains attention, which implies that more complex tasks will be more vulnerable to heat stress. Performance on cognitive and psychomotor tasks is also optimal around 27 degrees Celsius and deteriorates beyond that point (Hygge, 1992; Ramsey, 1983).

The theory most commonly used to explain the effects of heat and other environmental factors on performance is arousal theory (Easterbrook, 1959; Hockey, 1983; Yerkes &

Dodson, 1908). Arousal theory and the inverted-U function were discussed in an earlier section. In relation to heat it is assumed that mild heat is de-arousing, whereas heat in excess of mild heat is over-arousing (Hygge, 1992).

The relationship between noise level and injury rate in the workplace remains unclear. There is only limited evidence that higher levels of noise are associated with increased injury rates (Smith & Jones, 1992b). In a review, Broadbent (1979) concluded that detrimental effects of noise on vigilance performance are found if the noise level is over 95dB, the duration of task performance must be long, and the signals must be difficult to see. In his review Smith (1992b) concluded that noise may alter strategy selection and efficiency of control processes. He also concluded that while the effects of noise on performance were definite, the precise nature of the effects depended upon factors such as the type of noise and the task being performed.

Heat, cold, noise, and other environmental factors do influence performance, and there are a number of good reviews of the literature (eg. Smith & Jones, 1992a). However the extent of this influence is highly dependent upon the specific form of environmental stress (eg. heat, cold, noise) and other factors such as task type and duration. Environmental stressors may also be associated with (state) anxiety which compounds the deleterious effects of these environmental factors on performance (Mueller, 1992).

Perhaps the most important and most commonly experienced form of stress placed upon military personnel is fatigue. Fatigue in this sense is discussed in the context of task performance involving partial sleep loss, such as performing in the early morning or late evening, and in the more extreme cases, total sleep deprivation. There are several thorough reviews available on this topic (Bonnet, 1994; Johnson, 1982; Lenné, 1998; Naitoh, 1976; Pilcher & Huffcutt, 1996; Tilley & Brown, 1992).

Fatigue is a huge area of research to capture in an overview. While the extent of partial or total sleep loss is the most obvious variable, as with other stressors, there are many factors that moderate the effects of fatigue on performance. For example, research has generally shown that the more difficult a task is, the more sensitive it will be to the effects of sleep loss (Bonnet, 1994; Johnson, 1982). In regard to the type of task, vigilance and reaction time tasks appear to be the most sensitive to the effects of sleep loss (Horne, 1988). Time of day also influences task performance for both partial and total sleep loss (eg. Dijk, Duffy, & Czeisler, 1992; Lenné, Triggs, & Redman, 1997; Lenné, Triggs, & Redman, 1998; Monk et al., 1997). Other non-task related factors that have been shown to influence fatigue-related performance are the novelty of the situation, the motivation of the individual, and the proficiency level, as newly acquired skills are more affected than highly automated skills (Bonnet, 1994; Johnson, 1982). Consideration of the factors listed above can help to minimise the effects of fatigue on performance.

In addition to the issues just mentioned, there are a range of countermeasures that are available to minimise the effects of fatigue on performance. Of course the best way to manage fatigue is to sleep. Where this is not possible, a number of approaches have been explored to reduce to magnitude of fatigue-induced decrements in performance.

The use of naps as a strategy to overcome fatigue-induced performance decrements has been prevalent in the literature. For example, the use of short naps has been shown to improve both mood and performance. It was found that a 30 minute nap increased subjective alertness and decreased sleepiness in subjects who had both a normal sleep and a night of restricted sleep (Gillberg, Kecklund, Axelsson, & Akerstedt, 1996). Other studies have also reported positive affects of naps on alertness (Bonnet, 1991; Hayashi, Ito, & Hori, 1999a; Takahashi & Arito, 1998; Takahashi, Fukuda, & Arito, 1998). These positive effects on mood often translate to positive effects on performance (Gillberg et al., 1996; Hayashi, Watanabe, & Hori, 1999b; Rosekind et al., 1995).

Recently naps have been used effectively in the driving domain. Horne and Reyner (1996) restricted subjects to five hours of sleep, and then asked them to drive for two one-hour sessions, separated either by a short nap or no nap. Whilst performance remained at high levels for the first 15 minutes after the break with no nap, performance was sustained for the full 60 minutes post-nap. Furthermore, in a second study, the effects of caffeine in combination with a short nap in sleepy subjects was found to be more effective than caffeine alone (Reyner & Horne, 1997).

There are many issues that need to be further addressed when examining the potential benefits of napping. These issues concern the optimum timing of the nap and nap length, and further investigation of the effects of sleep inertia following a nap. Sleep inertia refers to the impairment in performance and mood that occurs for a period of time after waking. While the duration and intensity of the effects of sleep inertia depend upon many factors such as the length of nap, duration of prior wakefulness, and the type of task, the effects of sleep inertia usually do not last for more than about 30 minutes (Bruck & Pisani, 1999; Dinges, Orne, Whitehouse, & Orne, 1987; Gillberg et al., 1996; Muzet, Nicolas, Tassi, Dewasmes, & Bonneau, 1995; Rosekind et al., 1995; Salame et al., 1995).

Drugs such as caffeine and stimulants are also used to stave off the decrements in performance and mood associated with fatigue. It has been known for many years that caffeine in a range of doses can improve psychomotor and memory-related performance as well as subjective mood (Bonnet, 1991; Bonnet & Arand, 1994; Buysse, 1991; Horne & Reyner, 1995). The effects of caffeine only usually persist for a couple of hours. The effects of caffeine (250 mg) were recently shown to be particularly effective in halting the decline in psychomotor performance over time in older subjects (Rees, Allen, & Lader, 1999). The effects of caffeine are intuitively dependent upon the degree to which a person is fatigued. For example, Reyner (2000) found that caffeine (200 mg) improved performance and reduced levels of subjective sleepiness for two hours in a restricted sleep condition but only for 30 minutes in the no sleep condition.

4.2.1 Summary

There are many stressful situations that are likely to be encountered by military personnel. Some of the stressors include heat, cold, noise, and fatigue. Generally speaking, if performance on tasks such as complex reaction time, vigilance, and other psychomotor tasks is impaired, it is reasonable to assume that more general processes such as information processing and decision-making are also disrupted to an extent. There is the potential for disruption of these processes to influence the prevalence of safe and unsafe behaviours in specific situations.

Research conducted to date is not able to answer the question of whether these types of stressors do influence safe and unsafe behaviours.

4.3 GUIDELINES FOR PHYSICAL ACTIVITY FOR HEALTH GAIN

The main message of the US Surgeon General’s report on physical activity and health (US Department of Health and Human Services, 1996) is that the American population can substantially improve their health and quality of life by including moderate amounts of physical activity each day. Health benefits appear to be proportional to amount of activity.

Major conclusions of the US Surgeon General's report are:

- All ages and both genders benefit from regular physical activity.
- Significant health benefits can be obtained with a moderate amount of daily activity such as a 30-minute brisk walk, 30 minutes of lawn mowing or raking leaves, a 15-minute run, or 45 minutes of playing volleyball.
- Additional benefits can be gained with greater amounts of physical activity.
- Physical activity reduces the risk of premature mortality in general, and of coronary heart disease, hypertension, colon cancer, and diabetes mellitus in particular. Physical activity improves mental health and the health of muscles, bones and joints.
- Over 60% of American adults are not regularly physically active with 25% having no physical activity beyond daily living.
- Research on understanding and promoting physical activity is at an early stage, but some evaluated interventions in schools, worksites and health care settings have been successful.

4.3.1 Effects of reduction in physical activity

Many of the beneficial effects of exercise training diminish within 2 weeks if physical activity is substantially reduced and effects disappear within 2 to 8 months if physical activity is not resumed (Bloomfield & Coyle, 1993; Shephard & Shek, 1995; US Department of Health and Human Services, 1996). There is a need for research to determine the minimal and optimal amounts of exercise for disease prevention (US Department of Health and Human Services, 1996).

4.3.2 Measurement of physical activity

Measurement of physical activity for health benefit requires incorporating several components (eg. intensity, frequency, duration and type) which can be conducted in different settings (eg. leisure, occupational, incidental and transport) using different forms of physical activity (eg. energy expenditure, fitness, strength and flexibility) (Armstrong et al., 2000). The type, intensity and duration of activity vary according to the requirement for different health outcomes (eg. moderate intensity regular activity to prevent cardiovascular disease compared with weight-bearing and strength and balance training to prevent falls injury in the elderly).

Tools for measuring physical activity range from subjective self report to objective assessment (Commonwealth of Australia, 1995; US Department of Health and Human Services, 1996). Reliability of recall measures of physical activity have been shown to be acceptable (Booth, Owen, Bauman, & Gore, 1996). The Australian Army Basic Fitness Test is the standard measure of fitness for all members of the Australian army (Molloy, 1990).

Consistent epidemiological estimates for incidence, prevalence, remission and mortality for physical activity in New Zealand show promise for predicting the effectiveness of health promotion strategies (Tobias & Roberts, 2001). Multi-state life table methods can model health risks and diseases and can be used as a decision support tool to improve the quality of policy advice in the area of promoting physical activity and to determine the relative effectiveness of different strategies.

5. BARRIERS TO AND INTERVENTIONS FOR PARTICIPATION IN PHYSICAL ACTIVITY

5.1 PSYCHOLOGICAL BARRIERS TO PARTICIPATION IN PHYSICAL ACTIVITY

We have the understanding that some defence force personnel engage in sub-optimal levels of physical activity. If levels of physical activity are to be increased, it is important to gain an appreciation for the determinants of, and barriers to, physical activity. Knowledge of these factors and the theories that explain how these factors influence physical activity is necessary to more effectively design interventions that promote physical activity.

There is considerable empirical support for the role of physical activity and fitness in disease prevention, and limited support for the role of physical activity in enhancing mental health and cognitive performance. As such there is a need to examine the determinants of physical activity to further elucidate the factors that influence behaviour and to assist in developing appropriate intervention strategies to promote higher levels of physical activity.

5.1.1 Determinants of physical activity

Numerous studies have researched determinants of physical activity. The most recent review of the association of determinants with physical activity in adults by Sallis and Owen (1999) incorporates approximately 300 studies. The determinants of physical activity fall within six major categories. These categories are highlighted in the table below along with examples of factors within each category that are strongly associated (either positively or negatively) with physical activity.

Table 5.1 Categories of determinants of physical activity

Category of Determinant	Strong Positive Association	Strong Negative Association
Demographic & biological factors	Education, genetic factors, income	Age, race (non-white)
Psychological, cognitive, and emotional factors	Enjoyment of exercise, expected benefits, self-efficacy, motivation, intention to exercise	Barriers to exercise, mood disturbance
Behavioural attributes and skills	Activity history during adulthood, dietary habits	Smoking
Social and cultural factors	Physician influence, social support (family, peers, friends)	
Physical environment factors	Access to facilities	Climate/season
Physical activity characteristics		Intensity, perceived effort

A number of variables that are often subject to modification have been consistently associated with physical activity. In particular, variables from the psychological, behavioural, and social categories have strong associations with physical activity, such as social support, self-efficacy, perceived barriers, perceived benefits, intention to exercise, and eating habits. Intuitively, research should be directed to evaluating intervention programs that are designed to alter the factors that are associated with physical activity and may therefore mediate physical activity.

5.1.2 Theories of behaviour that are relevant to physical activity

There are a number of theories that have been described in the literature to explain how some of the above factors influence participation in physical activity. These theories have been applied to other health related behaviours and are described in detail elsewhere (Biddle & Nigg, 2000; Maddux, 1995; Sallis & Owen, 1999; US Department of Health and Human Services, 1996).

The oldest theory is the health belief model (Becker et al., 1977a; Becker & Maiman, 1975; Becker, Maiman, Kirscht, Haefner, & Drachman, 1977b), which proposes that only psychological factors influence health behaviours. According to this model the presence of perceived barriers decreases the likelihood of engaging in preventative health practices, particularly if the perceived barriers outweigh the perceived benefits (Allison, Dwyer, & Makin, 1999a; Allison, Dwyer, & Makin, 1999b).

The theory of planned behaviour is also almost a completely psychologically orientated theory (Ajzen, 1985). This theory proposes that intention is the primary determinant of behaviours under personal control, including physical activity. The theory of planned behaviour uses an individual’s subjective judgements or attitudes about a behaviour, and subjective norms (and desire to comply with those norms), as the basis for determining the probability of an outcome happening. The intention to perform an act is the immediate precursor to the actual behaviour, and accurate measures of intent should also be reliable for measuring behaviour. Indeed a review by Godin (1994) reported a mean correlation between intention with exercise across 12 studies of 0.55, lending some scientific support to the theory. This theory also puts forward an influential role for the perceptions of the beliefs of significant others about the behaviour in question.

The broadest model is social cognitive theory, which incorporates the interactions between intrapersonal, social, and physical environment influences on behaviour. According to Bandura’s (1986) social cognitive theory, self-efficacy is the most important determinant of behaviour. In the context of physical activity self-efficacy represents confidence in one’s ability to perform specific physical activities in specific situations, and the more specific the measure of self-efficacy the more highly associated it should be with physical activity. This theory has received much support in the literature because self-efficacy is usually the strongest correlate of physical activity (Sallis & Owen, 1999).

Barriers to participation can encompass any number of the determinants associated with physical activity outlined in the table above. In addition, other factors such as stressful life events and perceived stress have also been found to be barriers to participation in physical activity (Sallis & Owen, 1999). However, regardless of whether the barriers to participation represent objective or subjective reality, there is a strong correlation between barriers and participation in physical activity (Sallis, Hovell, Hofstetter, & Barrington, 1992; Sallis & Owen, 1999). Again, it is obvious that the association between barriers to participation and rates of participation has a significant bearing on interventions designed to increase rates of participation in physical activity. If the barriers are objective then interventions to change the social and physical environment are needed, whereas if the barriers are more subjective then interventions targeting beliefs are more useful (Sallis & Owen, 1999).

5.2 PSYCHOLOGICAL INTERVENTIONS TO PROMOTE PHYSICAL ACTIVITY

The differing theories are used to accommodate different types of interventions. For example, the health belief model is applied in the development of knowledge-based interventions for health education, including risk appraisals. The theory of planned behaviour is sometimes applied in interventions involving mass communication that attempt to change attitudes. Social cognitive theory is often used in a variety of behaviour modification interventions (Sallis & Owen, 1999).

There have been many studies that have evaluated the effectiveness of various interventions to promote physical activity. A meta-analysis of 127 intervention studies was published by Dishman and Buckworth (1996b) and will form the focus of discussions in this section. The mean weighted effect size over all studies was 0.75, indicating that interventions to promote physical activity generally do have large effects, although the larger studies tended to be more effective.

The type of intervention was related to effect size. Behaviour modification had an extremely large effect size (0.92), whereas other interventions such as cognitive behaviour modification and health education/risk appraisal had effect sizes around 0.10. There was, however, large variation within each category, which indicates that a particular intervention is dependent upon other factors such as nature of the problem and the design of the intervention program.

Briefly, behaviour therapy is traditionally founded on the work of Skinner (1953), Bandura (Bandura, 1986), and Pavlov (see Corsini & Wedding, 1995). Skinner (1953) emphasised the role of environmental antecedents and consequences in controlling behaviour. Examples of antecedents in the context of physical activity include keeping gym clothes in the car or having exercise equipment at home. Consequences are the most powerful determinants of behaviour. Consequences that increase a particular behaviour are rewards or reinforcers, while those that are designed to decrease the incidence of a particular behaviour are punishers. Clearly the rewards and punishments are dependent upon the specific nature of the problem.

Both cognitive and behavioural methods are used to modify behaviours and so it is common to refer to cognitive behaviour therapy (CBT) rather than behaviour therapy. Corsini (1995) notes that the incorporation of cognitive theory and therapy into behaviour therapy is so total that it is difficult to find pure behaviour therapists working in outpatient settings.

Cognitive behavioural interventions are primarily derived from social cognitive theory (Bandura, 1986), and include self-monitoring of behaviours, goal setting, increasing positive thoughts about the behaviour, and relapse prevention (Sallis & Owen, 1999). As discussed earlier, there has been much research confirming the link between self-efficacy and physical activity, and so specific cognitive behavioural interventions can (at the least) provide short-term increases in physical activity.

Finally, the goal of the physical activity was also an important determinant of the effectiveness of the intervention programs. The goal of increasing physical activity in recreation time was the most effective in increasing activity (effect size 0.85), as were strength training and prescribed aerobic exercise to a much lesser extent. Activity that emphasised low to moderate intensity training (rather than high intensity) and unsupervised training (rather than supervised) were also extremely effective (Sallis & Owen, 1999).

After controlling for all other factors, regression analysis revealed that the larger effect sizes were associated with interventions that involved combined ages (not just young or old), group programs (rather than individual), and healthy groups (rather than high risk or disease groups). Effective intervention characteristics were behaviour modification, mediated approaches, low to moderate intensity, and those that focussed on increasing activity in recreation time. The outcome measure associated with the strongest effect size was attendance as opposed to activity monitors or fitness testing (Dishman & Buckworth, 1996b; Sallis & Owen, 1999).

5.2.1 Summary

There are many known determinants of physical activity in the general community. It is not known to what extent these are determinants of physical activity in the military context. There are a number of theories that have been described in the literature to explain how some of the above factors influence participation in physical activity. The differing theories are used to accommodate different types of interventions. CBT, incorporating cognitive and behavioural methods, appears to be the most appropriate and effective intervention for the military context. Interventions involving behaviour modification and with the goal of increasing activity in recreation time have traditionally been the more effective interventions to promote physical activity in the general community.

5.3 PUBLIC HEALTH AND OTHER INTERVENTIONS TO PROMOTE PHYSICAL ACTIVITY AMONG ADULTS

The three main reasons given by Victorians for non-participation in sport and physical activity were reported by the Australian Bureau of Statistics (Australian Bureau of Statistics, 1996; Booth, Bauman, Owen, & Gore, 1997) as *no time/too busy* (32%) *not interested* (30%) and *injury/illness* (22%). Useful information about injury as a barrier to participation in physical activity and/or sport and recreational activity is hampered by a lack of specificity and detail in available injury data in Australia (Finch & Owen, 2001; Jones, Cowan, & Knapik, 1994). For example, there is no ongoing collection of specific sport and physical activity injury data and exposure status in national collections nor are there any available valid and reliable tools for population survey data collection. Further, current collections tend to categorise injury together with illness or disability rather than employing discrete and specific variables. These issues are also applicable to ADF data systems, with a consequent lack of specificity for assessing risk factors for injury.

Consistent influences on physical activity patterns among adults and young people include confidence in one’s ability to engage in regular physical activity (eg. self-efficacy), enjoyment of the activity, support from others, positive beliefs concerning the benefits of physical activity, and lack of perceived barriers to being physically active (US Department of Health and Human Services, 1996). Consideration of barriers to participation in physical activity and design of sport and intervention strategies to overcome these barriers are crucial to any promotion program.

Generally, physical activity is more likely to be initiated and maintained (US Department of Health and Human Services, 1996) if the individual:

- Perceives a net benefit
- Chooses an enjoyable activity
- Feels competent doing the activity
- Feels safe doing the activity
- Can easily access the activity on a regular basis
- Feels that the activity does not generate financial or social costs that he or she is unwilling to bear
- Experiences a minimum of negative consequences such as injury, loss of time, negative peer pressure, and problems with self-identity
- Is able to successfully address issues of competing time demands
- Recognises the need to balance the use of labour-saving devices (cars, golf carts) and sedentary activities (watching television, use of computers) with activities that involve a higher level of physical exertion.

In some settings, policy-level interventions may be necessary to enable people to achieve and maintain an adequate level of activity (US Department of Health and Human Services, 1996). Policy changes that increase opportunities for physical activity can facilitate activity maintenance for motivated individuals and increase readiness to change among the less motivated.

Four core elements of the National Physical Activity Guidelines for Australia (Commonwealth Department of Health and Aged Care, 1999) provide the rationale for increasing physical activity. Approaches for achieving this increase include a positive attitude to activity, regular daily routines of activity with shorter time periods of moderate intensity activity (brisk walking, cycling) and additional periods of enjoyable vigorous sporting and other fitness activities. Although there is advice on the need for warm-up and cool-down periods, the guidelines do not explicitly address the reduction of risk for those musculoskeletal and traumatic injuries associated with physical activity (Finch & Owen, 2001).

5.3.1 Behavioural management approaches

A major review of individual behavioural management approaches to increase physical activity generally indicates that only small unsustained effects are achievable (US Department of Health and Human Services, 1996). More research is needed using longer time frames, larger sample sizes, and control groups to determine maintenance of effect of behaviour change. Parallels from other successful fields of public health interventions may inform effort in initiating and maintaining increased activity levels. Examples could include the Sunsmart campaign to reduce skin cancer and interventions to prevent transmission of Human Immunodeficiency Virus (HIV).

5.3.2 Interventions in health care settings

Interventions in health care settings offer an opportunity to counsel adults about physical activity and other healthy behaviours (Calfas, Sallis, Lovato, & Campbell, 1994). The Physician-based Assessment and Counselling for Exercise (PACE) program involved brief

(2-5 minutes) counselling messages for patients. Compared with patients who did not receive counselling, those who did had significantly greater improvements at 4-6 weeks in their reported stage of physical activity readiness, their reported amount of walking for exercise, and their scores from an activity monitor (Calfas et al., 1994). Nevertheless, many providers do not believe that physical activity is an important topic to discuss with their patients and many lack effective counselling skills (US Department of Health and Human Services, 1996).

5.3.3 Health promotion interventions

Three large community-wide trials for reducing risk factors for cardiovascular disease, using a variety of strategies including promotion of physical activity, showed relatively modest effects for increased physical activity. The trials, funded by the National Heart, Lung and Blood Institute, were the Minnesota Heart Health Program (MHHP) (Luepker et al., 1994), the Pawtucket Heart Health Program (Carleton, Lasater, Assaf, Feldman, & McKinlay, 1995), and the Stanford Five-City Projects (Farquhar et al., 1990). Physical activity programs to encourage weight loss or prevent weight gain in the Minnesota Heart Health Program (Jeffery, 1995) showed that financial incentives in conjunction with correspondence courses were more effective than face-to-face educational classes alone. Indeed, preventing weight gain through exercise may be easier to promote than weight loss (Wing, 1995) particularly if targeted at three time periods of higher risk for weight gain: between 25 and 35 years, in the peri-menopausal period for women, and in the year following successful weight loss. Programs to promote physical activity in many of these large heart health studies have been only one element of a larger number of different interventions to reduce multiple risk factors and consequently may not have been sufficiently robust to produce greater effects.

5.3.4 Worksite interventions

Worksite interventions have the potential to reach a large proportion of the population with easy access to employees and social networks and the application of workplace environmental change to influence worker behaviour (US Department of Health and Human Services, 1996). A buddy system of workmates and friends can support behaviour change for increasing physical activity. Worksites have the potential to encourage increased physical activity by offering opportunities, reminders and rewards for doing so. A controlled study across four automotive manufacturing plants tested three approaches to increase physical activity and fitness of workers (Heirich, Foote, Arfurt, & Konopka, 1993). The approaches were (1) a staffed physical fitness facility (2) one-to-one counselling and outreach with high-risk employees (eg. those with hypertension, excess weight, smokers) and (3) one-to-one counselling and outreach to all employees, peer support, and organisational change (eg. establishing non-smoking areas). The fourth site acted as a control and offered health education classes and special events. At the end of 3 years, exercise prevalence was lowest at the plant with the exercise facility. Nearly half of the employees at the 2 outreach sites reported exercising 3 times a week. Although the introduction of worksite activity programs across western countries is now substantial, there is insufficient evidence to determine which elements are necessary for effectively increasing and maintaining activity levels among all employees (US Department of Health and Human Services, 1996). Nevertheless, limited evidence indicates that widespread employee involvement and support, together with organisational commitment through policies and programs, may be important factors in increasing physical activity.

5.3.5 Communication strategies

Communication strategies have the potential to rapidly reach a very large audience. Generally, media can (1) increase the perceived health importance of physical activity (2) communicate the healthy benefits of physical activity (3) increase interest and awareness of availability of physical activity programs (4) provide role models for active lifestyles and (5) encourage involvement through cues for action such as signs to use stairs instead of escalators (Blamey, Murtrie, & Aitchison, 1995; Donovan & Owen, 1994). The effectiveness of media to initiate and maintain physical activity is unclear due to a lack of systematic evaluation. Nevertheless, communication strategies may be more effective if they are linked with opportunities to act on media messages or if messages are tailored to stages of change or the needs of sub-population groups (Carleton et al., 1995; Donovan & Owen, 1994; Young, Haskell, Taylor, & Fortmann, 1996).

Promising research strategies in promoting physical activity include (1) tailoring interventions to people’s needs, experiences and stage of change (2) timing of interventions to reinforce new behaviours and prevent relapse (3) peer involvement and support and, (4) an engaged community at all levels (US Department of Health and Human Services, 1996).

Most evaluated interventions are discrete programs lacking concomitant support from the larger environment in which the intervention takes place (US Department of Health and Human Services, 1996). Many physical activity researchers believe that environmental and policy approaches (with their powerful moderating effect on individual volition) are necessary to complement interventions that focus on behaviour change. Thus interventions require comprehensive, population-based approaches incorporating both individual and societal-level strategies (Green & Simons-Morton, 1996; Schmid, Pratt, & Howze, 1995). Interventions should not rely exclusively on individuals actively initiating participation in physical activity but should also incorporate passive strategies through the provision of accessible, convenient and affordable amenities and policies that support participation.

5.3.6 Summary

Overall, controlled interventions in the workplace, health care settings and in communities to increase physical activity have been positive but effects tend to be small (range 5-10%) and short lived (US Department of Health and Human Services, 1996) suggesting that multiple interventions over time may be necessary to sustain effects. A meta-analysis of 127 interventions to increase physical activity in the community, workplace, school, home, and health care settings involved 131,000 subjects (Dishman & Buckworth, 1996a). The results indicated moderate positive effects for increased activity and that effects were larger when interventions used behaviour modification, employed a quasi-experimental design or were of short duration. Further experimental confirmation using clinical trial methods is required to determine the optimal ways for selection of intervention components, settings, and population segments to maintain increases in physical activity (Dishman & Buckworth, 1996a).

Research is needed to establish the processes of promoting, developing and maintaining healthier habits of physical activity because of evidence of an increasingly under-active population. A major research focus is to determine the most effective and cost-effective intervention approaches through studies to identify key determinants of physically active lifestyles among diverse populations and to use the information to design and disseminate effective programs (US Department of Health and Human Services, 1996).

6. POTENTIAL ADVERSE EFFECTS OF PARTICIPATION IN PHYSICAL ACTIVITY

6.1 INTRODUCTION

There are a number of risks associated with physical activity of which injury is the most common (US Department of Health and Human Services, 1996). Injury is caused by acute exposure to physical agents (mechanical energy, heat, electricity, chemicals, ionising radiation) interacting with the body in amounts or at rates that exceed the threshold of human tolerance (Baker, O'Neill, Ginsburg, & Li, 1992). Generally, injury frequency varies inversely with injury severity whereby severe injuries (deaths, hospitalisations) are relatively rare compared with injury of lower severity (presenting to emergency departments, general practice or other health professions).

Potential adverse injury outcomes of sport and physical activity (Table 6.1) can interfere with the enjoyment of sport and physical activity and reduce the health benefits of long term risk reduction in chronic disease (cardiovascular disease, type 2 diabetes, poor functional fitness at older ages, and psychopathology). Importantly, they can also result in lost work time, or in extreme cases, to disability or death.

Table 6.1 Potential adverse outcomes of sport and physical activity injuries

Injury leads to prevention or limitation of participation in sport and physical activity by:

- Time lost from sport/physical activity
- Non-participation
- Limited athletic participation/performance in terms of frequency and duration
- Limited performance, whether or not there is also time lost to sports/physical activity
- Threats to career for elite athletes unable to perform their work

Injury affects the health of participants by:

- Causing permanent physical, psychological, or emotional damage and disability
- Creating significant treatment needs (eg surgery, physiotherapy, medication)
- Creating significant rehabilitation needs
- Resulting in fear of future injury
- Resulting in non-participation and subsequent implications for future health status

Injury results in significant health costs through:

- Health system expenditure
  - Health insurance costs
  - Costs of insurance against injury
- Being associated with other financial costs to the individual (eg. protective equipment)
- Being associated with significant costs to industry (sport and employment)
- Being associated with loss of potential income for individuals and sporting clubs/organisations
- Being associated with time away from work or other activity

Source: Finch & Owen 2001

The most common injuries associated with physical activity are musculoskeletal which are relatively mild and self-limiting (US Department of Health and Human Services, 1996). They include strains, sprains and tears particularly involving the knee, ankle and foot, and less commonly, dislocations and fractures. Repetitive activities can increase risk for injury in associated joints, tendons and muscles. The risk for injury associated with physical activity increases with increased intensity, frequency, and duration of activity and depends on the type of activity. Moderation of these parameters can reduce risk. Avoidance of excessive amounts of physical activity or excessively high levels of activity intensity can reduce musculoskeletal injuries (US Department of Health and Human Services, 1996).

6.2 BASIC TRAINING AND PHYSICAL ACTIVITY INJURIES IN THE MILITARY

6.2.1 International studies

Injury epidemiology

The US Armed Forces Epidemiological Board (AFEB) Injury Prevention and Control Work Group reported in a review that non-combatant injuries are the leading cause of death, disabilities, hospitalisations, outpatient visits, and manpower losses among all three branches of the military services (Jones, Perrotta, Canham-Chervak, Nee, & Brundage, 2000; Kaufman, Brodine, & Shaffer, 2000; Songer & La Porte, 2000). Training injuries, sports, falls, and motor vehicle crashes are among the most important causes of morbidity. In 1990, rates for disability for the US Navy and Marine Corps, the Army, and the Air Force were over 20, 16, and 10/1000 respectively. More than half of the disability cases for the Army and Navy were orthopaedic, mostly injury-related compared with 20-30% for the Air Force. The leading conditions resulting in lifetime compensation appear to be lower back and knee conditions (Songer & La Porte, 2000). Total direct costs of compensation were $US1.5 billion for the financial year 1990.

Injury rates vary depending on the type of unit and type and amount of training. Rates during US military training range from 6 to 12 per 100 male recruits per month to 30 per month for Naval special warfare training (Kaufman et al., 2000). Injury rates for military recruits and infantry soldiers appear to be similar to endurance or competitive athletes and vigorous exercise participants, but considerably lower than for contact sports participants (Kaufman et al., 2000; Lauder, Baker, Smith, & Lincoln, 2000).

In 1994, injuries accounted for 11% of hospitalisations in the Army, 9% in the Navy, 14% in the Marine Corps, and 8% in the Air Force (Jones et al., 2000). The major sporting injuries in the Army were to the knee and involved the anterior cruciate ligament, the meniscus, ankle sprains and fractures mainly during football and basketball (Lauder et al., 2000). Outpatient injuries, such as ankle sprains and stress fractures (mainly to the tibia, with some foot and femur stress fractures) were common and tended to be mild to moderately severe. However they represent a major cause of manpower loss to the forces (Jones et al., 2000; Knapik, Ang, Reynolds, & Jones, 1993). The time loss or duty limitation varies with the type of injury. During a six month period, fractures accounted for the highest mean number of limited duty days (103 days), sprains (17 days) and fewer days for tendonitis (7) and strains (3)(Knapik et al., 1993).

Approximately 25% of male and 50% of female US Marine Corps Officer recruits sustained one or more injuries during 6 weeks of basic training in 1997 (Piantanida, Knapik, Brannen, & O'Connor, 2000). Other studies during basic military training show similar findings (Bijur et al., 1997; Jones & Knapik, 1999; Jordaan & Schwellnus, 1994) The injury rate for the US Marine Corps was 3.9/1,000 hours of training with the highest rates occurring during weeks 2, 3 and 6. On average, injured recruits were assigned to more than three modified training days for each injury. The rate for bone stress reaction in females exceeded that for males by more than a factor of three. In a separate study, the most common foot injuries per 1,000 recruit training days in the US Marine Corps were stress fractures (0.56/1000 days) ankle sprains (0.53/1000 days) and Achilles tendonitis (0.39/1000 days) (Linenger & Shwayhat, 1992).

Although athletic capability is vital for satisfactory military basic training and successful service, orthopaedic conditions are common reasons for hospitalisation and premature discharge of military recruits (Cox, Clark, Li, Powers, & Krauss, 2000). In the US, potential tri-service military recruits who are medically disqualified may receive a waiver to enter the service on a case-by-case basis. A study to assess outcomes of this system compared 281 individuals with a medical waiver for knee problems to 843 recruits without a hospitalisation or discharge history for knee injury (Cox et al., 2000). The Relative Risks (RR) for hospitalisation and premature medical discharge for a knee condition in the high risk (medical waiver) group were significant at 8.0 (CI 2.1, 29.9) and 14.0 (4.6, 39.6) respectively. The high risk group was also significantly more likely to be hospitalised for any diagnosis (RR 1.4) and prematurely discharged for any condition (RR 2.1). Given that defence forces need to develop and maintain physically active personnel, research is needed on the prevention and control of knee morbidity during training and military duty, particularly in those with previous knee injury.

In a prospective study of the natural history of anterior knee pain caused by overactivity, 15% of 390 elite Israeli infantry recruits had anterior pain in 77 knees during 14 weeks of basic training (Milgrom, Finestone, Shlamkovitch, Giladi, & Radin, 1996). After 6 years (3 years after returning to civilian life) self-report indicated that half of the knees were still symptomatic, but only 8% of the knees had severe enough pain to hinder physical activity. Most ankle sprains occurring over a period of three months in US Military Academy cadets resulted in a return to sports by 6 weeks, but dysfunction persisted in 40% of cadets for up to six months after injury (Gerber, Williams, Scoville, Arciero, & Taylor, 1998).

Stress fractures of the lower leg account for approximately 3% of US Army recruit injuries, sprains and muscle strains 3-5%, tendonitis and low back pain approximately 7% each (Kaufman et al., 2000). Similar injuries occur in the Marine Corps. Rates can vary according to differences in training and differences in the definition and classification of musculoskeletal injuries (Kaufman et al., 2000). Female Navy recruits who developed pelvic stress fractures during basic training were shorter and lighter and more frequently Asian or Hispanic than recruits without stress fractures (Kelly, Jonson, Cohen, & Shaffer, 2000). An increased rate of Achilles tendon ruptures in blacks compared with whites in the US military was associated with basketball (Davis, Mason, & Clark, 1999). As basketball exposure status was not measured, the possible association of injury with racial differences cannot be substantiated. This study illustrated clearly the need for exposure status in studies of causal analyses.

A review of possible aetiological theories for stress injuries to bone indicates that multiple factors including mechanical (loading, muscle physiology, tendon), anthropomorphic (height, tibia size, foot type), training (overtraining, transitional training) and bone health characteristics influence the risk for fracture and the risk varies by gender (Arendt, 2000). Bone health and the prevention of osteoporosis (as measured by bone mineral density) are dependent on adequate calcium and vitamin D intake and exercise for peak bone mass and its preservation throughout life (NIH Consensus Development Panel on Osteoporosis Prevention Diagnosis and Therapy, 2001).

A study of 106 British Army Officer cadets during the first 14 weeks of their Commissioning Course found nearly half (46%) sustained a reported injury with no gender difference (Harwood, Rayson, & Nevill, 1999). The most common body parts injured were at the lower extremity, including the foot (19%) knee (15%) and ankle (11%). Trauma and overuse accounted for 51% and 41% of the injuries respectively.

The same British Army study (Harwood et al., 1999) also assessed the effectiveness of the Commissioning Course in improving fitness and the ability to perform the variety of physical tasks demanded of army cadet work. Although 91% of cadets passed the course, there was variation in the magnitude and direction of change in fitness, a lack of smooth progression of fitness, a lack of emphasis on strength training, variation between gender, and failure to maintain standards of fitness over the 44 week program. The lack of emphasis on strength training is surprising given the need for strength-related materials handling activities in the armed forces. Further, there are important gains from strength training in injury prevention and for performing lifting tasks and loaded marching (Harwood et al., 1999; Reynolds, Heckel, & Witt, 1994; Williams, Rayson, & Jones, 1999b).

The effects of basic training on physical fitness and material handling ability in British Army recruits found favourable adaptations particularly for aerobic fitness (Williams, Rayson, & Jones, 1999a). Physical training included 71 periods of 40 minutes, within the first 10 weeks of basic training, made up of sports (19) circuit training (18) agility (10) swimming (9) endurance, mainly running (7) and manual handling tuition in safe technique (2). There was no progressive resistance training during basic training. Importantly, basic training did not improve the muscular strength and material handing ability of recruits. As many of the tasks that soldiers encounter in their military careers require adequate performance in this area, there are major implications for future injury risk during material handling and a need to establish optimal preventive strategies during training and physical activity.

In a review of resistance training, effects were found for the muscular, endocrine, skeletal, metabolic, immune, neural and respiratory systems (Kraemer & Duncan, 1998). Benefits include fitness development, improved health, and the prevention and rehabilitation of orthopaedic injuries (Feigenbaum & Pollock, 1999). Programs of resistance training should be varied to maximise gains and prevent overtraining. Strength and resistance training could be incorporated into both basic training and also included as essential physical activity for development and maintenance of performance in material handling tasks during defence force service (Williams et al., 1999a).

The rate of female personnel medically discharged from the British Army steadily rose between 1992 (3/1000/year) and 1996 (35/1000/year) with only a correspondingly minor increase for males (Bergman & Miller, 2001). Females under 22 years accounted for the majority of the excess medical discharges which were due to musculoskeletal disorders and injuries caused by military training. Three quarters of the discharges were recruits and 70% had sustained mainly lower limb stress fractures and overuse injuries. Reduction in excess risk of injury during training may depend on some modification of training for females while retaining similar performance outcomes. Trials of adapted less injurious training programs are warranted.

Risk factors for injury

Risk factors for training injuries include higher age (Heir & Eide, 1997), female gender (Kaufman et al., 2000), greater amounts of running (Jones et al., 1994), low levels of physical activity/sedentary lifestyle (Heir & Eide, 1997; Jones, Bovee, Harris, & Cowan, 1993a; Jones et al., 1993b; Shaffer, Brodine, Almeida, & Ronaghy, 1999a), low levels of aerobic fitness/performance (Heir & Eide, 1997; Jones et al., 1993b; Knapik et al., 1993; Shaffer et al., 1999a), previous injury history (Kaufman et al., 2000), high and low degrees of flexibility (Jones et al., 1993b; Knapik, Jones, Bauman, & Harris, 1992), high arches of feet (Cowan, Jones, & Robinson, 1993), cigarette smoking (Altarac et al., 2000; Jones et al., 1993b; Reynolds et al., 1994) smokeless tobacco use (Heir & Eide, 1997) and cold weather (Reynolds, Williams, Miller, Mathis, & Dettori, 2000).

A prospective study (Jones et al., 1993a) of intrinsic risk factors for exercise-related injuries among army trainees during 8 weeks of training found females (RR 1.8), low levels of running performance, high Body Mass Index (BMI) for men (RR 3.4), an inactive life-style among men (RR 12.4), and short stature for women (RR 1.7) were associated with injury. An earlier prospective study of 400 female Army recruits found an average of 13 days of training lost due to injury (Kowal, 1980). Early training overuse injury accounted for 42% of reported injuries. Injury was attributed to lack of prior conditioning, greater body weight and fat percent, and limited leg strength. Identification of these factors before training and remedial activity may minimise risk for injury during training. Inherent physiological factors such as wide pelvis, less strength and greater joint flexibility may also contribute to increased risk of injury.

Injury surveillance and injury coding

US Military injury hospitalisations are coded using the NATO Standardised Agreement (STANAG) system and used for injury surveillance across the services (Amoroso, Bell, Smith, Senier, & Pickett, 2000a; Smith, Dannenberg, & Amoroso, 2000). It has been recommended that the International Classification of Disease (ICD) system used in civilian hospitals would be a cost efficient solution for updating the STANAG system (Amoroso, Smith, & Bell, 2000b; Lincoln, Smith, & Baker, 2000). The ability to compare military and civilian injury epidemiology to inform prevention would be a major advantage of adopting the ICD. In the Australian context, this would entail coding according to ICD-10 Australian modification (ICD-10-AM), Second Edition (July 2000).

The US Naval Health Research Centre developed the Sports Medicine Research Team Systems (SMARTS) software application to support epidemiological research in outpatient musculoskeletal injuries (Brodine, Shaffer, Johnson, Le, & Garland, 1995). Data from six training sites using the SMARTS software show that musculoskeletal injury incidence is associated with the intensity of training. For men, the highest incidence occurred during Naval Special Warfare training (42%), followed by the US Marine Corps basic training (26%), and US Navy basic training (11%). Among women, the highest incidence occurred in US Marine Corps officer candidate training (62%), followed by US Marine Corps basic training (44%) and US Navy basic training (37%) (Shaffer, Brodine, Ito, & Le, 1999b).

The US Army also has a comprehensive disease and injury surveillance system, the Defence Medical Epidemiological database (DMED), which contains data on hospitalisations, ambulatory visits and reportable diseases (Kaufman et al., 2000). Although the system codes for injury type, it lacks cause-of-injury codes (E-codes) and codes for duty activity related to injury. This detailed information is necessary for defining specific injury problems and informing injury prevention strategies. [The ADF has made good progress on upgrading injury surveillance with the recent introduction of the Defence Injury Prevention Program Injury Surveillance System].

It is important that differences in injury definition, methods of data collection (medical records, questionnaires, interviews) training programs, and differential access to medical care be carefully considered before drawing major conclusions about comparisons between studies of injury incidence in the armed forces (Knapik et al., 1993). In particular, research is needed for injury prevention strategies and programs which are evidence-based for a positive effect.

6.2.2 Australian studies

Injury and its consequences are major health issues for the Australian Defence Force (ADF) (Defence Health Service Branch, 2000; Rudski, 1993). Approximately half of all injuries are related to sport and other physical activity, largely training. Injuries during physical training account for the highest loss of working days, days of hospitalisation, sick days and light duty days. Similarly, in an ADF culture of strong competitiveness in sport, soccer, rugby union/league, running/jogging and touch football injuries account for substantial loss of personnel working capacity (Table 6.2). In 1997-98, one percent of the full-time ADF personnel retired largely as a result of disorders of the musculoskeletal system.

In the first Australian study of risk factors for injury during basic training in the Royal Australian Air Force, most severe or moderately severe injuries (resulting in being delayed to join a later course and/or a loss of 5 days training) occurred during the first two weeks of training (Ross & Woodward, 1994). The incidence rate for these injuries was 2.7% (238) of which 123 were overuse injuries and 115 acute injury. Risk factors for both types of injury combined included female gender, body mass index >26.9, winter training, and a history of lower limb injury. The associations were stronger for overuse injury. Low pre-enlistment physical activity was also a risk factor for overuse injury. No separate results were included for acute injury. In a more recent report involving 1538 male Army recruits, Pope et al (2000) found that the most consistent and strongest predictor of injury risk across all soft tissue and bone injury categories except ankle strain was fitness as assessed by the 20m shuttle run test. Other significant predictors were age and enlistment date.

In a RCT of a standard recruit training program (N=180) or a weighted march activity substituted for all formal run periods in the training program (N=170), lower limb injury occurred to 80% and 61% of recruits respectively (Rudzki, 1997b). The rank of injuries in the run group were knee, ankle, foot, and shin and for the march group, foot, knee, ankle and shoulder. Causes of injury were running, physical training and the obstacle course for the run group compared with marching, physical training and the obstacle course for the march group.

In 1999, a cohort study (Pope, Herbert, Kirwan , & Graham, 1999a) found that lower limb injury status predicted attrition from a 12 week basic training program in the Australian Army. A lower limb injury was sustained in 21% (276) of the subjects with tibial stress fracture or periostitis accounting for 36% of these injuries. Injured subjects were 10 times less likely to complete training than non-injured subjects.

Table 6.2. Summary distribution and patterns of injuries in sport and physical activities in the ADF 1997-98.

Activity ranked by work days lost	Nature of injury %		Location (body site injured) %		Mechanism %		Environmental Agency Ranking
Physical training Casualties n=744 Work days lost n=7361	Sprains and strains Disorders of muscles/tendons/soft tissues Fractures Other*	48.5 12.0 9.8 29.7	Lower limb Mainly knee (33.0) and ankle (33.0) Upper limb Mainly shoulder (35.8) and finger (16.0) Trunk Mainly lower trunk (50.0) Head Other**	48.0 19.9 17.9 5.4 8.4	Body stressing Falls/trips/slips Being hit by moving object Hitting another object Other and unspecified	34.5 29.0 14.7 7.7 11.7	1. Traffic and ground surface other 2. Buildings and other structures 3. Wet and oily traffic
Touch football Casualties n=172 Work days lost n=3341	Sprains and strains Disorders of muscles/tendons/soft tissues Fractures Other	43.6 17.4 11.0 28.0	Lower limb Mainly knee (50.0) and ankle (33.0) Upper limb mainly shoulder (40.0) and finger (6.0) Trunk Head Other	55.8 25.6 9.9 3.5 5.2	Body stressing Falls/trips/slips Being hit by moving object Hitting another object Other and unspecified	22.1 33.7 15.1 14.5 14.6	1. Traffic and ground surface other 2. Wet and oily traffic and ground

Activity ranked by work days lost	Nature of injury %		Location (body site injured) %		Mechanism %		Environmental Agency Ranking
Running/jogging Casualties n=186 Work days lost n=2261	Sprains and strains Disorders of muscles/tendons/soft tissues Fractures Other	52.2 16.7 7.5 23.6	Lower limb Mainly knee (18.8) ankle (26.9) upper leg (5.9) and lower leg (11.3) Upper limb Trunk Other incl head	80.0 7.0 7.0 6.0	Body stressing Falls/trips/slips Hitting another object Other and unspecified	32.3 40.3 4.3.0 23.1	1.Environment 2. Equipment
Rugby Casualties n=214 Work days lost n=2120	Sprains and strains Fractures Disorders of muscles/tendons/soft tissues Other	34.6 15.9 13.6 35.9	Lower limb mainly knee (50.0) and ankle (21.0) Upper limb mainly shoulder (58.0) finger (14.0) and wrist (14.0) Trunk Head Other	30.8 31.3 13.6 14.5 9.8	Body stressing Falls/trips/slips Being hit by moving object Hitting another object Other and unspecified	8.0 11.0 66.0 10.0 5.0	1. Environment 2. Equipment
Soccer Casualties n=158 Work days lost n=1854	Sprains and strains Fractures Disorders of muscles/tendons/soft tissues Other	47.5 20.3 10.8 21.4	Lower limb mainly knee (22.8) ankle (22.8) and lower leg (8.9) Upper limb Trunk Other incl head	69.0 13.0 7.0 11.0	Body stressing1 Falls/trips/slips Being hit by moving object Hitting another object Other and unspecified	12.7 19.0 46.8 15.2 6.3	1. Equipment 2. Playing surface

Source:(Defence Health Service Branch, 2000)

**Other: contusion/crushing, dislocation, open wound, unspecified*

***Other: spine/pelvis, chest/abdomen, other/unspecified.*

A review of sports participation, sports injuries and osteoarthritis in the general population found that the onset of osteoarthritis appears to depend on age, gender and the frequency, intensity, and duration of physical activity (Cheng et al., 2000; Saxon, Finch, & Bass, 1999). Excessive participation in high impact sports, especially over a long period and at elite levels, can increase the risk for developing osteoarthritis (Saxon et al., 1999). Risk may be increased in the presence of previous joint injury, knee surgery, abnormal joint anatomy or alignment, joint instability, underlying muscle weakness, or imbalance. Overweight individuals may also be at increased risk if engaging in significant levels of exercise. Further research using cohort or case control studies to confirm the relationship between exposure to risk factors and later development of osteoarthritis is needed. These findings for the general population have implications for the military with respect to injury, disability and premature discharge costs among personnel.

6.3 SPECIAL TRAINING AND INJURY

A retrospective observational study using 10 years of US Army Safety Centre data indicated females had more than twice the parachuting injury rate of males in 1985 but by 1994 the rate approached that of males at approximately 20/10,000 jumpers/year (Amoroso, Bell, & Jones, 1997). Nevertheless, female parachutists appeared to be at greater risk of serious injury, particularly lower extremity fractures, than males, despite jumping under conditions considered to be safer such as during daylight hours or in static-line non-tactical environments. In contrast, male parachutists were more likely to sustain upper limb extremity injury associated with ground hazards. These observations suggest that modification of parachuting conditions particularly for females may prevent injury. Further prospective, controlled research studies could clearly assess pertinent risk factors and evaluate prevention measures, including strength training and footwear for females, to reduce parachuting injuries in the military.

A prospective study examined running history as a risk factor for subsequent overuse injury in Navy, Sea, Air and Land (SEAL) recruits (Shwayhat, Linenger, Hofherr, Slyman, & Johnson, 1994). These recruits undergo 6 months of vigorous training (considered to be among the most demanding in the world) placing them at high risk for overuse injury. The incidence of overuse injuries among the 224 recruits was 3.4/1000 recruit days. Recruits who ran at a pace slower than 8 minutes/mile or on softer surfaces in the 6 months before commencing basic training were significantly more likely to sustain an overuse injury during basic training (Odds Ratio (OR) 3.6 and 2.0 respectively). This was also the case for those who ran for 30 minutes or less (OR 2.2) and less than 17 miles/week (OR 2.1). The findings suggest that reduction in risk for overuse injuries may be achieved by adjusting exercise routines before training. Running on varied surface types with a gradual increase in speed, duration, and weekly distance covered may reduce risk of overuse injury. A later study showed no evidence for a protective effect on overuse injuries of resting from running for 1 week at any time in an 8 week basic military training period in a population of 1357 army recruits (Popovich, Gardner, Potter, Knapik, & Jones, 2000).

6.4 PHYSICAL ACTIVITY INJURIES IN THE GENERAL POPULATION

In the general population in 1992, fatalities at home and on the road were 28 times more common, and occupational fatalities 2.5 times more common in England and Wales than deaths due to leisure and sporting activities (Ball, 1998a). The average fatality risk per 100 million participations was highest for air sports, mountaineering and motor sports (100-1000 deaths per unit of exposure), moderate for water related activities (boating, fishing and swimming 10-60 deaths per unit of exposure), low for ball sports (soccer, rugby, hockey and cricket, 2-4 per unit of exposure) and very low for golf, tennis and badminton (0.2-1.0 per unit of exposure).

Emergency Department data for non-fatal injuries showed a different picture. Although 44% of all sports injury was associated with soccer, the rank for risk of injury per unit of exposure was rugby, soccer, cricket, hockey and skiing. Swimming carried a very low risk of non-fatal injury (Ball, 1998a). The UK Sports Council survey (Nicholl et al., 1991; Nicholl et al., 1995) encompassed all sporting injuries including those attended by general practitioners, physiotherapists and other professions or treated at home. Results showed very much higher frequencies of injury but many similarities in risk ranking with the Emergency data reported above. These data reflect the pyramid structure found for other major injury categories where fatalities and hospital attendances are merely the tip of a large injury iceberg. In assessing the significance of these risks for fatal and non-fatal injuries associated with popular sports and exercises it is also essential to examine the substantial benefits of the associated activities to the health of the population.

The risk for injury in some popular sports can be very high compared with general activities (Ball, 1998b). Risk for serious soccer related injuries is more than a hundred times that of serious injury in jobs considered to be relatively hazardous such as mining and construction. Most injury rates for sports are derived from an average over the participating population, which is made up primarily of young to middle aged males, especially athletes. Comparatively few studies deal with those over 50 years or the unfit, where the main benefits of exercise are expected to accrue. Further research on the risks and benefits of increased exercise is needed for these groups.

6.5 COSTS ASSOCIATED WITH INJURY RESULTING FROM PHYSICAL ACTIVITY

Fundamental to all fields of safety is the concept of reducing risks until they are As Low As Reasonably Practical (ALARP), a concept defined by the courts (Ball, 1998b). Thus, risks of harm must be reduced until the point has been reached such that the cost and difficulty of applying further measures outweighs the benefits in terms of risk reduction. Contrary to the accepted notion of exercise benefiting all age groups, there are strong arguments from the perspective of medical care costs that are in favour of exercise in adults 45 years and over, but not for younger adults (Ball, 1998b). The cost of treating injuries in the young outweigh the reduced costs of treating heart disease and other selected conditions in this age group.

Injury associated with sport and physical activity can lead to substantial health care costs and possible disability (Australian Institute of Health and Welfare, 2000; Finch & Owen, 2001). Subsequent reduced mobility may result in inactivity, increasing the risk for cardiovascular disease and other health problems. Physical activity programs should be integrated with robust injury prevention principles and systematic evaluation of all relevant effects. These principles apply to both the ADF and the general Australian population.

6.6 OTHER HEALTH RISKS ASSOCIATED WITH PHYSICAL ACTIVITY

The most serious but rarer risks associated with participation in physical activity include myocardial infarction and sudden death (Kohl, Powell, Gordon, Blair, & Paffenbarger, 1992; Mittleman et al., 1993; Willich et al., 1993). These deaths occur particularly with unaccustomed strenuous exercise but the net effect of regular activity is a lower risk of mortality from cardiovascular disease. Data are inadequate to determine whether stroke incidence is affected by physical activity or exercise training (US Department of Health and Human Services, 1996). It is important for sedentary individuals to gradually build up to the desired level of activity and if they have known cardiovascular disease or multiple risk factors they should have a medical evaluation before embarking on vigorous activities (US Department of Health and Human Services, 1996). The Centers for Disease Control and the National Institutes of Health recommend that accumulating physical activity over the course of the day for heart health is a satisfactory process despite limited evidence.

7. INTERVENTIONS TO PREVENT ADVERSE SIDE EFFECTS OF PHYSICAL ACTIVITY

7.1 INTRODUCTION

The chain of circumstances and conditions culminating in an injury event can be analysed and categorised into pre-event, event and post-event (Haddon, 1972). Measures to prevent or control injury generally target the links in this chain and fall into three groups; primary, secondary and tertiary countermeasures (Figure 7.1).

Figure 7.1 Primary, secondary and tertiary countermeasures to injury

Primary countermeasures (preventive actions taken before an event that may cause injury) →	• active supervision of recruits • pre-sporting competition conditioning and fitness program • environmental factors
↓	
Secondary countermeasures (actions taken to prevent or reduce the severity of injury during an event) →	• protective equipment • safe falling techniques • speed kept under control
↓	
Tertiary countermeasures (actions taken after an event to minimise harmful consequences →	• prompt access to quality first aid and medical care on site • appropriate treatment and referral

There is compelling evidence that physical training and sporting injury is a major problem for the ADF (Defence Health Service Branch, 2000). Prevention measures should ideally address protection through individual and collective evidence-based countermeasures. These countermeasures should not discourage active participation in physical activity since the indicators of low physical activity levels such as overweight, hypertension and high cholesterol are risk factors for cardiovascular disease and psychopathology (Finch & Owen, 2001). Properly planned interventions should address primary risk factors such as the amount and level of training intensity, levels of fitness, and possibly equipment (eg. footwear). Such interventions would be expected to result in a substantial reduction of lost work time/training time, attrition, and medical costs, while maintaining military readiness (Kaufman et al., 2000). Prevention programs could impact optimal fitness of the ADF and associated long term health gains with consequent cost savings in treatment and retirement benefits because of injury and chronic health problems.

7.2 PREVENTION OF INJURY RELATED TO MILITARY TRAINING

7.2.1 General training

Preventive strategies in military training should target the primary risk factors for musculoskeletal injury (Kaufman et al., 2000). These include the amount and level of intensity of training, levels of physical fitness and possibly equipment such as footwear. However, it is important to consider the individual differences in response to regular physical activity when planning training activities (Bouchard & Rankinen, 2001). The strong evidence for heterogeneity of training response to physical activity is related to pre-training levels in some cases but appears to have little association with age, sex, and ethnic origin. Familial factors are significantly associated with variability in training response.

As access to military recruits is limited before attending basic training, the most likely effective method of improving physical fitness levels while minimising injury risk may be to modify their training regimen to a gradual increase in duration, frequency and intensity of training activities over the training period (Kaufman et al., 2000). This modified approach was trialed in US Marine Corps by reducing the distance run, gradually increasing exercise and military hiking, and emphasising aerobic activities in early training phases before progressing to anaerobic activities and strength conditioning (Almeida et al., 1997). The evaluation of the intervention showed a significant reduction in overuse injuries, a lower extremity stress fracture reduction of 55%, and an annual cost saving of $US 4.5million for the San Diego Marine Corps. Recruit fitness at the end of the modified training was as high as that for previous recruit intakes undergoing standard training.

A controlled intervention study examined the role of stretching in reducing lower extremity overuse injury in a 13 week US military infantry basic training course in two companies (Hartig & Henderson, 1999). Increasing the flexibility of the hamstring musculotendinous unit resulted in a significant positive effect on injury for the intervention company (hamstring injury incidence 16.7%, N=150) compared with the control company (29.1%, N=148)

By contrast, a randomised trial of pre-exercise stretching for prevention of lower-limb injury during a 12 week training program for 1538 Australian male army recruits showed no significant effect of stretching on all-injuries risk (Hazard Ratio 0.95, 95% CI 0.77-1.18), nor on soft-tissue injury risk or bone injury risk (Pope, Herbert, Kirwan, & Graham, 2000). Similarly there was no significant effect for pre-exercise calf muscle stretching on injury risk in a quasi-random cohort study in Australian Army recruits (N=1093) (Pope, Herbert, & Kirwan, 1998). The study had relatively low power and could not necessarily detect modest but clinically useful effects.

In an Australian study of sequential army training cohorts, the incidence of training related female pelvic stress fractures reduced from 11.2% (N=143) (male rate 0.1%) to 0.6% (N=161) after the introduction of training changes (Pope, 1999). These changes were: a reduced route march speed (7.5 to 5km/h), running on softer surfaces, individual step length promotion rather than marching in step, march and run formations more widely spaced, and interval-running training rather than middle distance runs. The results suggest that modification of physical training can reduce injury while maintaining training efficiency.

After basic training, individuals are required to maintain at least a minimum modest fitness level, particularly for aerobic capacity, regardless of job needs (Kaufman et al., 2000).

However, as aerobic fitness may not be closely linked with job requirements or 'military fitness' (Rudzki, 1989), physical fitness standards should also include muscular strength, power, and endurance for satisfactory job performance (Kraemer & Newton, 2000). Muscular power is a product of strength and speed of movement, and power development through training is paramount for optimal neuromuscular function (Kraemer & Newton, 2000).

7.2.2 Reducing running distance

Prevention of lower extremity injuries during basic training is a major focus for the military (Jones et al., 2000). A reduction in stress fractures in US Army recruits was achieved by the quasi-randomised introduction of a week of reduced lower limb activity (no running, jumping or double timing during the third week of training) (Scully & Besterman, 1982). In a RCT, a reduction in marching distance from 168 to 110km over 11 weeks of training in the Israeli Army found no evidence for a reduction in stress fracture rate (Gilardi, Milgrom, Danon, & Aharansom, 1985). In Australia, recruits were randomised to a standard training program (N=180) or a substituted weighted march activity for all running periods in the program (N=170) (Rudzki, 1997a). Although the relative risk for all injury in the running group was not significant (RR 1.24), there were significant reductions in both the incidence of lower-limb injury and the overall severity of injury.

In an observational study (N=1,634 males, N=318 females) of changes in the Australian Army recruit training program (cessation of road runs, introduction of 400-to 800-m interval training, reduction in test run distance from 5 to 2.4 km, standardisation of route marches, and the introduction of deep-water running) there was a 46.6% reduction in the total injury rate (Rudzki, 1999).The annual rate of male medical discharges decreased from 81.1 to 47.0/1,000 recruits but increased for females from 104 to 164.2/1,000. Other outcome measures included estimated cost savings of $A1,267,805 for male medical discharges and $A61,539 for the 50% reduction in bone scans. The disparity between discharge rates for gender suggest a potential benefit from a review of mixed training and the possible introduction of initial entry fitness standards.

There appears to be a threshold for the benefit gained from the distance run in training above which injury rates increase without any further increase in aerobic fitness (Jones et al., 1994; Pollock, Gettman, & Milesis, 1977). These findings reflect those for running injuries and their prevention for the general population where risk factors for injury include higher weekly distance run, faster running pace, not participating regularly in other sports, and a history of previous running injury (Jacobs & Berson, 1986; Koplan, Powell, & Sikes, 1982; Marti, Vader, & Minder, 1988). In 1995, a prospective study by the US Naval Health Research Centre showed that a 50% reduction in stress fracture incidence without loss of aerobic fitness benefit could be achieved by gradual progression of training and reducing running distances (Almeida et al., 1997; Jones & Knapik, 1999; Kaufman et al., 2000). Indeed, it is important that thresholds of optimal training be identified for individuals of different fitness and performance levels so that the high risks due to overtraining can be avoided while still maximising physical fitness (Kaufman et al., 2000).

Given the overuse injuries associated with military training, deep water running can be an effective option for maintaining land-based running performance because of similar mechanics (Burns & Lauder, 2001). Deep water running decreases stress and weight-bearing on injured tissues and joints, while maintaining cardiovascular fitness and the necessary training effect. In a program of deep water running involving 181 soldiers precluded from weight-bearing exercise because of injury, the physiological characteristics, program design, and mechanics of deep water running and its advantages over other aerobic exercise in maintaining land running performance in military personnel was reviewed (Burns & Lauder, 2001). All participants showed good tolerance for the deep water running program and satisfactory maintenance of specified fitness.

7.2.3 Shock-absorbent boot insoles

Three RCTs compared the use of an orthotic insole in military training footwear (Andrish, Bergfield, & Walheim, 1974) (N=2777 US Naval recruits, foam rubber heel-pad in tennis shoes for running) (Milgrom et al., 1985) (N=295 Israeli Army recruits, 'military stress orthotic' insole in army boots); (Schwellnus, Jordaan, & Noakes, 1990) (N=1388 South African Army recruits, neoprene insole). Pooled data from these studies analysed for a Cochrane Review indicated that insoles significantly reduced the total number of stress fractures and stress reactions of bone in military recruits (Gillespie & Grant, 2001). The most common stress fractures of the lower limb are to the tibia followed by the foot, femur and pelvis (Matheson et al., 1987; Schwellnus et al., 1990). In a recent RCT, military recruits were randomised to a custom-made soft or semi-rigid biomechanical shoe orthosis or no orthosis for 14 week training (Finestone et al., 1999). Results showed a 10.7%, 15.7% and 27% incidence of stress fractures respectively. The soft orthoses were tolerated better by recruits than the semi-rigid orthoses. The authors conclude that among trainees at high risk for stress fractures, prophylactic use of custom made biomechanical orthoses may be warranted.

In earlier studies, the comparative use of shock-absorbent visco-elastic polymer boot insoles or standard mesh insoles in a large randomised trial (N=3,025) did not demonstrate a difference in stress fractures and stress reactions of the lower extremities in US Marine recruits during 12 weeks of training (Gardner, Dzindos, & Jones, 1988). A smaller study of US Marine recruits (N=90) compared cellular neoprene and cellular polyurethane insoles in normal military footwear and found no significant difference in stress fractures (Smith, Walter, & Bailey, 1985). A comparison between training in basketball shoes and normal military boots in the Israeli Army was inconclusive for total stress fractures and reactions but training in basketball shoes was associated with a significant reduction in the incidence of stress fractures of the foot (Milgrom et al., 1992). These studies suggest that the variation in results may be related to the type of insole and footwear, and the type and level of training.

Importantly, the choice of orthotic material appears to be crucial to prevention of injury (Kaufman et al., 2000). In a prospective trial, neoprene (Schwellnus et al., 1990) was shown to be effective while a controlled trial showed sorbathane (viscoelastic polymer) to be ineffective (Gardner et al., 1988) at preventing injury. However, neoprene compacts quickly so is not a practical solution for injury prevention in the longer term. More advanced orthotic materials with both shock absorption and durability characteristics remain to be trialed (Kaufman et al., 2000). In particular, optimisation of many characteristics are required for properly functioning military footwear. These characteristics include good support (stiffness) to minimise ankle sprains which necessarily competes with good shock absorption (low stiffness) to minimise overuse injury. Other characteristics such as slip resistance and protection from heat, cold, and water are essential for footwear performance. More research such as randomised trials using a factorial design for different training and footwear conditions are needed in this area (Kaufman et al., 2000).

7.2.4 Specific tasks/performance

A randomised trial (N=745) by the US Army Safety Centre to study the effect of outside-the-boot ankle braces on 745 parachutists found an 85% reduction in ankle sprain incidence from 1.8% to 0.3% (Risk Ratio =6.9) (Amoroso et al., 1998). The ankle brace is now in routine use in the Army Airborne School in Georgia (Jones et al., 2000). This approach may require testing under Australian conditions (if substantially different from the US) before possible implementation for Australian Army parachutists. It is important that any implementation of evidence-based injury intervention strategies be evaluated for benefit/costs and monitored for ongoing effectiveness over time (Kaufman et al., 2000).

Table 7.1 Summary of countermeasures to injury in military training

Injury type/activity	Strategy/ Countermeasure	Key findings/references	Quality of Evidence*	Comments/recommen dations
All injury/basic training N=1634 males, 318 females	Prospective observational study of modified training incorporating interval training, deepwater running, route march standardisation, cessation of road runs	46.6% reduction in all injury rate, 40.8% reduction in medical discharge rate for males, female rate increased by 58.3% (Rudzki, 1999)	Weak-stronger	Some support for other studies of modified training (Almeida et al., 1997; Kaufman et al., 2000). Requires confirmation with RCTs
All injury/basic training	Intervention trial of reduction in running miles, increase in exercise hiking, early emphasis on aerobic exercise followed by later strength training	Reduction in all injury, 50% in stress fracture incidence, mainly tibia. (Almeida et al., 1997)	Stronger	Promising. Requires confirmation with RCTs
Running injury/basic training N= 180, 170	Cluster randomisation of standardised training versus weighted marching	No significant reduction in all injury (RR=1.24) but reduction in lower limb injury and overall severity of injury (Rudzki, 1997a)	Stronger	Promising. Requires confirmation with RCTs
Lower limb/basic training N=1583	RCT pre-exercise stretching	Hazard ratio 0.95 (95% CI 0.77-1.18). No effect on all injury, soft tissue, or bone injury risk (Pope et al., 2000)	Stronger	Sample size possibly insufficient to demonstrate more modest but clinically useful effects
Lower limb/basic training N=1093	Quasi random cohort study of calf stretching	No statistically significant effect on injury risk (p=0.76) (Pope et al., 1998)	Weak-stronger	Sample size may have been insufficient to demonstrate an effect
Hamstring injury/basic training N=150, 148	Intervention (controlled by company) of stretching hamstring musculotendinous unit	Rate of hamstring injury intervention company 16.7%, for control 29.1% (p=0.02) (Hartig & Henderson, 1999)	Weak-stronger	Promising. Requires confirmation with RCTs
Female pelvic stress fractures/ basic training N= 143, 161	Sequential cohort study of reduced route march, running on softer surfaces, individual step size promotion for marching, interval running	Female pelvic stress fracture rate reduced by 95% (p<0.001) (Pope, 1999)	Weak-stronger	Modification of training can reduce injury while maintaining training efficiency Requires RCT to confirm
Stress fracture lower limb/basic training	Quasi random trial presumably by squad of reduced lower limb activity with no running, jumping	Cochrane Review Reduction in stress fractures Peto OR 0.36 (95% CI 0.17-0.76) when assuming individual randomisation but not for cluster randomisation	Weak-stronger	Basic evidence Requires confirmation with RCTs

	or double timing during the third week of training	(Gillespie & Grant, 2001; Scully & Besterman, 1982)		
Stress fracture rate/basic training	Quasi randomised trial of reduced marching distance versus standard training	No reduction in injury (3.8% and 3.9 % injuries per squad respectively (Gilardi et al., 1985)	Strongest	Early study
Lower extremity stress fractures/ vigorous military training	Shock absorbent insoles in military boots	Pooled data from 4 RCTs in civilian and military populations showed insoles reduced incidence of stress fractures (OR 0.47; CI 0.30-0.76) Ref: Gillespie & Grant (2000)-Cochrane review	Weak-stronger	Promising. Choice of orthotic material crucial: neoprene effective but has short life, sorbathene ineffective
Ankle injuries account for 30-60% of all parachuting injuries N=745	Outside the boot ankle brace to reduce ankle sprains during Army paratrooper training	RCT involving 745 army volunteers who made 5 static jumps. Incidence of ankle sprains was 1.9% in non-brace-wearers vs. 0.3 in brace-wearers (RR=6.9, p=0.04). There was no increase in risk for overall injuries in those wearing the brace (RR=1.2, p=0.65) Ref: Amoroso et al 1998	Brace prevented lateral or inversion ankle sprains. Promising countermeasure	RCT confirmation under Australian conditions

*** Weak, Stronger, Strongest - refer to Table 1.1 for definition**

7.3 PREVENTION OF INJURY IN PHYSICAL TRAINING AND SPORTS

In 1997/8, 5,038 full time ADF personnel reported a workplace injury or illness to DEFCARE, 9.1% of the full-time force (Defence Health Service Branch, 2000). The total number of working days lost (WDL) for these illnesses and injuries was 32,644 (1,216 hospital days, 6,287 sick days and 25,141 light duty days). The annual cost impact of lost time is estimated to exceed $7m. per year. The injury and poisoning group accounted for over three-quarters (76.1%) of all casualties. In the ADF Health Status Report casualty-producing physical activities are classified into six groupings: work-related {including walking (non-sport and fitness), equipment maintenance, stores handling, driving, fighting and cleaning}, sports, physical training, military training, motor vehicle and other (Defence Health Service Branch, 2000).

Physical training (PT) is the leading casualty-producing physical activity accounting for 14.3% of total casualties among full-time ADF personnel. Three sports –rugby union/league, touch football and soccer– rank among the ten leading causes of casualties (and WDL) accounting for 3.9%, 3.2% and 3.1% of total casualties respectively. Other sports that are prominent in the ranked list of casualty-producing physical activities (and associated with significant proportions of WDL) are: running/jogging (2.0% of all casualties); Australian football (1.9%); and basketball/netball (1.8%). Volleyball is ranked among the 'top 15' physical activities associated with WDL but did not rank in the 'top 15' for casualties.

In this section of the report our aim is to suggest strategies and countermeasures to reduce the burden and cost of physical activity-related injury in PT and sports using two approaches. The first investigates potential countermeasures to knee, ankle and shoulder injuries with reference to the efficacy of interventions reported in the research literature. These three body sites are most associated with casualties and WDL in PT and sports according to DEFCARE data (Defence Health Service Branch, 2000).

In the second approach, potential strategies and countermeasures to injury in the three sports most associated with WDL (touch football, rugby and soccer) are presented. The recommendations for prevention are based on an analysis of DEFCARE data on the frequency, pattern, mechanism and circumstances of injuries in these sports. Because these data are limited and may be biased due to under-reporting, the general sports injury literature was accessed to 'fill in the gaps' with the focus on studies in similar populations (predominantly male and mostly participating at the community competition level). The incidence, nature, pattern and risk and contributory factors to sports injury at the community participation level are not well researched. Direct comparison between studies is often difficult because data are frequently drawn from different populations (in terms of age and gender mix and skills/competition level) and accessed from different sources (for example retrospective or prospective studies of cohorts of participants, insurance or hospital data) that may have inherent biases. To further complicate matters, researchers have adopted different definitions of sport and sports injury, data classification systems and methods of reporting results.

The research literature was also accessed to identify promising and, less frequently because of their rarity, proven countermeasures. In general, the evidence on the effectiveness of the various putative prevention measures is inconclusive because of shortcomings and weaknesses in evaluation design, for example small sample sizes, lack of controls and use of unsophisticated statistical techniques. Therefore, the intervention strategies and countermeasures identified in this review fall mostly into the category of 'promising' rather than 'proven' and require confirmation in well-designed trials.

7.3.1 Generic countermeasures to ankle, knee and shoulder injuries in physical training and sports

Table 6.2 shows that the most frequently occurring injuries in PE and the four sports most associated with injury (touch, soccer, rugby and running/jogging) and WDL are knee, ankle and shoulder injuries (Defence Health Service Branch, 2000). Knee injuries predominate, accounting for 18.0% of all injuries in these five physical activities, followed by ankle injuries (15.9%). The overall contribution of shoulder injuries could not be calculated from the information given but they comprise more than 8% of the total.

The precise contribution of each of these body sites to the overall injury toll in all PE- and sports- related physical activities is unable to be estimated because detailed data on body site injured were not reported in the ADF Health Status Report (Defence Health Service Branch, 2000).

7.3.1.1 Preventing knee injuries

Knee injuries were the most frequently occurring injury in the five leading physical activities related to WDL due to injury and illness in the ADF in 1997/8 (PT, touch, soccer, rugby and running/jogging) (Defence Health Service Branch, 2000). They comprised 18.0% of all injuries in these five physical activities (n=1,474). Knee injuries were more frequent in touch (27.9%) than in the other four sports in which they accounted for 15.4% to 18.8% of injuries. The specific nature of these injuries is not detailed in the ADF Health Status Report (Defence Health Service Branch, 2000) except that they appear to be mostly sprains and strains and disorders of the muscle, tendons and other soft tissue. Analysis of additional data from the newly established Canberra ADF Health Service sports injury database for the first 6 months of 2001 for touch, soccer, rugby, running/jogging, and Australian football show that the knee injuries in the football codes are predominantly sprains of meniscal/labral and anterior cruciate ligaments. By contrast, in running/jogging overuse knee injuries (patellar-femoral syndrome and tendinitis) predominate. These data are tentative because the numbers of injuries for each body site were generally small.

There are few well-developed and evaluated preventive strategies for knee injuries in the literature. The most promising are the programs designed to reduce non-contact ACL injuries in females based on altering biomechanical risk factors through neuromuscular training. There is a burgeoning interest in understanding and preventing sports-related ACL injuries in women because a number of studies have shown that females are at greatly increased risk of ACL injury compared to males in sports in which they compete with similar equipment and rules (Griffin, 2000).

Acute injuries (ligament damage)

Non-contact knee ligament injuries are caused by forces generated by the individual either through a sudden twist or violent muscle contraction. They are estimated to comprise approximately 70% of sports-related knee ligament injuries but the proportion of non-contact to contact knee ligament injuries can vary between sports. They frequently occur when an athlete makes a sudden change of direction, a common manoeuvre in team ball sports and skiing. Preliminary evidence suggests that specific training and skills development programs have the potential to reduce the risk of non-contact knee injuries in jumping and pivoting sports (Griffin, 2000; Harmon, 2000).

Two kinds of neuromuscular training programs –balance board training and plyometric training– have shown positive results in controlled studies involving male soccer players and female participants in high school soccer, basketball and volleyball teams, respectively (Caraffa, 1996; Hewett, 1996). In neither study were subjects (or teams) randomised into intervention and control groups, so selection bias may have affected results. Both studies had low statistical power because of the small number of observed knee ligament injuries in the study period.

Balance board (proprioceptive) training

Caraffa et al. (1996) investigated the possible preventive effect of a gradual proprioceptive (balance board) training program on the incidence of ACL injuries in a prospective controlled study (non-randomised) involving 600 male soccer players in 40 semi-professional and amateur teams (Caraffa, 1996). Three hundred players were instructed to train 20 minutes per day in a graduated 5-phase program based on increasingly difficult skills performed initially without a balance board and progressing through the use of a series of balance boards of different designs. A control group of 300 players from comparable teams playing with similar equipment on similar fields trained 'normally' (with no balance board training). Players were observed over three full seasons. The authors report a seven-fold reduction in ACL injuries per team per year in the intervention group compared to the control group (0.15 injuries per team per year vs. 1.15 injuries, P=0.001).

These findings need to be confirmed before widespread implementation is recommended, especially since a conflicting report is now published from an RCT of the effectiveness of a balance board intervention to decrease lower limb injuries in Swedish female soccer players (Soderman, 2000). As described previously, the Swedish trial found that 20-minutes of balance board training integrated into the team's regular training regime had no effect on the frequency and rate of ankle and knee injuries in the intervention group compared to controls who trained normally. The number of ACL injuries that occurred in the study period was small (six in all, five of which occurred in the intervention group).

Plyometric (jump) training

Hewett et al. (1996) initially piloted the effect of a six-week jump training program in a preliminary biomechanical study involving eleven female volleyball players (Hewett, 1996). Landing mechanics and lower extremity strength were compared with male athletes before and after training. Before training, females were found to have a marked imbalance between hamstring and quadriceps muscle strength and much lower knee flexor moments during landing from a jump than male athletes. Note that a recent case control study of knee injuries, a small sub-study of the West Australian sports injury prospective cohort study, found that hamstring concentric strength and previous injury were the only two variables to emerge from multivariate analysis as significant risk factors for knee injuries in the four sports studied - hockey, football, basketball and netball (Sports Medicine Australia, 2001).

After the six-week plyometric stretching and strength program, peak landing forces were decreased significantly in the females and there were significant increases in hamstring muscle power and strength and hamstring-to-quadriceps peak torque ratios. The program also decreased side-to-side hamstring muscle strength imbalances. These positive results led the researchers to hypothesise that this program could decrease knee ligament injury rates in female athletes. They subsequently trialed the intervention in a larger population of high school sports participants.

In their major study, the researchers recruited 43 soccer, volleyball and basketball teams from 12 area high schools. Fifteen female teams (*n*=366) elected to be in the intervention group and 15 female teams (*n*=463) and 13 male teams (*n*=434) elected to be controls. (The non-random allocation of teams to intervention and control groups is a methodological weakness.) The training program implemented in the pilot study was used, including flexibility, plyometrics and progressive resistance weight training for the lower leg. Team coaches and trainers in the intervention group were sent an instruction manual and video, and a certified athletic trainer and physical therapist demonstrated stretching and plyometric techniques with an emphasis on proper form.

The training sessions lasted approximately 60-90 minutes and were conducted 3 times a week on alternating days. All players completed a pre-season screening questionnaire and the certified athletic trainers attached to the teams completed weekly injury report forms to monitor injuries and exposure to training and games over one season (participation in a game or training session = one athlete exposure). All serious knee injuries were diagnosed by a certified trainer and referred to a sports medicine physician. ACL ruptures were confirmed by arthroscopy. Only those players who completed at least 4 weeks of the pre-season training were included in data analysis.

There were 14 serious knee injuries (eight anterior cruciate and six medial collateral ligament ruptures) in the 1,263 athletes tracked through the study. Ten of 463 untrained athletes sustained serious knee injuries (0.43 injuries/1000 athlete exposures; 8 non-contact), 2 of 366 trained female athletes sustained serious knee injuries (0.12/1000; 0 non-contact) and 2 of 434 male athletes sustained serious knee injuries (0.09/1,000; 1 non-contact) (p=0.02). Untrained female athletes experienced a 3.6 times higher serious knee injury rate compared with trained female athletes (p=0.05) and a 4.8 times higher rate than untrained male athletes (p=0.03). There was no significant difference in serious knee injuries between the trained female group and the male control group.

This study demonstrates that a specific plyometric training program may decrease knee injury risk in female athletes but this finding needs to be confirmed in larger studies where subjects or teams are randomised and other study design biases remedied. As raised by the authors, there were more volleyball players in the trained group and this may have biased this group towards lower knee ligament injury rates (there is some evidence that women's volleyball has a lower rate of knee injury than women's soccer or basketball).

<u>Modifications to play techniques</u>

There is some laboratory and epidemiological evidence that suggests that modifying play techniques, particularly landing techniques, may reduce the risk of lower limb injuries, including knee instability.

McNair et al. (2000) investigated the effects of technical instruction for landing, auditory cue (listen to impact sound) and imagery on ground reaction forces (measured by a force plate) in a laboratory study involving 80 asymptomatic male subjects who were randomly assigned to three intervention groups and a control group.

All 80 subjects were adults, mean age 24 years, and currently active in recreational sports that did not involve jumping. Subjects in the technical instruction group were told to land as softly as possible by positioning themselves on the balls of the feet with bent knees just before landing and, on landing, by lowering their heels slowly to the ground and keeping knees bent until well after landing. Subjects in the auditory cue group were asked to listen to the sound of their landing and use that information to assist them to land more softly in subsequent jumps. Subjects in the imagery rehearsal group were asked to picture themselves as bubbles, feathers, leaves or snowflakes floating to the ground when they performed their next jumps. Control subjects were asked to use the experience of their first set of jumps to land more softly on their next set of jumps.

The authors reported that the peak vertical ground reaction forces in both the technical instruction group and the auditory group were significantly less that those in the control group. In both cases, the peak ground reaction force decreased by 0.4 BW (13%). There was no significant difference between the imagery and control groups. The authors conclude that the findings may have clinical relevance to the rehabilitation and prevention of knee instability and osteoarthritis because these conditions have been linked to repeated stresses on the knee. They recommend that when subjects are learning landing techniques, their training program should include exercises to strengthen and control quadriceps and plantaflexor muscles.

Biomechanical studies of the landing techniques of skilled netball players by Steele and associates (Steele, 1993) identified several landing technique modifications that minimise stress on the musculoskeletal system, particularly the knee.

On the basis of these and studies in other sports, netball players are advised by Steele (1993) to:

- land with the foot neutrally aligned;
- ensure adequate hip flexion (approximately 33 degrees when the foot initially contacts the ground and 45 degrees during the maximum landing force);
- flex the knee adequately (approximately 17 degrees at initial foot-ground contact and 40 degrees at the maximum landing force); and
- land with trunk upright.

There are no 'real world' evaluation studies to show whether adopting this landing technique reduces the risk of knee ligament injuries in netball players.

Epidemiological studies also indicate that awareness raising and training in safe landing techniques may prevent ACL injuries. Ettlinger et al. (1995) conducted awareness raising sessions for skilled skiers (ski instructors and patrollers) in ski resorts in Vermont, USA alerting them to the high risk of ACL injuries from a particular type of uncontrolled fall, using a training video that showed actual injury events. Participants were trained to recognise the potential high-risk fall situation and to quickly correct one or more of the six elements of the fall that were believed to contribute to the risk of ACL injury. The taught response included landing on both feet after a jump whenever possible and keeping knees flexed and skis together on landing or falling.

Comparison of pre- and post- intervention data on ACL injuries in 4,000 on-slope ski area staff from the 20 ski areas that fully participated in the training program were compared to data from 22 ski areas where staff were not exposed. In the intervention group serious knee sprains declined by 62% in trained patrollers and instructors compared to two previous seasons, but no decline occurred in the unexposed group (*P*=0.005). The intervention and comparison groups were not carefully defined and no data were collected from participants on the level of adoption of the recommended landing techniques.

The landing technique in skiing is probably of limited direct relevance to other sports but similar advice on the importance of knee flexion on landing is given to netballers and basketballers. Preliminary evidence from a prospective study involving female college basketball players suggests that modification of landing technique, through training drills, is a promising countermeasure to ACL injury.

Henning et al. (1994) conducted a 10-year in-depth investigation of 'not-hit' (non-contact) and 'hit' (contact) ACL injuries presenting to the mid-America Center for Sports Medicine. Overall, the case series covered 673 ACL injuries of which 534 (79%) were 'not-hit' (non-contact) and 133 (20%) were 'hit'. The sports with the highest frequency of 'not hit' ACL injuries were: basketball (152 cases); gridiron (77); snow skiing (68); baseball/softball (57); soccer (51); and volleyball (28).

The authors concluded, from a detailed examination of the mechanisms and circumstances (play situations) of the non-hit ACL injuries, that the majority involved three common injury-producing deceleration techniques (plant and cut, straight knee landing and the one-step stop with the knee extended). The authors then formulated a prevention program, tailored to the six specific sports with the highest frequencies of ACL injuries. The basic program consisted of drills in which athletes practise substituting an accelerated rounded turn (off a bent knee) for the pivot and cut, flexed-knee landing for straight leg landing and the three-step stop instead of the one-step stop. The program is currently being trialed in a prospective study comparing knee injury incidence in two elite female junior college basketball teams. Preliminary results indicate that there is promise of a significant decrease in ACL injuries when these techniques are taught prospectively (Griffin, 2000).

<u>Shoe-surface interface</u>

One of the most likely extrinsic risk factors postulated for non-contact ACL injuries is the shoe-surface interface. An important contributor to knee injury is the relative fixation of the foot to the ground (Moore, 1994). The interactions between the leg, the foot, footwear and surface is complex and not well understood in relation to lower limb injury. Characteristics of the surface and playing shoe that have been shown to be associated with knee injury (in American football) are playing on a synthetic surface (Skovron, 1990) (meta-analysis)] and cleat (heal and forefoot) length and shape (Lambson, 1996; Nedwidek, 1969; Torg, 1974). An early study showed that the replacement of the traditional 7-cleat shoes worn in American football with 'soccer-type' boots (with moulded soles) resulted in a marked decrease in both the incidence and severity of knee injuries in American high school football leagues (Torg, 1971). More recently, Lambson et al. (1996) reported an association between football cleat design and non-contact ACL injury in a 3-year prospective study in gridiron. The study showed that football boots with a greater number of cleats and higher torsional resistance are associated with an increased number of non-contact ACL injuries.

Non-contact ACL injuries are relatively common in all football codes, and particularly so in Australian football. Orchard et al. (2001) recently published the findings from a prospective study of the interaction of intrinsic (player-related) and extrinsic (environment related) risk factors for ACL injuries in Australian football at the elite level. The authors utilised logistic regression analysis to control for confounding factors. There were 63 proven non-contact ACL tears recorded between 1992 and 1999 in 100,820 player exposures. By far the strongest risk factors were a player history of ACL ligament reconstruction either in the previous 12 months (RR 11.3; 95% CI 4.02-31.91) or before the previous 12 months (RR 4.44; 95% CI 4.02-31.91). (These findings raise the question of the safest time for players to return to play after ACL reconstruction and, for the ADF, whether personnel with reconstructed knees should be allowed to participate in sports that carry any risk of ACL injury).

Weather conditions associated with dry field conditions were also shown to be significantly associated with non-contact ACL injuries. High water evaporation in the month before the match (RR 2.55, 95% CI 1.44-4.52) and low rainfall in the year before the match (RR 2.87, 95% CI 1.30-6.32) more than doubled the risk of ACL injuries in players. The authors suggest that these weather patterns are probably linked to harder grounds that have lower shoe-surface traction forces and, consequently, lower force transmission to the knee in movements such as pivoting (cutting). They recommend consistent extra watering and, perhaps, covering of grounds during times of high water evaporation, as well as sowing grass types that result in lower traction. The same research group is currently involved in a further study of ACL injuries in elite players that includes the direct measurement of ground conditions, using a penetrometer that measures ground hardness, for all matches conducted in Victoria and interstate in the Australian Football League (AFL).

The findings outlined above may be relevant to other football codes played on natural turf such as rugby, soccer and touch. An association between ACL injuries and dry conditions was previously noted in a review of non-contact ACL injuries in American football (Scranton, 1997).

The role of the football shoe in knee injury in Australian football has not been researched. A new type of Australian football boot, in which the traditional studs or stops are replaced by wide rubber ribs, was introduced onto the market in the early 1990s. The designer and manufacturer claim that the new 'Blade' shoe decreases the risk of foot fixation and, therefore, reduces the torsional forces on the knee and ankle. This new style of boot has not been subject to independent laboratory testing or controlled field trials.

Knee pads, taping and bracing

Contact knee ligament injuries (caused by an external force directed at or near the knee) are estimated to account for between 30-40% of knee ligament injuries. The most common contact knee ligament injury is a tear of the medial collateral ligament (MCL). This injury is typically caused when another player applies force to the lateral side of a leg when an athlete has his or her foot fixed to the ground and the knee is at or near full extension. This usually occurs in a tackle or unintentional hit situation. If the force is great the ACL may also be damaged. ACL damage in isolation is less common but can occur if an athlete is tackled or hit from behind the knees or if the knee is bent backwards. Strict enforcement of rules forbidding below the knee tackles may prevent some of these injuries in football codes. Knee ligament injury from impact with the ground or structures such as goalposts are less frequent.

Knee pads are recommended for sports where there is a high risk of direct trauma due to contact with the playing surface, for example American football and volleyball. There is no tradition of wearing them in other sports such as rugby or Australian Rules football where knee-ground impacts are also common.

The evidence on the effectiveness of knee support in the prevention of knee ligament injury was recently reviewed by the Rugby Injury Prevention Program (RIPP) in New Zealand (Gerrard, 1998a). The reviewer concluded that taping of the patellar to relieve patellofemoral pain may be effective but should be regarded as an interim measure and one component of a comprehensive treatment program (Gerrard 1998). An early study showed that taping of the knee joint to prevent ligament injury was ineffective because taping provides minimal restriction and loosens after 5 minutes of vigorous exercise (Gerrard, 1998b).

With regard to bracing, a review by Moore and Frank (1994) compiled a body of epidemiological evidence that supports the efficacy of functional and prophylactic knee braces in reducing the incidence of knee injury in gridiron. This contrasted with the collective findings of the biomechanical studies they assembled which generally showed that both prophylactic and functional braces provide only limited or no protection to the knee. On the basis of their review, the authors conclude that prophylactic braces 'cannot be recommended at this time' but that functional knee bracing has a place in knee rehabilitation (Moore, 1994). This is the consensus view expressed in more recent reviews (Gerrard, 1998a; Griffin, 2000). Their prophylactic use of knee braces is not permitted in rugby and Australian football.

Overload/overuse injuries (Jumper's knee)

Jumper's knee (overuse injury of the tendinous portions of the extensor mechanisms of the knee) is the most frequent overuse injury in jumping sports such as basketball, netball, tennis and volleyball and running sports (soccer and long distance running). The high prevalence of jumper's knee among high level players in jumping sports is assumed to be caused by the high number of jumps performed during training and games. For example, elite volleyball players average 150 maximum effort vertical jumps per match (Schafle, 1990). A runner with a stride of 1.5m makes contact with the ground approximately 670 times/km^{-1} (Van Mechelen, 1994).

Extrinsic factors (specifically, frequency of training and hardness of playing/running surface) appear more important than intrinsic factors (structural abnormalities) in the development of jumper's knee (Ferretti, 1986). A significant difference in the number of training sessions between volleyball players with and without jumper's knee was also found by Lian et al. (1996) when recruiting elite Norwegian volleyball players into a study to characterise the jump performance ability of players with jumper's knee.

Various authors have made general recommendations for the prevention of knee injuries but none is well developed or evaluated.

<u>Training regimes</u>

The frequency, rather than the type, of training sessions appear to influence the development of jumper's knee. Training more than four times a week increased the likelihood of jumper's knee in volleyball (Ferretti, 1990; Lian, 1996). The inclusion of weight and plyometric training do not appear to be associated with any increased risk of jumper's knee in volleyball which suggests that it is the quantity rather than the type of training that has adverse effects (Ferretti, 1990; Lian, 1996).

A significant relationship between running frequency and recreational running overuse injuries is found in most running studies that address this issue (Jacobs, 1986; Macera, 1989; Van Mechelen, 1992; Walter, 1989) but not in Marti et al's (1988) study. Pollock et al. (1972, cited in Jones et al., 1994) in an experimentally controlled study found that running-related injury occurred more than twice as often among those running 5 days/week compared to those running 1 or 3 days/week. In a later study, Walter et al. (1989) found that compared to less than 3 days running any increase in the number of days run increased the overuse injury rate. However, in recreational running, weekly distance is the strongest predictor of future overuse injuries (Jones, 1994; Van Mechelen, 1992).

There is limited evidence-based advice in the literature on the optimal content, length and frequency of weekly training sessions to maximise performance and minimise the risk of jumper's knee in jumping sports. Rice & Anderson (1994) recommend a conservative approach to jump training. The authors advise that plyometric exercises should be gradually introduced by slowly increasing the intensity and frequency of exercises over time to allow for proper adaptation of the musculoskeletal structure involved (Rice, 1994). Also, the floor should be cushioned and players should wear proper training shoes. The most skilled jumpers are particularly vulnerable to jumper's knee. Several authors recommended that these players (and players with knee symptoms) limit the amount of time spent on jump training and pay close attention to their technique (Briner & Kacmar, 1997; Lian, 1996; Rice, 1994; Richards, 1996). Recreational runners who have sustained injuries are advised to run no more than 32 km per week (Macera, 1992).

In terms of training content, Ferretti et al. (1990) recommend adequate warm-up, isometric strengthening of the quadriceps muscles, stretching of the quadriceps and hamstrings, the application of ice packs after any vigorous training sessions and careful choice of training and playing surfaces.

Playing/running surface

There is a paucity of research on these issues. Ferretti (1990) recommends wooden parquet floors or synthetic floors with similar elastic properties to minimise the risk of jumper's knee in players. His research in volleyball showed that training and playing on hard surfaces such as concrete and lino increased the risk of jumper's knee. Macera et al. (1989) found, after both univariate and multivariate analysis, that women who ran primarily on concrete had 5 times the injury risk during follow-up as women who ran primarily on other surfaces, even after controlling for weekly distance and previous injury (OR 5.6, 95% CI 1.1-29.3)(Macera, 1989). This relation did not hold for men.

Treatment and rehabilitation

Jumper's knee has the potential to become a debilitating condition if ignored. A retrospective study of the course of jumper's knee in 100 athletes, predominantly basketball players, presenting to a Melbourne sports injury clinic over a nine-year period provides some data on the clinical course of the condition (Cook, 1997). Symptoms prevented 33% of players from participating in sport for more than six months and 18% were sidelined for more than 12 months. Forty-nine per cent of subjects had two or more separate episodes of the condition. Sixty-three patients were managed conservatively using physiotherapy, rest or both treatments. Thirty-eight subjects had surgery (open patellar tenotomy), the indication for which was pain lasting for more than twelve months. Their recovery time for return to sport varied from three months to more than a year. The authors could not compare the effectiveness of treatment regimes because patients were not randomised into treatment groups. There are no studies reporting evidence-based treatment protocols for this condition.

Summary

Overall, the evidence supporting the effectiveness of interventions to reduce knee ligament injuries is weak. Prevention programs designed to increase balance and neuromuscular control, such as balance board and plyometric (jump) training. appear to be promising interventions for the reduction of serious non-contact knee ligament injuries. Plyometric training should only be trialed in teams that have suitably qualified coaches and trainers, but balance board training is more accessible to community level teams. Laboratory and epidemiological studies in a range of sports suggest that the risk of ACL injuries may be reduced by the introduction of improved playing techniques, particularly bent knee landing. The influence of the shoe-surface interface on ligament injuries is not well researched.

Several authors recommend that preventive programs for jumper's knee should concentrate on adjustment of training regimes and techniques, careful choice of floor surfaces for training and playing and early treatment (when symptoms first appear). In players with symptoms, conservative treatment (rest, stretching, physical therapy and anti-inflammatory drugs) is usually successful and most athletes completely resume sports activity at their previous level of play.

7.3.1.2 Preventing ankle injuries

Ankle injuries, mostly lateral ligament sprains, are the most common injury in sport. They occur particularly in sports activities in which participants frequently jump and land on one foot or are expected to make sharp cutting manoeuvres and change directions (for example basketball, soccer, football and volleyball). Ankle injuries (mostly sprains) were the second-most frequently occurring injury (behind knee injury) across the five leading physical activities related to WDL due to injury and illness in the ADF. They accounted for 15.9% of all injuries in these physical activities (*n*=1,474) but were more frequently reported in running/jogging (26.9%), touch (18.6%), soccer (15.8%) and PT (15.3%) than in rugby (6.5%).

A number of generic preventive measures to ankle injuries are reported in the literature. They include prophylactic ankle taping and bracing, ankle disc training, attention to take off and landing techniques and rule changes in sports where there is a high risk of ankle injury due to foot conflict (for example, to front line attackers in volleyball because of foot conflict under the net).

Thacker et al. (1999) recently conducted a thorough systematic review of the published evidence on the effectiveness of the various approaches to the prevention of exercise-related ankle injuries. The authors found ten reports that compared alternative methods of preventing ankle injuries in 621 citations identified through the literature search. The ten studies included seven randomised controlled trials (RCTs) of interventions in American football (gridiron), basketball and soccer and three cohort studies, two in football (gridiron) and one in volleyball. The evaluations investigated the effectiveness of taping, bracing and wrapping, player conditioning, shoe style, and training programs on ankle injury. The studies included in the review were subjected to rigorous quality assessment by three reviewers, and their findings weighted accordingly. The review revealed methodological flaws in all ten studies, some major including failure to report methods of randomisation and whether allocation of subjects was blinded, lack of attention to possible confounders and to statistical methods (Thacker, 1999). The methodological weaknesses in the evaluations to date indicate that care should be taken in using reported findings to underpin preventive programs and that any new programs should incorporate rigorous evaluation.

Two other recently published literature reviews on ankle injury prevention (Hume, 1998; Quinn, 2000) cover basically the same ground but the former (a Cochrane Collaboration review) included only randomised controlled trials. The Cochrane review concluded that there was good evidence for the beneficial effect of ankle supports in the form of semi-rigid orthoses or air-cast braces to prevent ankle ligament injury during high-risk sporting activities (for example soccer, basketball and netball). The Cochrane Collaboration is a network of researchers from a range of fields of medicine and health who systematically and continuously review the quality of evidence from randomised control trials in their particular area of expertise to determine the effectiveness of preventive, treatment and rehabilitative interventions.

Taping, wrapping and bracing

Ankle supports are designed to restrict the range of motion of plantar flexion and inversion of the ankle and to increase proprioceptive input. Taping and bracing are generally considered to be integral components of the management and rehabilitation process for ankle ligament injuries. Prophylactic (preventive) taping and bracing is becoming more common at senior levels of competition in sports that have high rates of ankle inversion injury, such as basketball, soccer, netball and volleyball.

<u>Taping and wrapping</u>

The most quoted study that provided limited evidence that taping reduces ankle injuries is an early RCT of 2,562 US intramural university basketball players (Garrick, 1973; Quinn, 2000; Thacker, 1999). The study was conducted prospectively over two seasons and tested the use of high and low top shoes, with tape, J-flex (elasticised wrap) or no tape. Participants were only randomised in the second season, in the first they self-selected their treatment.

The authors reported a decreased incidence of ankle sprains among players whose ankle were taped in comparison to those who were not taped. The protective effect was most evident in players with previously injured ankles, although it was also seen in uninjured players protected by both taping and high-top shoes. This study had significant weaknesses, so the findings are not definitive. The number of ankle-injured players in the study was small (*n*=55), the combined results for injury outcomes were presented for the two year study which was randomised for only the second year (treatment was self-selected for the first year), no information was provided on exposure (playing time), and no in-depth statistical analysis was carried out (Hume, 1998; Quinn, 2000; Thacker, 1999).

It is known, also, that there is a diminution of support for the taped ankle as early as 10 minutes into active participation (the amount of loosening depends on the vigour of play) and that taping offers almost no support after one hour (Renstrom, 1997). In a small laboratory study, involving seven female college volleyball players, Greene & Hillman (1990) compared the relative effectiveness of athletic taping and a semi-rigid orthosis in providing inversion-eversion range of-motion (ROM) restriction before, during, and after, a three-hour volleyball practice. Players were randomly assigned to one of two treatment groups and the designated support system was applied to both ankles. Ankle ROM was tested at five points on an ankle stability test instrument.

In the taped group ROM restriction was reduced from 41% in the pre-exercise test to 15% immediately after exercise and there were maximal losses in taping restriction at 20 minutes into exercise. By contrast, the braced ankle demonstrated a 42% initial ROM restriction, which was reduced to 37% after exercise. Neither system adversely affected players jumping ability. It is yet to be determined whether, and at what level, increased ROM restriction protects against ankle ligament injuries. If restriction is a reliable predictor of increased ligamentous support then these results suggest orthosis (bracing) is more effective than taping. A number of researchers have suggested that any residual protection offered by taping may be associated with increased proprioception that allows the peroneal muscles to react more rapidly to inhibit extreme ankle inversion but this explanation is disputed by others (Thacker, 1999).

Aside from the incomplete protection offered by taping, other disadvantages raised in the literature include the expense of taping for every match and practice, inconvenience, the lack of player skill in applying the tape correctly and adverse skin reactions to tape. There is no evidence that the use of elastic wrap or bandages protects against ankle sprain (Thacker, 1999).

Bracing

Prophylactic ankle stabilisers (braces) are gaining popularity. They are a more convenient and less expensive alternative to taping. Several studies, taken together, provide good evidence that ankle braces (orthoses) protect against ankle injury, particularly in previously injured ankles (Quinn, 2000; Thacker, 1999).

The Cochrane review panel (Quinn, 2000) pooled the results from four randomised controlled trials that compared the use of ankle brace/orthosis with controls (Ryan, 1994; Sitler, 1990; Tropp, 1985) (Surve, 1994). The analysis showed a significant reduction of number of ankle sprains in the intervention group (OR 0.49; 95% CI 0.37 to 0.66).

The strongest evidence for effectiveness comes from a large well-conducted randomised controlled trial on the effectiveness of a semi-rigid ankle stabiliser that involved 1,601 healthy US Military Academy cadets playing intermural basketball (Sitler, 1990). The study found that the stabilisers significantly reduced the frequency, but not the severity, of acute ankle injuries. The largest statistical reduction was seen in the previously injured ankle group but a positive effect was also evident in the group with protected healthy ankles. Ankle stabilisers were more effective for foot contact injuries, a finding that is relevant to jumping sports such as basketball, netball and volleyball where there is a high risk of foot conflict under the goal ring/ basket and the centre line net (in volleyball).

Three other RCTs, two in soccer and one in military training (parachuting) report positive protective effects for external ankle devices. Studies by Tropp et al. (1985) and Surve et al. (1994), both in cohorts of soccer players, found that ankle orthoses (braces) when used by players with previous ankle injury protect against re-injury. The latter study (involving

258 senior soccer players with previously injured ankles and 246 uninjured players) trialed the effectiveness of a particular brand of semi-rigid orthosis. The authors report a fivefold reduction in the incidence of recurrent ankle sprains in soccer players using the orthosis but no significant reduction of ankle sprains in players with previously uninjured ankles. The other RCT (Ryan, 1994) found a statistically significant reduction in ankle sprains in the group of army trainees who used an 'outside-the-boot' ankle brace in parachute training compared to trainees who did not wear braces.

All groups of reviewers (Hume, 1998; Quinn, 2000; Thacker, 1999) conclude that there is good evidence for the use of external ankle support devices to prevent ankle ligamentous injuries during high risk sporting activities for ankle injuries, particularly for players with previous ankle injury. Thacker et al. (1999) recommend that athletes with a sprained ankle complete supervised rehabilitation before returning to practice or competition and that athletes who have suffered a moderate or severe sprain should wear an appropriate orthosis (brace) for at least 6 months and, preferably, twelve months.

The benefit of the prophylactic use of ankle taping and bracing by players with healthy ankles is less well established. Quinn et al. (2000) note that a smaller benefit is likely for those who have no history of ankle injury. More supportive evidence is required before widespread implementation in uninjured players can be recommended. The cause and effect association between bracing and reduced ankle injury needs to be tested in well-designed trials over time in different sports populations before it is convincingly established.

Footwear

<u>High-top vs. low-top shoes</u>

The epidemiological evidence that high-top shoes reduce ankle sprains is equivocal. In the early RCT in college basketball players described above (Hume, 1998), players were randomly assigned to one of four groups (tape or no tape with low-top or high-top boots). The results showed that high-top boots provided superior protection against ankle sprain compared with low-top boots, but that low-top boots with taping was more protective than high-top shoes without taping. The best protection was observed in high-top boots with taping. These results suggest that taping provided most of the benefit.

By contrast, a later retrospective study in 297 U.S. collegiate footballers that investigated the effectiveness of wearing a laced stabiliser or taping in preventing ankle injuries reported that the combination that allowed the fewest injuries overall was laced ankle stabiliser and low-top shoes (Rovere, 1988). In another study, Barrett and co-workers compared high top shoes lined with inflatable air chambers with conventional high topped shoes and low topped shoes in a RCT of 622 male college intramural basketball players (Barrett, 1993). There was little difference in the incidence of ankle sprains in the groups of players wearing conventional low-top and high top shoes but the use of high top shoes with inflatable support chambers resulted in a slight, but not significant, reduction in the risk of ankle injury.

The overall ankle injury rate in the Barrett study was much less than found in the previous studies by Garrick & Recqua (1973, cited in Hume & Gerrard, 1987) (Rovere, 1988). Barrett (1993) and colleagues provide two possible explanations for this discrepancy. First, players in their study were provided with new shoes and, second, the games they observed were shorter (30 minutes) than the games in the other studies. This suggests that that the 'wear and tear' of shoes and player fatigue may contribute to ankle injury.

In summary, there is no convincing evidence to show that shoe height protects against ankle sprains. It is possible that new shoes may provide better protection than worn shoes.

Shoe design

The interface between footwear heel and sole material and playing surface, in terms of the optimal degree of friction for ankle and knee injury prevention, is an important but complex consideration that has received little attention in the published literature. There is no published evidence to guide shoe selection in any sport but obviously correct and firm fit and comfort are important. Sports footwear and playing surface manufacturers and sports injury researchers need to work co-operatively on this issue.

There is also a need for a source of independent advice on sports footwear. Manufacturers characteristically make extravagant claims about the injury protective effects of specific design features of their shoes and the suitability of certain shoes for specific sports without providing the consumer with any supportive evidence from laboratory studies and field testing.

In a review article, Robbins and Waked (1998) challenge the prevailing orthodoxy on the need for additional external support for the ankle in sports, and question whether any external device can provide sufficient structural support to the ankle to prevent sprains. The authors claim (without citations) that epidemiological studies show that there are few ankle sprains in barefoot athletes and contend that the proliferation of ankle injuries in shod athletes is a direct result of the poorly designed modern sports footwear that decreases foot position awareness (proprioception). They argue that any apparent protective effect of ankle support devices (i.e., tape or brace) is probably due to the restoration of tactile cues on the plantar surface of the foot either by an increase in skin pressure (from taping) or skin traction (from bracing). Ankle support, therefore, enables shod players to better ‘sense’ correct foot position and orientation before making full contact with playing surfaces. They suggest that the best solution to ankle inversions in sport is thinner- and firmer-soled sports footwear designed to heighten the wearer’s awareness of foot position. This hypothesis needs to be tested.

Playing surface

Steele (1990) reviewed the body of evidence that explores the association between playing surface and the frequency and type of sports injuries and concludes that definitive evidence is lacking and many aspects of the issue require further investigation. She pointed out that the evaluation of the suitability of a surface for a particular sport is a complex matter. Decision-making by sports administrators requires consideration of the functional needs of the sport and the durability and upkeep costs of the surface, along with detailed performance information on the material properties of the surface that may impact on safety and comfort. Natural turf presents particular problems because the surface characteristics are highly variable and can change between seasons and from week to week over a given season in response to the prevailing weather conditions and intensity of use.

Steele (1990) identified several characteristics of playing surfaces that appear to have an impact on injury incidence: stiffness (shock absorbency); resilience (degree of hardness or softness); slip-resistance (frictional properties); heat absorption; colour and reflectivity; the effect of surface uniformity on game speed and impact forces; toxicity and fire performance. She recommended the establishment of performance values for specific sports to guide administrators in their choice of surface/s but stated that the establishment of such values requires extensive laboratory and field research.

There is currently a paucity of information to assist sports administrators and/or facility owners to select the most suitable surface/s from the range on offer when new facilities or replacement flooring/surfacing is being planned.

Specific conditioning programs

Thacker et al. (1999) suggest that the results of the randomised controlled trial of a multi-strategic intervention in senior male soccer players conducted in Sweden provides some evidence that training sessions, focussed on agility and flexibility, decrease the risk of ankle injury (Ekstrand, 1983b). However, in the original journal article the authors attribute the observed reduction in leg muscle strains, not ankle sprains, to the training program which concentrated on contact-relax leg stretching exercises (Ekstrand, 1983b). The components of the trial that were designed to specifically target ankle sprains were ankle taping for players with previous ankle injury and/or clinical instability and controlled rehabilitation, under medical supervision, of players with ankle injuries. There was a statistically significant reduction in ankle sprains in the intervention group.

Grana (1994) recommended a preventive ankle conditioning program consisting of: toe raises (40 repetitions);

resistive exercises (40 repetitions: dorsiflexion, plantarflexion, inversion and eversion) performed by theraband program or manual resistance; balance activities (5 minutes) performed by single limb balancing or on balance board; plyometrics (5 minutes) hopping, skipping, stepping etc.; and stretching (5 minutes). He presents no evidence on the effectiveness of this program for ankle injury prevention. Only one of the components of this program, balance board training, has been trialed.

Ankle disc (balance board) training

Ankle disc (also known as balance, tilt or wobble board) training appears a promising intervention to prevent ankle injury in players with previous ankle sprains in a range of sports. One RCT of disc training (in soccer) by Tropp et al. (1985), met the study quality inclusion criteria for the Cochrane review (Quinn, 2000). The trial involved 450 soccer players who were randomly allocated to one of three groups: controls; offered ankle orthoses (brace); and a third group that was subdivided into a group with previous ankle problems who were given ankle disc training and a group with no previous ankle problems that were given no disc training. The study found that ankle disc training significantly reduced ankle sprains in male soccer players with a history of ankle problems compared to controls (OR 0.30; 95% CI 0.15 to 0.60). The reduction was to the same level found in the group using ankle braces.

Two recent RCTs conducted in female handball and soccer players report conflicting finding on the protective effect of ankle disc (balance board) training for ankle and knee ligament injuries (Wedderkopp, 1999) (Soderman, 2000). In the handball trial, involving 237 Danish female players, the twenty-two teams that participated were randomly assigned to the intervention and control groups. Players in the intervention group used the ankle disc for 10-15 minutes in all practice sessions, for one ten-month season. The results indicated that disc training reduced the risk of injury by 80% during games and 71% during practice. In addition, the players in the control group had a 5.9 times higher risk of acquiring an injury than the players in the intervention group (Wedderkopp, 1999).

By contrast, Soderman et al. (2000) reported no significant differences between the intervention and control groups with respect to the frequency, incidence or type of traumatic injuries of the lower extremity from their study involving 221 Swedish female soccer players. Thirteen second and third division teams volunteered into the study and were randomised into intervention (7 teams, n=121 players) and control (6 teams, n=100 players) groups. The groups were followed during one outdoor season (7 months). Players in the intervention group included 10-15 minutes of balance board training into their normal training routine. The control group trained as normal. Over one-third (37%) of the intervention group dropped out of the study. The only positive effect reported was that balance board training appeared to prevent re-injury in players who had been injured in the three-month period prior to the study.

Our literature search found one other report that provides some supportive evidence on the beneficial effects of balance board training, a pre- and post- evaluation of a multi-strategy intervention in 719 Norwegian male volleyball players (Bahr, 1997b). Injury data were studied retrospectively in the 1991-92 season and prospectively in the 1992-93 season (to inform preventive measures and to form the baseline for the evaluation). The intervention program was introduced during the 1993-94 season, and injury data from the 1994-95 season were used to evaluate the effects of the preventive program (Bahr, 1994; Bahr, 1997a; Bahr, 1997b).

The intervention consisted of a 1-hour awareness raising session for coaches and players on the risk factors for ankle injuries conducted by the researchers and a 1.5-2 hour practical session also conducted by the research team. The practical session covered technical skills training for all players (jumping and landing techniques), and practical demonstration and practice in the correct use of ankle discs (balance boards) for players with previous ankle injury. Two balance boards were given to each team and a written training program was distributed to players with previous ankle injuries. Just before the 1994-95 season all coaches and players were given a booklet that outlined the prevention program to reinforce the information given during team visits by the research group in the 1993-94 season. No further direct contact was made with players

The evaluation had major limitations including lack of randomisation and a comparison group, lack of information on compliance to the interventions and reporting and other biases. Notwithstanding these shortcomings, the injury outcome data suggest that the intervention was effective. The study demonstrated a substantial decrease in the incidence of ankle sprains from 0.9±0.1 per 1,000 players during the 1992-93 pre-intervention season (48 injuries) to 0.7±0.1 during the 1993-94 season when the program was partially implemented (38 injuries; n.s. vs. 1992-93) and to 0.5±0.1 during the 1994-95 season when it was fully implemented (24 injuries, $P<0.01$vs.1992-93), with no change in the occurrence of other injuries. The authors also observed a reduction in the number of ankle injuries caused by landing on the foot of an opponent or team mate from the first season (28 injuries) to the last season (14 injuries; $P<0.05$) and there was a gradual decline in the risk of new ankle injury in players with previous ankle injuries.

The weak evaluation design does not allow any assessment of the relative contribution of the individual components of the trial. However, the results suggest that the injury reductions may have been associated with the training components (jumping and landing, block formation drills and disc training) rather than the information session per se. The observed reduction in injuries associated with foot conflict suggests that the 'step in' and the block drill may have had some effect and the observed gradual decline in ankle re-injuries indicates that the ankle disc training component (which was exclusively targeted at players with ankle instability) also made a contribution. The promising findings from this study prompted the design of a large randomised controlled trial of ankle disc (balance board) training in volleyball in The Netherlands (Verhagen, personal communication) which has just commenced.

Foot orthoses (other than ankle bracing)

The term 'foot orthosis' is used to refer to one of a variety of devices that are used inside the shoe to provide support, increase shock absorption, or influence foot position in some way (Janisse, 1994). Orthoses can be pre-made or custom-made and range from heel cushions and arch supports to full insoles.

It is generally proposed that corrective biomechanical orthoses alleviate symptoms and reduce the risk of lower limb overuse injuries caused by abnormal position or functions of the joints of the lower limb and foot (Kilmartin, 1994). Two reviews of the literature, one recent, conclude that there is a body of evidence that supports the proposition that orthoses provide symptomatic relief from some lower extremity complaints (Gross, 1993; Razeghi, 2000). Surveys of injured athletes (mostly runners) and healthy military recruits consistently indicate that a significant proportion of athletes with a broad range of hip, knee, foot and ankle problems report that orthotic devices resolved or alleviated their symptoms (Gross, 1993; Razeghi, 2000). Gross & Napoli (1993) caution that successful treatment requires careful evaluation of the player's feet and the formulation of a properly fitted orthosis .

Kilmartin & Wallace (1994) reviewed the scientific basis for the use of biomechanical foot orthoses in the treatment of lower limb sports injuries. They acknowledged the existence of a body of clinical and epidemiological evidence that supports the usefulness of orthoses in relieving pain related to lower leg and foot overuse injuries. However, they could find no clear scientific evidence to explain how orthoses work. They have not been shown to have any effect on knee function and, although they limit rearfoot movement, the clinical significance of excessive rearfoot movement in overuse injuries is not established. The authors conclude that a randomised controlled trial (in a population with no foot pain) is required to test the advantage of placing the foot in a supinated or neutral position rather than a pronated position. They recommend that widespread promotion of orthoses should be delayed until the their usefulness is justified by clinical trials.

Summary

Available evidence shows that either ankle taping or semi-rigid bracing reduces the incidence and severity of ankle sprains, but bracing is more effective and convenient and less expensive. The weight of evidence supports the proposition that the protective effect of bracing is confined to players with previous ankle injury but one US study in basketball players suggests a protective effect in previously uninjured athletes (Sitler, 1990). Ankle disc (balance board) training is a promising preventive measure for lower limb injury but confirmation is well-designed trials is required before widespread implementation. Although studies have shown that footwear and the playing surface contribute to ankle ligament injury, a complete understanding of the complex interactions between the lower extremity, footwear, playing surface and the shoe-surface interaction has not been achieved. More research is needed to underpin guidelines for footwear and surface choice for specific sports.

The role of malalignment in lower limb overuse injury is not established nor is the scientific basis for the treatment of overuse injury with orthoses. The hypotheses that structural abnormalities are a risk factor for overuse injuries and that these can be corrected with orthoses requires testing in well-designed controlled studies. Gross & Napoli (1993) suggest that orthotics be used in the treatment of overuse syndromes as an adjunct to other measures, namely rest, training modification and a change in the playing surface or shoe.

7.3.1.3 Preventing shoulder injuries

Of the five leading physical activities related to WDL due to injury and illness in the ADF (PT, touch, soccer, rugby and running/jogging), shoulder injuries most frequently occurred in rugby (18.2% of all rugby injuries) and touch (17.4% of all touch injuries). They also accounted for 7.1% of PT injuries, <13% of soccer injuries and <7% of running/jogging injuries. The precise contribution of shoulder injuries to the overall injury toll in the five sports could not be calculated because the frequencies of shoulder injuries in soccer and running/jogging were not reported.

Acute injuries

Acute shoulder injuries predominantly occur in contact sports such as American and Australian football and rugby. The most common acute injuries are dislocations (acromioclavical and glenohumeral), clavicular fractures and rotator cuff contusions. The mechanism of acute shoulder injuries is forceful contact with another player or with the playing surface after a fall, tackle or dive for the ball. The two countermeasures to acute shoulder injuries suggested in the literature are coaching of players in contact sports in proper landing and tackling techniques (Mallon, 1994) and the wearing of shoulder pads (Gerrard, 1998a; Mallon, 1994).

<u>Technical training</u>

Mallon & Hawkins (1994) suggest that players should be taught to land and roll on the shoulder rather than the outstretched arm when landing from a fall, but the authors presumed that the shoulder was protected by pads. They advised, also, that players should not attempt to block or tackle with their arms but to move their body quickly enough so they are in the position to block or tackle with their body.

<u>Shoulder padding</u>

Shoulder pads are increasingly being used by rugby league players and are allowed in rugby union. The laws of rugby union permit the wearing of shoulder pads, made of soft and thin materials, no thicker than 1cm when uncompressed. No parts of the pads may have a density of more than 45kg per cubic metre. The real protective benefit of the available and allowable padding is debatable (Gerrard, 1998b). Laboratory and field trials are required to develop protective padding that is effective and acceptable to rugby peak sports bodies and players. The major concern of rugby authorities is that harder or thicker shoulder padding, if not carefully introduced, could be used by players as a weapon or encourage reckless play as was the case in gridiron.

Overuse injuries

Shoulder overuse injuries, mostly tendinitis of the rotator cuff or biceps tendon or impingement syndromes, appear to be quite common in sports that require vigorous upper arm activities such as volleyball, rowing, swimming, and racquet and throwing sports (tennis, squash, baseball/softball and cricket). Attackers in team overhead sports, pitchers, bowlers and athletes who play and practise frequently are at high risk.

Exercise and conditioning

There is sparse advice on prevention of shoulder overuse injuries in the literature. Authors of the two small laboratory studies of shoulder problems in volleyball players recommend exercise programs to prevent and correct the imbalances and lack of flexibility that appear to characterise the dominant shoulder of volleyball players (and may be associated with rotator cuff injury) (Kugler, 1996; Wang, 2000). Mallon & Hawkins (1994) recommend strengthening and stretching the shoulder girdle during preseason and in-season conditioning in all overhead sports, and thorough warm-up that includes stretching the shoulder muscles and low-intensity build-up to the sport activity. They also recommend that coaches, knowledgeable in the biomechanics of the particular sport, work with players to develop techniques that minimise stress on the shoulder.

Kugler et al. (1996) found that volleyball players had a shortened dorsal capsule of the playing shoulder and a diminished ability to stretch the dorsal muscles and these adaptations were more marked in players with shoulder pain. The authors suggest that all players should stretch the shortened muscles and strengthen the scapular fixation muscles both to prevent and alleviate shoulder symptoms. Wang et al. (2000) reported that elite volleyball players develop a ratio of internal to external shoulder rotator strength that is abnormally high and a reduction in the range of internal motion in the dominant shoulder. They suggest that these adaptations are responses to the repeated forceful internal rotations associated with attacking (spiking) and overhead serving. They recommend that training should include exercises that maintain a favourable internal/external rotation strength balance and increase the flexibility of internal rotation to prevent or lessen the severity of repetitive overuse injuries.

A number of shoulder rehabilitation programs that have been developed in response to shoulder overuse pathologies in throwing athletes and tennis players (Chandler, 1992; McCann, 1994; Meister, 2000). A program with a more preventive approach has been developed for baseball pitchers by the U.S. Institute of Preventive Sports Medicine using a technique of proprioceptive neuromuscular facilitation (PNF) (Janda, 1991). The authors claim that PNF is equally suitable for non-throwing athletes involved in overhead activities. It involves the coordinated performance of a series of resistance exercises through the full range of motion of the shoulder but also focuses on the neck, upper trunk and upper extremities. The athlete is in a supine or prone position on a table and performs the patterns with the assistance of a trainer in the first instance, then a 'buddy'. The exercises are explained and illustrated in an article *"Preventative Approach to the Athlete's Shoulder"* (Janda D.H.) published on the Institute's website (www.ipsm.org). None of these programs has been systematically trialed (in groups of athletes with and without shoulder pain) and evaluated for injury prevention effects.

Summary

There is sparse evidence on the effectiveness of measures to prevent acute and overuse shoulder injuries. The two countermeasures to acute shoulder injuries suggested in the literature are coaching of players in contact sports in proper landing and tackling techniques and the wearing of shoulder pads. Exercise programs are recommended to prevent and correct the imbalances and lack of flexibility that appear to characterise the dominant shoulder of players in sports with high risk profile for shoulder overuse injuries. Authors also recommend that coaches, knowledgeable in the biomechanics of the particular sport, work with players to develop techniques that minimise stress on the shoulder. None of the measures to prevent overuse injuries has been systematically trialed (in groups of athletes with and without shoulder pain) and evaluated for injury prevention effects.

7.3.2 Preventing injuries in touch, rugby and soccer

DEFCARE data shows that touch, rugby and soccer are the three sports that contributed most to casualties and WDL in the ADF in the financial year 1997/8 (Defence Health Service Branch, 2000). The available DEFCARE data on the pattern, mechanisms and circumstances of injuries in these sports is sparse, so the general sports injury literature was consulted for each sport for information on injury patterns at the adult community participation level. The newly established ADF sports injury database should provide rich data on sports injuries when it has been operating at full strength for a 12 month period.

7.3.2.1 Touch

Touch football, correctly known as 'touch', has its origins in NSW rugby league training in the 1950s and 60s when coaches used it as a training activity to simulate rugby play without the injury risks associated with full contact tackling. According to DEFCARE data, however, touch is the second-highest ranked physical activity associated with WDL in the ADF, behind physical training (Defence Health Service Branch, 2000). In the financial year 1997/98, touch accounted for 175 casualties and 3,341 WDL. Given that touch is a minimum contact sport (players are only allowed to tag or touch the opposition) the relatively high frequency of injuries and work days lost in the ADF due to touch injuries may reflect high participation and/or exposure (number of hours/games played).

Accurate exposure data are needed to test this assumption. Our understanding is that touch is played on many levels by ADF personnel. Enthusiasts participate in organised external and internal (ADF-sponsored) formal competitions and a wide range of personnel participate in touch in organised PE sessions and in informal and casual (adhoc) matches (R. Pope, personal communication). A special investigation of the ADF 'culture' of participation in touch is warranted to determine whether environmental factors (rules, organisational aspects and playing conditions) and player factors (such as gender, inexperience/lack of skills and the 'spirit' in which the game is played) are implicated in injuries.

Touch is played extensively in Australia (where 250,000 players are registered) and New Zealand, and participation has spread to 20 other countries. The rules of the game as published on the web by the Australian Touch Association (ATA) are in line with the internationally accepted set of laws for the game (http://touchfootball.sportingpulse.com/austouch). The ATA allows affiliates to adapt the rules for local and park level games.

Touch is an extremely fast game played on a grass field 70m x 50m. As in rugby, the attacking and defending teams line up facing each other and the oval shaped ball is moved forward on the field while in an attacking player's possession, yet it cannot be passed forward. The object of the game is for each team to score touchdowns and to prevent the opposition from scoring. The ball is passed, knocked or handed between onside players of the attacking team who may in turn run or otherwise move with the ball in an attempt to gain territorial advantage and score. Defending players prevent the attacking team from gaining territorial advantage by touching the ball carrier. Either defending or attacking players may initiate touches upon which play stops and is usually restarted with a roll ball. A touch is defined as any body contact between opposing players. Each side has six opportunities to score (if not legitimately dispossessed) before being required to surrender possession.

Touch is marketed as a minimal contact game that carries less injury risk than full contact football codes such as rugby and Australian football, and the rules are designed to support this safety aspect. A touch, which may be made by a defending player or the player in possession, includes contact on any part of the body (including hair and clothing) or on the ball. Touch rules require players to ‘use the minimum force necessary to effect touches’. Breaching this rule results in a penalty awarded to the non-offending team and, as a minimum, a warning to the offending player. Referees have the power to dismiss a player to the ‘sin-bin’ for a period of time for continual breaches of the rules or a serious offence. Referees may also dismiss players for the remainder of a match (which carries an automatic 2-match suspension) for gross misconduct, a dangerous act or if they have already been sent off and re-offend. Dismissed players cannot be replaced. Examples of misconduct given in the ATA rule book include using physical force in making a touch, attacking the head of an opponent and tripping (Australian Touch Association Playing Rules 7th Edition. Website: (http://touchfootball.sportingpulse.com/austouch).

The characteristic skills of the game are speed, changing direction and diving (along with teamwork). The game demands a high level of aerobic fitness and puts stress on the lower limbs.

Injury frequency and pattern

Only two studies on injury in touch have been published (Cunningham, 1996; Neumann, 1998). The more comprehensive of the two is the retrospective study of injuries sustained over a one year period (1996) by 345 Queensland touch players surveyed at either the Gold Coast Cup held in January 1997 or the Ipswich Touch Association fixtures at the playing fields (Neumann, 1998).

The pattern of injury in ADF touch football cases (*n*=177) recorded on the DEFCARE database in 1997/8 is broadly similar to the pattern reported from the Queensland club players’ survey (*n*=345), taking study differences into consideration, for example source of data, definitions of injury and injury classification systems, and gender mix of subjects (Table 7.2). Injuries to the lower limb, predominantly to the ankle and knee, were most common. Lower limb injuries accounted for 56% and 71% of all injuries in ADF and

Queensland club touch players respectively. Knee injuries comprised a higher proportion of injuries in ADF touch compared to Queensland club touch (~25% v 14%).

Upper limb injuries were also common, but were more frequent in ADF touch (accounting for 26% of all touch injuries) than in Queensland club touch (15%). In both studies the shoulder and hand/finger were most frequently involved. The proportion of trunk injuries reported was similar (10% and 12% of all touch injuries), but neither study provided any detail on the precise site of these injuries (injuries to the groin appeared to be classified as lower limb injuries in the Queensland study). Head, neck and facial injuries were relatively infrequent, comprising 6% of all ADF touch injuries and 3% of Queensland club touch injuries.

Sprains and strains were the most frequently reported type of injury, although they accounted for a considerably lower proportion of all touch injuries in ADF players compared with Queensland club players (44% versus 72%). By contrast, fractures and dislocations are much more prominent in ADF touch (17%) than in Queensland club touch (~7%). These discrepancies may reflect the fact that the injury data are drawn from different sources. Nonetheless, the high frequency of fractures in ADF touch players demands further investigation in case there are problems with the surfaces on which touch is played in the ADF or with the intensity of play in ADF teams/players, many of whom would have a rugby background.

Both studies, but particularly the Queensland clubs study, provide a limited perspective on the causes and circumstances of injuries in touch. Falls, trips or slips (34%) was the major mechanism (cause) of touch injuries in the ADF study, closely followed by hit by/collision with objects, including humans (30%) and body stressing (22%). There is no detailed information on the mechanisms of injury in the Queensland clubs study, except that contact with another player (tackling) was associated with 17% of injuries. A much higher proportion of ADF touch injuries (~30%) involved 'human agencies' (body contact). There is no indication of what proportion of these contact injuries resulted from illegal play. Over one-third (39%) of ADF touch injuries reportedly involved environmental factors (especially wet ground conditions) which raises the issue of appropriate footwear. The role of environmental factors in ADF touch injuries, especially playing surface/ground conditions and shoe-surface interface, requires further investigation.

Injury severity data were not reported in the ADF study, except that touch injuries generally and knee injuries in particular were relatively severe in terms of WDL when compared to all reported sports and physical training injury cases. The 26 knee injury cases in touch in 1997/8 resulted in an average of 41 WDL per case. The average WDL for all touch cases was 16 days compared to 6.5 days for all sport and physical activity injury cases on the DEFCARE database.

Neumann et al. (1998) reports that the injury rate in touch in males (6 injuries per 1,000 hours of playing and training) compares favourably with the rates reported from fairly similarly designed studies in soccer (12-17/1,000 hours), rugby union (14-24/1,000 hours), rugby league (44-45/1,000 hours), Australian Rules (34-96/1,000 hours) and Gaelic football (16.6/1,000 hours). Note that a recent longitudinal study of injury in four popular sports conducted in Western Australia (Stevenson, 2000) reported a much lower injury rate (20/1,000 hours) for club-level Australian football. Despite possible biases in the data, they support the proposition that touch is a comparatively safe sport at the community club level. Participation and exposure data were not available for ADF touch so the injury rate could not be calculated and compared.

Because of the shortcomings of available data, the ADF is advised to conduct a prospective study of injuries in touch prior to devising a prevention strategy and instituting prevention measures specific to the sport. Accurate exposure data are needed to establish whether or not the high injury frequency in touch in the ADF reflects high participation rates and hours of play or other factors related to the players and the rules and conditions under which the game is played by Defence Force personnel (especially informal and 'scratch' games). Systematic analysis of the cases recorded on the newly introduced sports injury surveillance data system should supply more information on the nature, severity, mechanism and circumstances of touch injury to underpin prevention measures. The data supplied from the Canberra ADF sports injury database (which covered sport and physical activity injury cases recorded from Jan-June 2000) included only 10 cases of touch injury, too few to supply meaningful information.

Table 7.2 Comparison of frequency, pattern and mechanism of injury in ADF touch players compared to club-level touch players

Pattern of injury	ADF Health Status Report 2000 (DEFCARE database)	Queensland touch clubs player survey (Neumann, 1998)
Definition	All injury incidents, compulsorily reported by ADF personnel	Loss of playing or training for at least one week
Type of study	Cases recorded on DEFCARE database in 1997/8 (biased towards serious injury, major under-reporting)	Retrospective survey (*n*=345 players) on injuries in previous 12 months
Frequency	Casualties (n=173), participation and exposure data not collected Work days lost (n=3,341)	177 injuries in 117 players (34%) Injury rate: 4.85/1000 hours of playing and training (95% CI 4.17-5.62)
Age & gender	M:F injury frequency (and rates) unavailable	Mean age 26.6 years (range: 16-47 years) M: 5.95 injuries/1,000 hrs, CI 4.94-7.11 F: 3.47 injuries/1,000 hrs, CI 2.62-4.51
Anatomical site of injury	Lower limb (55.8%, predominantly knee (~25%) and ankle (~18%)) Upper limb (25.6%, predominantly shoulder (~10%), hand/finger (6%)) Trunk (9.9%) Head & neck (5.8%)	Lower limb (71%, predominantly ankle (23%), knee (14%), thigh (8%), groin (6%) Upper limb (15%, predominantly hand/finger (8%) and shoulder (6%)) Trunk (12%) Head and neck (3%)
Nature of injury	Sprains and strains (43.6%) Disorders of the muscles tendons & soft tissues (17.4%) Fractures (11.0%) Dislocation (5.8%) Dorsopathies (back) and arthropathies (joints) (3.5%) Other and unspecified (18.7%)	Sprains and strains (72%) Overuse & soft tissue (11%) Fractures (7%) Wounds (5%) Other (5%)
Injury severity	Not detailed Knee injuries: 41 work days lost (WDL) per touch casualty Ankle injuries: NOD Shoulder: 7 WDL per touch casualty Finger/hand: NOD	Mild (prevented play for <2 weeks): 54% Moderate (undefined in report): 23% Severe (undefined in report): 23% 80% of injured players (n=117) sought treatment: physio (59%), GP (39%), hospital (15%), trainer (7%), naturopath (3%) and other (3%)
Mechanism/cause	Falls/trips/slips (33.7%) Body stressing (22.1%) Being hit by moving object or person (15.1%) Hitting another object or person (14.5%) Other and unspecified (14.5%)	Contact with another player (17%) Non-contact (83%) (NOD)
Agency	Environmental factors (39%), including ground surface (other), wet, oily or icy	No details

	ground surface, holes in the ground, vegetation and ground surface with hazardous object Animal, human and biological agency (30%) NOD	

Contributory factors

There are no established risk factors for injury in touch. Neumann et al (1998) reported a significantly higher injury rate in males compared to females (5.95/1,000 hours (95% CI 4.894-7.007) versus 3.47/1,000 hours (95% CI 2.565-4.376)) but retrospectivity may have biased this study. The authors speculate that the higher rate in males may be related to gender differences, playing style or rugby background. They noted no significant differences in injury rates between representative (i.e. inter league, state and national players) and non-representative players and those who trained and those who did not. These findings are in conflict with studies in other football codes and require further investigation using analytic methods.

The specific countermeasures for touch injuries that should be considered in a prevention strategy are outlined in Table 7.3. These are based on the sparse available data on touch football injury or are informed by research in other comparable sports.

Table 7.3 Suggested countermeasures to injuries in touch

Potential countermeasure	Application
Pre-event (primary prevention)	
• Reduce/control exposure - Limit/ban participation in informal play - Reduce hours of participation - Increase size of teams and rotation of players • Provide a safe playing environment, including equipment, field and surrounds	• Ban informal and 'scratch' games **OR** • Restrict informal/scratch games by establishing strict conditions under which ADF touch games are played that cover: - permitted variation of field dimensions including minimum size of playing space and the amount of clear space around marked ground (if smaller than ATA regulation size then team size should be adjusted) - compulsory line markings - use of ATA approved ball - permitted ground surface material (grass or other soft surface) and condition of surface (ground inspection by referee prior to play) - minimum size of team including substitutes, maximum number of players on field, number of substitutes allowed - compulsory wearing of identification numbers - permitted gender mix on teams (if mixed teams allowed) - maximum match duration - basic fitness requirements - wearing of ATA regulation footwear - officiation (trained referee), strict enforcement of rules and code of behaviour - player and official code of behaviour - warm-up and cool down regime - availability of trained first aider & first aid equipment For all games controlled/under aegis of ADF: • Prohibit play on hard (concrete), contaminated (wet, oily) or uneven surfaces • Supply appropriate footwear, sets of team colours/numbers, ATA approved balls, line marker and tape.

	• Remove obstacles in immediate surrounds • Mark ground appropriately • Ground inspection prior to play • Line markings visible
• Pre-season fitness test (6 weeks before start of season)	• Pre-season fitness test to ensure that no player carries an injury into the new season • ADF personnel with unstable knees/history of knee injuries should be discouraged from participation
• Adequate pre-season and in-season training and conditioning	• As appropriate to the sport - regimes should be specific to the player and the sport and include components to build strength, flexibility, muscular endurance, stamina, agility, balance/proprioception (2-3 workouts per week)
• Player skills development by trained coaches, attention to good technique and injury prevention	• If informal/scratch play allowed, all ADF personnel should be given a thorough grounding in the basic skills, techniques and injury prevention in Basic Training/PE sessions
• Promotion of good knowledge of game rules in players and referee	• If informal play allowed, broad training of ADF personnel in the rules of the game • Broad program of referee training so that all informal games (if permitted) are under the control of a trained referee
• Modified rules	• Formal games should be conducted under international rules published by Australian Touch Association (ATA) • Only ADF-approved modified rules should be allowed in informal/scratch games, if these are permitted
Event (secondary prevention)	
• Use of protective equipment	• Ankle bracing compulsory for players with unstable ankles (all players?)
• Appropriate footwear	• ATA-approved footwear (light leather or synthetic boots with soft moulded soles, individual studs no longer than 13 mm in length), inspected by referee prior to game
• Attention to correct technique	• Encouraged by coaches and team captains during match
• Knowledge and enforcement of game rules	• Strict enforcement of the appropriate set of rules (ATA or ADF-approved modified rules), particularly in relation to tackling (minimum force rule) and player misconduct
• Reduce exposure to injury	• Strict enforcement of maximum game playing time (consider reducing playing time if <14 players on team (including substitutes) or <6 on playing field) • Strict enforcement of mixed gender rule throughout game (ATA rule: maximum number of males on the field of play in mixed teams (3) minimum male requirement (1)) • Encouragement of substitution through matches to reduce player exposure
Post-event (tertiary prevention)	
• Availability of first aid equipment and ice	• ADF to supply first aid equipment kits and ice chest and ready supply of ice
• Availability of personnel with first-aid training at all games and events	• Widespread training of ADF personnel in sports first aid skills
• Appropriate and adequate treatment and rehabilitation	• Best practice sports injury treatment and rehabilitation provided through Defence Health Services
• Return-to-play rules for injured players	• Strict enforcement by medical personnel, coaches, commanders and managers at all levels.

7.3.2.1 Rugby Union/League

Rugby (union and league) injuries accounted for a total of 214 casualties reported to DEFCARE and 2,100 WDL. Rugby was the third-highest ranked cause of WDL associated with physical activity, behind physical training and touch in 1997/8.

Rugby is an extremely physical game and players require a combination of speed, endurance, strength and agility. It is a full body contact sport, inherently involving impact and collision at speed. These features of the game can result in significant musculoskeletal injury. Current evidence strongly suggests that rugby (union and league) has the highest incidence of injury of all major sports played in Australia (Hodgson Phillips, 1998; Neumann, 1998; Seward, 1993; Stevenson, 2000). In New Zealand, rugby union is the largest contributor to sports injury costs borne by the New Zealand mandatory injury compensation scheme, the Accident Compensation Corporation (Quarrie, 2001).

A limited literature search (*Medline* 1990-2001) was undertaken to inform this section on rugby injury because a comprehensive review of countermeasures to rugby injury is currently being prepared by Deakin University funded by Sport and Recreation Victoria (C Finch, personal communication). Also, the National Health and Medical Research Council (NHMRC) is currently updating the 1993 report *Football injuries of the head and neck*. Both these reports will be released in 2001 and should be used to inform future preventive action on rugby injuries in the ADF. Our review covers the key recent journal articles on rugby injury included on the *Medline* database, with particular attention to reports from the New Zealand Rugby Injury and Performance Project (RIPP). This multi-phase program of research is based on a prospective 5-year cohort study of 356 male and female rugby players (playing at different levels) undertaken to investigate risk and protective factors for rugby injury in order to develop prevention measures. The final papers from this combined research and intervention program, that report the findings on the efficacy of protective equipment, are not yet published.

Injury frequency and pattern

Data on the frequency, pattern and mechanisms of injury in ADF rugby (union and league combined) compared to those published from the RIPP prospective cohort study on rugby union injuries and a recent study of injury in Queensland amateur rugby league are shown in Table 7.4. These studies were selected because they are prospective in design, the cohorts are large and are drawn from a similar population to ADF rugby players (predominantly male and club-level amateur players). Most other published studies on injury in rugby are on professional or semi-professional players or are based on single clubs.

Differences in the definition of injury, reporting of injury incidence, data classification systems and non-reporting of some data make comparisons between the chosen studies difficult. Also, injury data on the two styles of rugby are combined in the ADF report, which further complicates comparisons. Conclusions on the pattern of injury related to injury site and nature are tentative but when the studies are compared it appears that:

- upper limb injury, predominantly shoulder injuries, may be more common in ADF rugby than in community rugby (Data from the ADF Canberra sports injury database for the first six months of 2001 show that 39% of rugby injuries (*n*=77) were to the upper limb and that 26% of all rugby injuries were to the shoulder, mostly muscle strains and dislocation/subluxation).

- the proportion of lower limb injury overall is lower in ADF rugby than in community rugby (union), although the proportion of all injuries that are knee sprains/strains(11-15%) and ankle sprains/strains (~7%) appear to be similar;

- head, face and neck injuries are common in all three rugby populations accounting for 21-38% of all injuries;

- trunk injuries account for 8-14% of injuries in the three rugby populations;

- sprains and strains were the most frequently reported type of injury in all three studies, although they appear to account for a considerably lower proportion of rugby injuries in ADF players (35%) compared to RIPP and Queensland club players (52-55%).

- fractures and dislocations are much more prominent in ADF rugby (24% of all injuries) than in RIPP rugby (8%), although this discrepancy may reflect the fact that the data are drawn from different sources. (Fractures and dislocations/subluxations accounted for 12% of rugby injuries (*n*=77) recorded on the Canberra sports injury database in the first six months of 2001.)

None of the studies provide much information on the causes and circumstances of injuries in rugby. Being hit by a moving object or person and hitting objects or persons with parts of the body accounted for three-quarters of the injuries in ADF rugby, and falls trips and slips a further 11%. There is no detailed information on the mechanisms of injury in the other studies except that the RIPP study reported that foul play was involved in 13% of rugby union game injury events.

Injury severity data for rugby were not reported in the ADF study, except that knee injuries accounted for the highest proportion of WDL of all rugby injuries, followed by head and neck injuries (combined). The two cases of fracture of the vertical column in ADF rugby players in one year is noteworthy, although there is no indication that either involved spinal cord damage. Although rare events, disabling cervical spine injuries occur particularly in rugby; their likelihood is enhanced by the fact that rugby players lead with the head. The scrum and tackle are the two phases of play most associated with spinal cord injuries and, despite rule changes, disabling injuries continue to occur (Rotem, 1998; Secin, 1999). It has been consistently reported that mismatches of skill and strength between opponents increase the possibility of spinal cord lesions (Secin, 1999).

Table 7.4 Comparison of frequency, nature and mechanism/circumstances of injury in ADF rugby players compared to club-level rugby players

Pattern of injury	**ADF Health Status Report 2000 (DEFCARE database)** **Rugby league and union combined**	**NZ Rugby Injury and Performance Project (RIPP): (Bird, 1998)** **Rugby union (amateur associations)**	**Injury in Queensland amateur rugby league competition: (Gabbett, 2000)** **Rugby league (amateur association)**
Definition of injury	All injury incidents, compulsorily reported by ADF personnel	An injury event in scheduled competition that caused the player to seek medical attention or to miss at least one scheduled game or team practice	Any pain or disability suffered by a player during an amateur match (including pre-season, fixture, exhibition or finals) and subsequently assessed by the head trainer during, or immediately after, a match.
Type of study	Cases recorded on DEFCARE database in 1997/8 (biased towards serious injury, major under-reporting)	Prospective study of 345 male and female rugby union club players through the 1993 competitive season. Players were interviewed weekly to obtain information on exposure and injuries.	Prospective study of injury in 600 players registered with an amateur rugby league organisation over three consecutive seasons. A single head trainer, accredited in injury prevention, assessment and management assessed all injuries.
Frequency	Casualties (*n*=214), participation and exposure data not collected Work days lost (*n*=2,100)	• 602 injuries in 345 players (258 males, 87 females): • Overall mean number of injury events per player: 1.84 (males), 0.73 (females) • Overall rate of injury 72 injuries/100 players (male and female) • Game injury rate (males): 10.9 injuries per 100 player-games • Practice injury rate (males): 1.3 injuries per 100 player-practices	• 941 injuries in 600 male players over 3 seasons • Overall mean number of injury events per player per season: 0.5 • Incidence: 160 injuries/1000 player position game hours, with forwards having a considerably higher incidence of injuries than backs (182.3/1000 v. 142.0/1000, chi2=14.60,df=1, p<0.001)
Age & gender	Age and gender data not reported.	• No age related data reported • M:F injury rate ratio (RR):1.8 (games), 2.2 (practices)	• All males, no age-related data reported

Anatomical site of injury	• **Upper limb** (31.3%, predominantly shoulder (18% of all rugby injuries) and wrist/finger (4%)) • **Lower limb** (30.8%, predominantly knee (15%) and ankle (7%)) • **Head & face** (14.5%); **neck** (7.0%) • **Trunk** (13.6%) • **Other** (<4.0%)	• **Lower limb** (45.5% overall) *Games:* (42.5%, predominantly knee (12% of all game injuries); thigh (8%) and ankle (5%)) *Practices* (58.4%, predominantly ankle (14% of all practice injuries); thigh (13%) and hamstring (11%)) • **Upper limb** (23.4%) *Games:* (24.0%, specific site not detailed but shoulder injuries are common) *Practices:* (21.3%, site not detailed) • **Head, face** (15.9%) **and neck** (5.8%) *Games*: Head and face (18% of all game injuries), neck (6.6%) *Practices*: Head and Face (7.1% of all practice injuries), neck (2.6%) • **Trunk** (7.8%) *Games*: 7.7% of all game injuries; Practices: 7.9% • **Unidentified:** 1.5%	• **Head & neck (25%), face (13%)** Head and neck: (~25%, 40.6/1000 player position game hours) Face: (13.3%, 21.3/1000) • **Trunk (13%)** Abdomen and thorax (13%, 21.3/1000) • **Lower limb (overall proportion not reported)** Knee (11%, 17.8/1000) Thigh, calf, ankle & foot: proportions not reported • **Upper limb (overall proportion not reported)** Shoulder, arm & hand: proportions not reported
Nature of injury	• Sprains and strains (34.6%) • Fractures (15.9%) & dislocations (7.9%) • Disorders of the muscles, tendons & soft tissues (13.6%) • Contusions and crushing injury (6.5%) • Open wound (4.2%) • Intracranial (4.2%) • Fracture of vertebral column (0.9%) • Other and unspecified (12.1%)	• Sprains and strains (52.2% of all injuries) • Haematoma (21.4%) • Laceration (7.6%) • Fractures (5.1%) & dislocations (3.2%) • Concussion (3.8%) • Other and unspecified (6.6%)	• Muscle injuries: haematomas plus strains (28.5%, 45.7/1000) • Joint injuries (sprains) (17.2%, 27.6/1000) • Lacerations (14.5%, 23.2/1000) • Fractures and dislocations (not reported) • Concussion (not reported) • Other (not reported)
Injury severity	Severity not detailed, WDL give some indication of severity • Knee injuries: accounted for 20.7% of WDL from rugby injuries	Using Abbreviated Injury Severity scale (AIS 1-3) • AIS1 (mild): 76.7%) • AIS2 (moderate): 22.8% • AIS3 (serious): 0.5%	

	• Ankle injuries: NOD • Head (6.7% WDL); Neck (7.5% WDL) • Trunk (8.2% WDL)	45% of injury events interfered with what players planned to do the next day	
Mechanism/cause	*Mechanism* • Being hit by moving object or person (65.9%) • Falls/trips/slips (11.2%) • Hitting objects or persons with part of the body (9.8%) • Body stressing (7.5%) • Other and unspecified (5.6%)	*Mechanism*: not reported *Circumstances* (phase of play) • Tackle:(40%) • Rucks (17%) • Mauls (12% • Back play (9%) • Scrums (7%)	Mechanism: not reported Circumstances: not reported
Agency	• Animal, human and biological agency (86%, mostly physical contact) • Environmental factors e.g. playing surface (NOD) • Equipment (NOD)	Foul play was reported as the cause of 13% of game injury events. In most of these cases (69%) no penalty was called.	Significantly more injuries occurred in the second half of the match and during the latter part of the season, suggesting fatigue or accumulative microtrauma may contribute to injury.

Risk/contributory factors to rugby injury

The New Zealand RIPP recently reported the findings from the first comprehensive epidemiological study in rugby to identify risk factors using a prospective multivariate approach (Quarrie, 2001). This methodology enabled the examination of the independent contribution of different variables. A cohort of 258 male players, mean age 20.6 years, was followed through a full competitive season. At a pre-season assessment, basic characteristics, health and lifestyle patterns, playing experience, injury experience, training patterns and anthropometric characteristics were recorded and then a battery of fitness tests was carried out. Risk factors were identified using both the injury incidence rate (IR) and injury severity, measured by proportion of season missed because of injury (PM), as outcome variables.

Different sets of risk factors were associated with each of these outcomes. Significant univariate associations with IR were observed for grade, age, previous injury experience, body mass index (BMI) and 30m sprint time from a 5m running start. After possible confounders were controlled for (by applying multiple logistic regression analysis) only two of these factors emerged as independent risk factors for rugby injury. Grade (players from high grades reported higher incidence rates than players from lower grades) and previous injury (beginning the season with an injury) were found to be significant and independent predictors of the risk for sustaining a rugby injury.

Univariate associations for PM were observed for: playing position, years of rugby experience, previous injury experience, strenuous physical activity, cigarette smoking status, alcohol use, and pushups. The factors that emerged from the multivariate analysis as robust independent risk factors for rugby injury that caused missed playing time were: previous injury experience (being injured at the time of pre-season examination), hours of strenuous physical activity per week (only for the group that engaged in 39 hours or more per week), cigarette smoking status (current and past) and number of pushups (poor performance was shown to be protective). BMI (<23) emerged as an independent risk factor for PM in the multivariate analysis but was not significantly associated with IR in the univariate analysis.

The two strongest findings of this study (that grade and previous injury are the most potent risk factors for rugby injury) are confirmed in other studies. Clark et al. (1990) and Garraway and McLeod (1995) both report higher incidences of injury in higher grade players than lower grade players from large prospective studies of rugby union injuries in South African and Scottish senior male players, respectively. Suggested explanations for this finding include more exposure to match play in higher grades, the increased size and strength of higher-grade players or attitudinal factors in elite/high level players such as increased competitiveness, vigour, aggression and foul play (Bird, 1998). Previous injury status was also found to be a significant predictor of new injury in a prospective study of sports injuries in young adults in The Netherlands that utilised multivariate analysis (Van Mechelen, 1996) and a prospective study of injury in US army recruits (Jones, 1993). The recent Western Australian sports injury prospective cohort study found that having a back problem that had been confirmed by a health professional increased the likelihood of injury by 69% and having sustained a sports injury in the 12 months in the 12 months preceding the study increased the risk of injury by 45% (Sports Medicine Australia, 2001).

Quarrie et al (2001) found that smoking significantly increased time lost from play but was not associated with increased injury risk. The authors suggest that this association may be related to smokers and ex-smokers requiring a longer injury recovery time or having a less dedicated attitude to sports that manifests itself in slower return to play after injury. Conflicting evidence is reported from two studies in army recruits that reported direct associations between cigarette smoking and training-related injuries (Cowan, 1993; Jones, 1993).

Player position was not a significant risk factor for injury in the RIPP risk factor study, although midfield backs missed a significantly greater proportion of the season than did the reference group (front row) (Quarrie, 2001). The literature is somewhat equivocal about the association between playing position and injury with earlier studies either reporting no difference (Bird, 1998; Garraway, 1995) or a disproportionate representation of forwards (variously loose forwards, centres, hookers and wings) among those injured (Clark, 1990; Gabbett, 2000; Hughes, 1994; Sharp, 2001). However, several of these studies only examined the proportion of injuries sustained by each positional group and did not factor in exposure.

The RIPP risk factor study found no association between higher BMI and lower aerobic fitness (and most other measures of physical performance) and IR (Quarrie, 2001). These results are inconsistent with evidence from earlier studies in rugby (Lee, 1997) and army recruits (Jones, 1993), but these two studies were weaker in terms of design.

The risk factors for tackling injuries have also been investigated. Garraway et al. (1999) undertook a prospective case control study in Scotland in which the tackling and tackled players ('the cases') involved in a tackle injury were each matched with 'control' players who held the same respective playing positions in the opposing teams. Information from subjects and controls was obtained from self-reported questionnaires and a validated battery of psychological tests. Experienced coaches recorded the circumstances of the tackles in after-match interviews with involved players. A total of 72 tackle injury episodes with correct matching of cases and controls were studies. No significant differences were observed between cases and controls on alcohol consumption before the match, feeling 'below par' through minor illness, feelings of anger or hostility, extent of match preparation, exposure to tackle practice and coaching. The influence of weather and pitch conditions was not investigated because the study had insufficient power.

The most striking finding was that more than one-half of the tackle injury episodes occurred behind the tackled player or within his peripheral field of vision. By contrast, the New Zealand RIPP prospective cohort study on tackle injuries found that these injuries were associated with stopping tackles to the trunk, from the front (63%) rather than the side or behind (Wilson, 1999). This difference could be related to different styles of play in the two countries. Garraway et al. (1999) mention that the more forceful or crunching tackles they investigated were head-on or within the tackled player's range of side vision.

Countermeasures to injury

Suggested countermeasures to injury in rugby drawn from our review of recent literature are outlined in Table 7.5. As mentioned earlier, two pending reports (by Deakin University on countermeasures to rugby injuries and by the National Health and Medical Research Council on football injuries to the head and neck) should provide additional guidance on the way forward for rugby injury prevention. Our review found no controlled trials of preventive interventions in rugby. Therefore, our recommendations are based on the available epidemiological evidence on the incidence, patterns, risk/contributory factors to rugby injury or intervention trials in other sports. The multifaceted New Zealand initiative *Tackling Rugby Injury* provides a blueprint for a systematic approach to reducing rugby injury.

In New Zealand, the Accident Compensation Council (a national compulsory personal injury insurance scheme), in partnership with the New Zealand Rugby Union and Rugby League peak bodies, has implemented 5-year injury prevention programs in both codes of rugby. The *Tackling Rugby Injury* programs are based on the recommendations of the Rugby Injury Prevention Project conducted by Otago University's Injury Prevention Research Unit (IPRU). The ACC reports that both programs have significantly reduced rugby injury claims and insurance costs and, in the case of rugby union, the incidence of injury per hundred player games (Table 7.6)

Table 7.6 Comparison of *the New Zealand Tackling Rugby Injury* program components and achievements in rugby union and league

Rugby Union Program (1996 - 1999)	**Rugby League Program (1996 - 1999)**
Key components: • Compulsory injury prevention workshops for coaches • Compulsory wearing of mouthguards by players • Resources for referees, coaches and players • Newsletters sent directly to all registered coaches	*Key components:* • Injury prevention workshops for coaches • Training workshops for referees • Compulsory wearing of mouthguards by players • Pre & off-season training guides for players • Setting up of an injury surveillance system
Results • New entitlement claims reduced progressively from 7,194 in 1995 to 5,587 in 1999 • Insurance costs decreased from \$NZ9.7m to \$NZ8.9m • Incidence of rugby union injury reduced from 10.9/100 in 1993 to 5.3/100 in 1997 and 1998 (IPRU surveillance data)	*Results* • New entitlement claims reduced progressively from 1,766 in 1995 to 760 in 1999 • Insurance costs decreased from \$NZ2.6m to \$NZ1.6m • Steadily declining injury rate (no other details) (New Zealand Rugby League Surveillance system)

Source: http:www.sportsmart.org.nz/success

The programs have spawned a website on sports injury prevention from which an education tutorial on preventing and managing sports injuries (SportSmart 10-point plan) can be downloaded, along with 10 leaflets for coaches and players on strategies to prevent injury (for example screening, physical conditioning, and protective equipment) and five resources to help sports people deal with common injuries (on concussion, shoulder injuries, hamstring , knee sprain and ankle sprain) (http://www.sportsmart.org.nz/resources)

Table 7.5 Suggested countermeasures to injuries in rugby

Potential countermeasure	Application	Evidence base
Pre-event (primary prevention)		
• Reduce/control exposure	• Limit/ban participation in informal /scratch rugby • Reduce hours of participation of ADF personnel in organised competitive rugby • Increase number of allowable substitutes (if feasible) and encourage rotation of players (but players should not be played out of position)	• Although injury rate data are lacking for ADF rugby, there is strong evidence that it is a comparatively high-risk sport for injury. Strategies to limit exposure to the sport should be explored.
• Provision of safe playing environment, including equipment, field and surrounds	For all games controlled/under aegis of ADF: • Supply sets of team colours, approved balls, line marker • Remove obstacles in immediate surrounds of field • Mark field appropriately (preferably regulation size) • Pad goalposts to 2m • Institute ground and goalpost safety inspection prior to play (by referee), all defects should be remedied before play begins and matches cancelled if ground conditions considered overly-hazardous	• Evidence from descriptive studies that hazardous field conditions (holes, cracks, sprinkler depressions and wet and uneven surfaces) are associated with fall injury in rugby and unpadded goalposts and other obstacles/fences close to boundaries cause collision injuries.
• Pre-season assessment	• Players should undergo a pre-season assessment (six weeks before start of the season) which should include tests for mechanical and functional instability of joints, linked to individual training and rehabilitation programs. Only fully rehabilitated players should be permitted to play.	• Strong epidemiological evidence, utilising multivariate analysis, shows that beginning the new rugby season with an injury is a significant risk factor for both the incidence of injury and time lost during the season (Quarrie, 2001).
• Adequate pre-season and in-season training and conditioning	• Include components to build strength, flexibility, muscular endurance, stamina, agility, balance/proprioception (2-3 workouts per week)	• Although the evidence on a positive association between fitness and injury risk is equivocal, the consensus view is that all players should undergo general and tailored pre-season and in-season fitness training to prepare their bodies to withstand the

	• Training and conditioning should be tailored so that players are equipped to meet the specific physical demands of their field positions	rigours of the sport (Quarrie, 2001). Pope et al.(2000) report that fitness, as measured by a 20-m progressive shuttle run score, was a significant predictor of injury risk in ADF army recruits during basic training.
	• Institute a regular balance board (disc/wobble board) training program into training sessions to decrease the risk of ankle inversion and ACL injuries in male players	• Positive evidence for a protective effect reported from RCTs in soccer (see below).
	• Include weights training for frail players (BMI <23) to build strength/resilience	• Low BMI found to be a significant risk factor for missed playing time due to injury in a prospective study utilising multivariate analysis (Quarrie, 2001)
	• Players should be exposed to physical impact drills in pre-season training to 'match harden' them prior to the start of the season.	• Evidence is equivocal but several studies report a declining incidence of injury through the rugby season (Armour, 1997) (Alsop, 2000) (Lee, 1996). Alsop et al. (2000) reported that the level of player fitness at the start of the season appeared to have no effect on how quickly the injury rate declined . Quarrie et al. (2001) suggest that the higher injury rate at the start of the season (mostly from tackles) may be related to lack of physical conditioning to the impacts of other players and the playing surface that players are exposed to in match play.
	• Training hours/length of time spent in strenuous activity should be monitored by coaches, players and commanders and overtraining actively discouraged.	• Two recent rugby studies have shown an association between very high levels of training or physical activity (>37 hours/week) and increased injury incidence or time lost to injury among players. The authors suggest overtraining as one explanation of these findings(Garraway, 2000) (Quarrie, 2001).
	• Players should be encouraged to keep a training and injury log and use it to monitor their weekly physical activities and injuries	
Warm up and cool down	• Warm up and cool down before and after each training session and match	• Consensus view in sports medicine that warm and cooldown may prevent muscular injury and prepare players psychologically and physically for the rigours of a game but supportive research evidence lacking or equivocal (Best, 1993; Safran, 1989). Strong evidence that a pre-exercise muscle stretch routine performed before exercise is not protective against injury (Pope, 2000).
• Player skills development by trained coaches, attention to	• All ADF rugby players should receive a thorough grounding in the basic skills and	

good technique and injury prevention	techniques of rugby in PE sessions/team training sessions. Fair play and injury prevention should also be covered. • All ADF rugby coaches should be accredited under the National Coaching Accreditation Scheme at least to Level 2 and fulfil update requirements. Special sessions on injury prevention should be included.	
• Promotion of good knowledge of game rules in players, coaches, officials and referees	• A broad program of referee training is instituted so that all matches auspiced by the ADF are under the control of an accredited referee, with injury prevention training. • An education program to develop a shared culture among players, coaches, officials (including commanders) and referees that encourages fair play and discourages fouls and misconduct.	• Foul play has been found to be associated with 13-33% of rugby union injuries (Bird, 1998; Lewis, 1994). These findings suggest that stricter refereeing has the potential to reduce injury. A broad educational approach is recommended because the support of coaches, officials and players is necessary for the development of a 'culture' of fair play in rugby.
Event (secondary prevention)		
• Use of personal protective equipment	• Compulsory ankle bracing for players with history of previous ankle sprains/clinical instability. Trial prophylactic bracing?	• No evidence of effectiveness in rugby. RCTs in gridiron, soccer and basketball support the effectiveness of ankle support (semi-rigid brace) in reducing ankle sprains in players with previously injured/unstable ankles (Quinn, 2000; Thacker, 1999) . Prophylactic bracing (of healthy ankles) found effective for foot conflict ankle injuries (Sitler, 1994). Ankle braces are permitted under rugby rules.
	• Allow temporary taping of the patella to reduce pain	• Taping of the patellar may be effective in reducing pain. Taping to prevent other knee injuries in rugby is ineffective (Gerrard, 1998b).
	• Allow wearing of soft knee braces only, for players rehabilitating from knee injuries	• Epidemiological evidence generally supports the efficacy of functional and prophylactic knee braces in reducing the incidence of knee injury in gridiron (Sitler, 1990). More research required before knee braces can be recommended for injury prevention in rugby (Gerrard, 1998b).
	• Trial the use of shoulder, chest and thigh pads	• Shoulder and chest pads are being used increasingly by rugby players but the real protective benefits of current padding is debatable (Gerrard, 1998b). Shoulder pads are permitted in rugby union provided they are made of soft and thin materials and

		cover the shoulder and collar bone only and are no thicker than 1 cm when uncompressed. Design work, laboratory testing and intervention trials are required before the introduction of more effective protective padding to these body sites. Rule changes will also be necessary. Thigh pads have been shown to reduce thigh injuries in small RCT involving Australian football players (Mitchell, 2000) but padded shorts are not permitted under rugby rules.
	• Compulsory wearing of shin guards	• Laboratory evidence shows that soccer shin guards are effective in attenuating the forces which lead to lower limb injury (Bir, 1995).
	• Consider the promotion of headgear (scrum cap) wearing after investigating the frequency, nature and severity of head lacerations and abrasions in rugby. Current available rugby headgear appears to be ineffective in preventing intracranial injuries.	• Sound epidemiological studies of injury and injury reduction when wearing protective headgear have not been reported (Wilson, 1998). Findings from impact testing of available rugby headgear (McIntosh, 2000) and a pilot RCT of headgear in junior rugby union strongly suggest that currently permitted headgear does not provide sufficient protection against concussion (McIntosh, 2000). Headgear may protect against lacerations and abrasions (Wilson, 1998).
	• Encourage facial greasing to protect against facial lacerations	
	• Mandate the wearing of mouthguards, subsidise mouthguard purchase and fitting.	• Clear support in the scientific literature for the use of mouthguards to protect against orofacial injuries in contact sports such as rugby (Chalmers, 1998). The effectiveness of mouthguards in preventing concussion is disputed (McCrory, 2001).
• Appropriate footwear	• Players should wear appropriate footwear for playing surface.	• Making recommendations on appropriate footwear is difficult because of variable condition of natural turf, and individual variations in ground reaction loads and footfall pattern during weight bearing (Milburn, 1998). • Milburn & Barry (1988) provide some general guidelines: - strict adherence to rugby's requirement of limit to stud (sprig) dimensions and conditions of wear; - stud dimensions and/or pattern should be designed to reduce the pressure on a player during direct contact between the shoe and a player; - there is a need to provide sufficient friction between the shoe and the surface to provide traction yet allow sufficient 'give' to dissipate any excess loads on to the lower extremity (adjusting detachable studs to suit playing surface may meet these demands); and

		- the shoe must conform to the orthopaedic and hygienic demands of the wearer.
• Attention to correct technique and fair play	• Good technique and fair play encouraged by coaches and team captains during match	See above
• Knowledge and enforcement of game rules	• Strict enforcement of rules, particularly in relation to tackling fouls and player misconduct	• Particular attention to enforcing scrum, charging and tackling (head high and spear tackle) rules because illegal play in these areas is associated with injury, particularly of the head and neck.
• Reduce player exposure to injury during game	• Encourage the full use of the four (permitted) player substitutes during matches to reduce player exposure time to injury. • Careful selection and rotation of starting players and substitutes so that players are not played out of position (particularly the front row of the scrum).	• Reduction of exposure time is an acknowledged injury prevention measure that has recently gained some acceptance in football codes as indicated by more liberal substitution rules. Weak evidence from a trial in soccer which showed that free substitution reduced the duration of minor injuries (Inklaar, 1994)
Post-event (tertiary prevention)		
• Availability of first aid equipment and ice	• ADF to supply first aid equipment kits, ice chest and ready supply of ice, stretcher and cervical collar	• Consensus view in sports medicine that prompt and appropriate first aid by a qualified person aids is beneficial. RICER first aid regime widely endorsed although research evidence on its effectiveness is lacking.
• Attendance of personnel with first-aid training at all games and events	• Widespread training of ADF personnel, referees and coaches in sports first aid skills especially for recognition and initial management of head and neck injuries	• NHMRC guidelines on head and neck injuries (currently under revision) provide best practice advice on the prevention and management of these injuries (NHMRC, 1993).
• Appropriate and adequate treatment and rehabilitation	• Best practice sports injury treatment and rehabilitation provided through Defence Health Services	• Inadequate rehabilitation and early return to play is an independent risk factor for rugby injury (Quarrie, 2001).
• Return-to-play rules for injured players developed and enforced	• Strict enforcement by medical staff, coaches, commanders and managers at all levels.	

7.3.2.2 Soccer

Soccer injuries reported to DEFCARE accounted for 158 casualties and 1,854 WDL during financial year 97/98. It was the fourth-highest ranked physical activity associated with work days lost, behind physical training, touch and soccer (Defence Health Service Branch, 2000). Given that soccer is not a full contact sport, the relatively high frequency of injuries and work days lost in the ADF due to soccer compared to sports such as rugby and Australian football suggests higher participation and/or exposure (number of hours played), but this aspect warrants further investigation.

The game of soccer puts many demands on the technical and physical skills of the player. The functional aspects of soccer -acceleration, deceleration, jumping, cutting, pivoting, turning and kicking the ball- put significant stress on the lower extremities (particularly the ankle and knee).

Injury frequency and pattern

There have been no prospective studies of injuries in Australian club-level soccer and a recent review of the published literature reveals that epidemiological studies of soccer injuries in male players are focussed mainly on elite (professional) and youth (mostly adolescent) populations (Dvorak, 2000; McGrath, 1997).

Table 7.7 compares the findings from the study of soccer injuries in the ADF utilising DEFCARE data (Defence Health Service Branch, 2000) to a recently published prospective study of soccer injuries in a group of 264 Czech male players of different age groups and skill levels who were followed over a 12-month period with weekly examinations by a sports medicine physician. Other prospective studies of soccer injuries in predominantly non-elite senior male players date back to the early 1980s (Ekstrand, 1983b; Jorgensen, 1984) or were based on small numbers (Poulsen, 1991), a short follow-up period (Inklaar, 1996) or on data from a single club (Neilsen, 1989).

The pattern of injury in ADF soccer injury cases (*n*=158) recorded on the DEFCARE database in 1997/8 is broadly similar to the pattern reported from the Czech soccer injury study (*n*=264), taking into consideration study differences, for example source of data, definition of injury, data classification systems and age mix of subjects (Table 7.7). The proportion of reported lower limb injuries was similar, accounting for 69-72% of all soccer injuries. In both studies ankle and knee injuries were the most frequently occurring lower limb injuries, each site accounting for approximately one-fifth of all soccer injuries. The additional data supplied from the newly established Canberra ADF sports injury database (which included sport and physical activity cases recorded from Jan-June 2000) included 52 cases of soccer injury which were predominantly ligament sprains to the knee (25% of soccer injuries) and ankle (20%). Five of the nine knee ligament injuries were to the meniscal/labral ligaments, two were anterior cruciate ligament (ACL) injuries and two were simply described as 'ligament sprains').

The ADF study reported a much higher proportion of upper limb injuries than the Czech study (18% versus 5%) and a lower proportion of trunk injuries (7% versus 13%). Head injuries were uniformly infrequent (accounting for <4% of all soccer injuries). The most frequently occurring type of injury was sprains and strains but these injuries accounted for a much lower proportion of injuries in the ADF soccer study compared to the Czech study (48% versus 87%). By contrast, fractures are apparently much more frequent in ADF soccer players than the Czech players (20% versus 3%). Although the source of data may partly account for this discrepancy, the comparatively high frequency of fractures in ADF soccer players (also evidenced in touch players) requires further investigation to eliminate environmental and player-related factors. There was also a substantial difference in the proportion of overuse injuries reported, much lower in the ADF study than in the Czech study (13% versus 23%).

Neither study provided detailed information on the mechanisms (causes) and circumstances of injury. The injury classification systems used on these parameters were very different. Both studies report, however, that contact with other players was responsible for approximately half of all the soccer injuries recorded. Peterson et al. (2000) investigated the impact of foul play on injury in the Czech player group in greater depth. Anecdotal player evidence indicated that one-third of all soccer injuries incurred by the players involved foul play. In a companion study of severe injuries in an extended group of Czech players (*n*=398) the authors reported that injured players attributed the majority of the severe contact injuries in games (27/36 injuries, 75%) to foul play, including professional fouls (Chomiak, 2000). Players reported that referees punished only two-thirds of the offending players. Only nine players were shown yellow cards and in no case was the red card shown. This suggests that stronger refereeing has the potential to reduce injuries in soccer.

Injury severity data were not reported in the ADF study, except that WDL by injury site was generally proportionate to the percentage of injury cases by injury site. The average WDL for all soccer injury cases was approximately 12 days (15 days for sprains and strains) compared to 6.5 days for all reported physical activity and sports injury cases.

Because of the shortcomings of available data, the ADF is advised to conduct a prospective study of injuries in soccer prior to devising a prevention strategy and instituting prevention measures. Again, accurate data on participation and hours of exposure are required, to establish whether or not the higher frequency of injuries in soccer particularly when compared to Rugby and Australian Rules reflects high exposure or factors related to the rules and conditions under which soccer is played by Defence Force personnel (especially informal games). Systematic analysis of the cases recorded on the newly introduced sports injury surveillance data system should supply more information on the nature, severity, mechanism and circumstances of soccer injury to underpin prevention measures.

Table 7.7 Comparison of frequency, pattern and mechanism of injury in ADF soccer players compared to club-level soccer players

Pattern of injury	**ADF Health Status Report 2000 (DEFCARE database)**	**(Peterson, 2000) (Prospective study of football (soccer injuries in different age and skill-level groups, conducted in the Czech Republic)**
Definition	All injury incidents, compulsorily reported by ADF personnel	Any tissue damage caused by soccer regardless of consequences with respect to absence from training or match
Type of study	Cases recorded on DEFCARE database in 1997/8 (biased towards serious injury, major under-reporting)	Prospective study of injuries sustained over 12 months by 264 players of different age (84 adult and 180 youth players) and skills levels (club to high level) in games and training. Subjects were examined weekly by a sports medicine physician.

Frequency	Casualties (n=158), participation and exposure data not collected Work days lost (n=1,854)	Frequency (adult and youth players combined): 216/264 (80%) injured, the majority of injured players (*n*=138) were injured more than once (558 injuries were recorded over the year). Injury rate for adult players: ranged from 1.8 (third league) to 3.8 (local team) per player per year Incidence per 1,000 hours of exposure (adults): local team (11.4), low-level amateurs (8.9), leading amateurs (4.6) and top-level adults (5.6)
Age & gender differences	Gender- and age- related data not reported	All males, age-related data not reported for adult males
Anatomical site of injury	• Lower limb (69.0%, comprising knee (22.8%), ankle (22.8%) lower leg (8.9%), foot (4.4%) and other (10.1%)) • Upper limb (13.0 %, NOD) • Trunk (7.0%) • Head (<4.0%) • Other and unspecified (7.0%)	• Lower limb (72.1%, comprising ankle (20.4%), knee (17.7%), thigh (14.5%) foot, toe (10.0%) and lower leg (9.5%)) • Trunk (13.2%) • Upper extremity (5.4%) • Head (3.6%) • Other (5.6%)
Nature of injury	• Sprains and strains (47.5%) • Fractures (20.3%) and dislocations (2.5%) • Disorders of the muscles, tendons & soft tissues (10.8%) • Contusions and crushing injury (7.0%) • Other and unspecified (12.0%)	• Sprains and strains (87.0%) • Fractures (3.1%) and dislocations (2.5%) • Contusion (4.2%) • Other (3.2%)
Injury severity	Not detailed • Knee injuries: accounted for 37.6% of WDL from all soccer injuries • Ankle injuries: 19.3% WDL • Lower leg: 4.2% WDL • Other lower limb: 4.7% WDL	• Mild (*symptoms lasting up to 1 week or absence from play for 1 week:* 52.2% • Moderate *(symptoms lasting from 2-4 weeks or absence for 2-4 weeks*): 32.4% • Severe (*symptoms for more than 4 weeks or absence for 4 or more weeks and any fractures/dislocations):* 15.4%
Mechanism/cause	• Being hit by moving object including other player (46.8%) • Falls/trips/slips (19.0%) • Hitting objects with part of the body (15.2%) • Body stressing (12.7%) • Other and unspecified (6.3%)	• Trauma (77% of injuries, comprising contact during game and training (43%), and non contact trauma (34%)) • Overuse (23%)
Agency	• Animal, human and biological agency (60%, mostly physical contact) • Environmental factors e.g. playing surface (15%) • Equipment (14%)	• Almost 50% of all injuries were caused by contact with another player and half of these cases were associated with foul play.

Risk/predisposing factors for soccer injury

In a recent review Dvorak and Junge (2000) identify a number of factors that available evidence suggests may predispose athletes to injury in soccer, although none have been established as independent risk factors in prospective cohort studies utilising multivariate statistical techniques to control for confounding. Predisposing factors to injury are generally categorised as either intrinsic (i.e., factors related to the biologic and psychosocial characteristics of a player) or extrinsic (i.e. factors related to environmental variables such as level of play, exercise load, position played and equipment).

Of the intrinsic predisposing factors to injury identified in the review, and in their own prospective study of soccer injuries in 389 Czech players (Dvorak, 2000), age of players and previous injury/inadequate rehabilitation have consistently been identified as strongly associated with the occurrence of injury. Other intrinsic factors with weaker evidence of a predictive association with injury include: clinical instability in knee and ankle joints; muscle strength, tightness and asymmetry; body mechanic defects; and psychological factors such as life event stress and prolonged reaction time.

Dvorak & Junge (2000) report that, of the extrinsic predisposing factors to injury, there is good epidemiologic evidence (from RCTs) that failure to use ankle support (taping or bracing) notably increases the risk of ankle injuries, and failure to wear shin guards is associated with an increase in the proportion of leg injuries. Their review reported contradictory results or weaker supportive evidence for the following: level of play and position on the field, duration of training, warm-up, shoe-surface interface, type and quality of footwear, pitch conditions and foul tackles.

Countermeasures to soccer injuries

Table 7.8 outlines the countermeasures to soccer injury that are suggested by our analysis of ADF soccer injury data and the research literature. A fuller account of many of these (and the evidence supporting their effectiveness) can be found in an earlier MUARC report *Heading injuries out of soccer: a review of the literature(McGrath, 1998).*

In all, our literature search found six randomised controlled trials of preventive interventions in soccer:

- An early trial of a multifactorial intervention in 12 Swedish male soccer teams (180 players) that comprised seven measures: (1) correction of training (inclusion of warm-up); (2) provision of optimum equipment (shin guards and ribbed training shoes for winter training); (3) prophylactic ankle taping for all players with a history of ankle injury/instability; (4) controlled rehabilitation under supervision;(5) exclusion of players with knee instability; (6) information (education) of players and coaches on the importance of disciplined play and injury prevention measures; and (7) oversighting (correction and supervision) of the prophylactic measures by members of the research team. The authors (Ekstrand et al, 1983) reported a significant reduction in the total number of soccer injuries ($p<0.001$), the number of ankle sprains ($p<0.05$), the number of knee sprains ($p<0.05$), the number of strains ($p<0.001$), the number of operations ($p<0.05$), the absence from practice ($p<0.001$) and the absence from practice ($p<0.001$) in the intervention group of teams compared to the control group over the six-month intervention period.

- A trial of free substitution (the possibility to substitute players at any time during the match) on the incidence and duration of soccer injuries (Inklaar, 1994). The trial found no significant difference between the intervention and control groups in injury incidence per 1000 match hours and in injury pattern. However, in the substitution group, the duration of minor injuries was significantly lower than in the control group. Compliance was positive among players, coaches and referees.

- Two RCTs that reported positive findings on the injury prevention efficacy of balance board training in *male* soccer players:

- An RCT of the injury prevention effects of regular balance board training and prophylactic ankle bracing (trialed separately) on ankle injuries in 450 Swedish male soccer players found that both interventions produced significant decreases in ankle injury in soccer players with a previous history of ankle injury compared to controls but not in players without previous problems (Tropp, 1985).

- A second RCT of progressive balance board training on the incidence of ACL injuries involving 600 players that reported a seven-fold reduction in ACL injuries per team per year in the intervention group compared to the control group (Caraffa, 1996).

- A recently published study that reported negative findings on the effectiveness of balance board training on lower extremity injury in an RCT involving 221 Swedish *female* soccer players followed over the 3-month intervention period. The authors reported no reduction in the number, incidence or type of traumatic injuries of the lower extremities in the intervention group of teams that included 10-15 minutes of balance board training into their soccer training regime compared to controls who did not (Soderman, 2000).

- An RCT by Surve et al. (1994) in 504 senior soccer players that found a fivefold reduction in the incidence of recurrent ankle sprains in soccer players using a semi-rigid ankle brace but no significant reduction in players with previously uninjured ankles.

Table 7.8 Suggested countermeasures to injuries in soccer

Potential countermeasure	Application	Evidence base
Pre-event (primary prevention)		
• Reduce/control exposure to soccer	• Consider ways to reduce participation if this strategy is shown to be warranted by an in-depth analysis of sports injury surveillance data including exposure data • Increase size of teams and rotation of players, decrease game time in ADF-controlled matches	Reduction in exposure is a well-acknowledged injury prevention measure. Rules governing participation of ADF personnel in soccer and the conditions under which it is played should be developed, underpinned by an in-depth analysis of a full 12 months of data from the ADF sports injury surveillance database (plus player exposure data) and broad consultation
• Provision of safe playing environment, including equipment, pitch and surrounds	For all games controlled/under aegis of ADF: • Prohibit play on hard (concrete), contaminated (oily) or uneven surfaces • Supply appropriate footwear for ground, sets of team colours, approved balls, line marker and tape • Remove/pad obstacles in immediate surrounds of pitch • Mark pitch as set down in soccer rules • Moveable goalposts be correctly installed, anchored, secured, counterweighted and padded; permanent goalposts should be padded • Develop a pitch and goalpost inspection protocol prior to play an institute inspection by referee prior to match. Matches should be cancelled if ground conditions are considered hazardous. • The use and storage of portable goalposts are	*Pitch conditions* • Eckstrand & Gillquist (1983) estimated that poor surface (in combination with other factors e.g. footwear) contributed to 24% of injuries in a prospective study of soccer injuries in 180 Swedish players. Several studies have implicated slippery, uneven, potholed pitches and inadequate safety perimeters with injury occurrence but the contributions of these factors to injury risk have not been statistically evaluated (Inklaar, 1994). • Evidence on the association between type of playing surface and injury is conflicting with studies finding either no difference in the incidence of injury between artificial, gravel or grass surfaces (Ekstrand, 1989), lower incidences of injury on artificial turf compared to gravel or grass (Engerbretsen, 1987), or a higher incidence of injury on artificial surfaces compared to natural surfaces (National Collegiate Athletic Association Men's Soccer Injury Surveillance System, 1993; National Collegiate Athletic Association Women's Soccer Injury Surveillance System, 1996). One contributor to the diversity of these findings may be the highly variable nature of natural turf and turf conditions on any given match day. *Goal posts* • No injuries were recorded from 7 player impacts over the 3-year pilot field test of padded soccer goalposts in US (Janda, 1995). • Portable goalposts have been implicated in a number of fatal incidents in US and Australia.

	covered in a new Standards Australia Handbook 227 *Portable soccer goals – manufacture, use and storage*	
• Adequate pre-season and in-season training and conditioning	• As appropriate to the sport: anaerobic and aerobic exercise	• Some evidence that soccer teams that have the longest training period or a higher than average number of training sessions have fewer injuries (Arnason, 1996; Ekstrand, 1983b).
• Warm-up and cool down	• Institute warm-up and cool-down before and after each training session and match	• Weak evidence that absence of muscle strain injuries appear to be directly related to initiation of a controlled warm-up and stretching program (Arnason, 1996) and that goal shooting before warm up increases the risk of quadricep muscle strains (Ekstrand, 1983b).
	• Consider the inclusion of year round strength training in soccer training program	• Pre- and post- evaluation of a year-round strength training program introduced into training sessions of one US college soccer team decreased the incidence of injury from 15.5 to 7.99 per 1,000 athletic exposures (Lehnhard, 1996).
	• Consider the inclusion of regular balance board (disc) training in soccer training sessions for male team members to reduce the risk of knee and ankle injuries	• A significant injury reduction effect reported for balance board training for male soccer players (Caraffa, 1996; Ekstrand, 1983b; Tropp, 1985) but not for females (Soderman, 2000). By contrast an earlier trial of disc training in the prevention of ankle and knee ligament injuries in female handball players reported significant reductions in the risk of these injuries in the intervention group compared to controls (Wedderkopp, 1999).
	• Coaches and players should avoid overuse injuries by employing variable training routines, doing cross training, limiting practice length and/or frequency and avoiding sudden changes in practice intensity, style, or terrain	• Training errors are strongly associated with exercise related overuse injury (Jones, 1994; Macera, 1992).
	• ADF personnel should be required to keep a weekly log of hours spent in sports training and playing, injury occurrence and rehabilitation details	

• Player skills development by trained coaches, attention to good technique and injury prevention	• All ADF soccer players given thorough grounding in the basic skills, correct techniques (including heading) and injury prevention in PE sessions/team training sessions • ADF soccer coaches should be accredited under the National Coaching Accreditation Scheme at least to Level 2, and fulfil update requirements	• Consensus among authors that coaches and trainers have a major role in injury prevention, through the development of players' skills and techniques, the promotion of individual and team fitness and the encouragement of a culture of fair play, but there is little empirical evidence to support this consensus view. • Theoretically, correct heading technique should prevent head and neck injuries but no supporting evidence for this proposition is currently available.
• Promotion of good knowledge of game rules in players, coaches, officials and referees	• Broad program of referee training so that all formal and informal games (if permitted) auspiced by the ADF are under the control of a trained referee. A culture developed among players, coaches, officials (including commanders) and referees that encourages fair play and discourages tackling fouls (especially 'professional' fouls).	• Anecdotal evidence from players and referees suggests that foul play is associated with 25% -35% of soccer injuries overall (Ekstrand, 1983a; Nielsen, 1989) and 75% of severe contact soccer injuries (Chomiak, 2000).
Event (secondary prevention)		
• Use of personal protective equipment	• Compulsory ankle bracing for players with history of previous ankle sprains/clinical instability. Trial prophylactic bracing.	• RCTs in soccer by Ekstrand (1982), Tropp et al. (1985), and Surve et al. (1994) support the effectiveness of ankle support (taping and semi-rigid brace) in reducing ankle sprains in soccer players with previously injured/unstable ankles. Taping is less effective because it becomes loose after 10 minutes or so of exercise, is expensive and requires skill to apply properly.
	• Compulsory shin guards	• Laboratory evidence shows that soccer shin guards are effective in attenuating the forces that lead to lower limb injury (Bir, 1995).
• Appropriate footwear	• Appropriate footwear, inspected by referee prior to game	• Consensus that shoes should be selected that are appropriate to weather conditions and surface characteristic but there are insufficient data to compare the relative safety of different shoe and cleat designs. Moulded cleats/ribbed soled designs may be safer than screw in cleats (Ekstrand, 1983a). Playing with cleated shoes on artificial turf may increase the rate of injury (Ekstrand, 1989).
• Attention to correct technique	• Good technique encouraged by coaches and team captains during match	
• Knowledge and enforcement of game rules	• Strict enforcement of rules, particularly in relation to tackling fouls and player misconduct	• Foul play associated with 25-35% of all soccer injuries and 75% of severe contact injuries (see above)

• Reduce exposure to injury during the game	• Encouragement of substitution	• Evidence from a single RCT showed that the free substitution rule reduces the risk of injury (Inklaar, 1994).
Post-event (tertiary prevention)		
• Availability of first aid equipment and ice • Attendance of personnel with first-aid training at all games and events	• ADF to supply first aid equipment kits and ice chest and ready supply of ice • Widespread training of ADF personnel in sports first aid skills	• Consensus view in sports medicine that prompt and appropriate first aid by a qualified person aids is beneficial. RICER first aid regime widely endorsed although research evidence on its effectiveness is lacking. • NHMRC guidelines on head and neck injuries (currently under revision) provide best practice advice on the prevention and management of these injuries (NHMRC, 1993).
• Appropriate and adequate treatment and rehabilitation • Return-to-play rules for injured players	• Best practice sports injury treatment and rehabilitation provided through Defence Health Services • Strict enforcement by commanders and managers at all levels.	• Previous injury/inadequate rehabilitation have consistently been identified as strongly associated with the occurrence of injury (Dvorak, 2000).

7.3.3 Reducing injuries in physical training and other sports associated with high injury frequencies and WDL

Physical training

The physical activity most associated with casualties and WDL in the ADF in 1997/8 was physical training (744 casualties and 7,361 WDL). The ADF Health Status Report did not detail the relative contribution to injury of the different components of physical training. These data (and exposure data) are needed before any sensible suggestions can be made about prevention. The newly established ADF sports injury database has the potential to provide some of the missing information on the activities most associated with PE injuries and WDL and more detail on body site injured, mechanisms and circumstances. However, a special prospective study would have to be mounted to collect exposure data (participation and time exposed) to determine the high-risk components for injury.

The literature provides good supportive evidence for the efficacy of programs to reduce injury in military populations through adjustment of physical training regimes and the conditions of training. For example, in a 1995 military study the Naval Health Research Center demonstrated that reducing running mileage and gradual progression of training resulted in a 50% reduction in the incidence of stress fractures without a degradation of aerobic fitness benefits (as measured by run times) (Kaufman, 2000).

Running/jogging, Australian football, basketball/netball and volleyball

Running/Jogging, Australian football, basketball/netball and volleyball each contributed approximately 2.0% of all casualties associated with workplace injuries and illnesses in the ADF in 1997/8 (Defence Health Service Branch, 2000). Time and budgetary considerations precluded any detailed discussion of the evidence base for specific countermeasures to injury in these sports in this report, although any trials in these sports of interventions to counter ankle, knee and shoulder injuries are covered. Attention is drawn to a series of comprehensive literature reviews on countermeasures to injury in these sports produced by MUARC and Deakin University, specifically:

- Running the race against injury: A review of the literature(McGrath, 1996)
- Tackling Australian football injuries: A review of the literature(Gabbe, 1998)
- Shooting for basketball injury prevention: A review of the literature(Speed, 1998)
- Attacking the goal of netball injury prevention; A literature review (McGrath, 1998)
- Spiking injury out of volleyball: A review of injury countermeasures (Cassell, 2001)

7.3.4 The *Safe Communities* approach to sports injury prevention

The approach recommended in this report to reduce non-work physical activity and sports related injuries and WDL is essentially 'top-down' ie., the ADF is advised to develop implement and evaluate a comprehensive risk management/sports safety plan based on available sports injury data, proven and promising countermeasures to injury in the literature and ongoing research instigated by the ADF. Of course, the plan and interventions should be developed in consultation with experts in the field and key stakeholders within the ADF. A complementary approach should also be taken at the local unit level to strengthen commitment to the reduction of sports-related injuries among all those actively involved in organising and leading ADF sports/physical activities and participants (this process has begun under the Defence Injury Prevention Program).

The *World Health Organisation (WHO) Safe communities* model provides a useful strategic approach to injury prevention at the local level. Essentially it is a community development approach in which a representative group of key local stakeholders, with strong grass roots representation, take responsibility for injury prevention at the community level utilising local injury data to devise and apply evidence-based solutions in a planned and systematic way. The term 'community' is broadly defined by the WHO and may encompass a delineated geographical area, groups with common interests, professional associations, or the individuals who provide services in a specific location.

Several of the communities that are members of the international *WHO Safe Communities Network* have included sports injury prevention in their community injury prevention strategy. The WHO Safe community program in Motala, Sweden recently reported positive results from the evaluation of a 12-month community intervention designed to reduce injuries during physical activities (Timpka, 2001). The quasi-experimental evaluation (that compared injury reductions in the intervention population to a non-random control population) showed a 14% reduction in injury incidence in the study area from 21 injuries/1000 population years to 18/1000 population years (OR 0.87; 95% CI 0.79 to 0.96) compared to no change in the control area (OR 0.93; 95% CI 0.93-1.07). In the intervention community the reduction in injury incidence was mainly due to a fall in moderately severe injuries (AIS (Abbreviated Injury Severity Scale) 2). Minor injuries (AIS 1) increased, and there was no change in the risk of severe injuries (AIS 3).

The interventions implemented under the aegis of the local sports assembly included:

- workshops on sports safety and injury prevention for physical education teachers, coaches and referees (including a fair play program to discourage foul play);
- the compulsory wearing of shin pads and warm-up for all players in a local workplace soccer competition;
- increased supervision of novice participants;
- courses for local coaches organised by an alliance of soccer clubs on how injuries can be avoided by proper physical preparation; and
- the introduction of a sports medicine service in the primary care system that advised injured patients on rehabilitation and how to avoid injury in the future.

Two other *WHO Safe Communities* programs (Harstad in Norway and Latrobe Safe Communities in Victoria, Australia) have reported reductions in sports-related injuries as result of community intervention programs but neither evaluation included a comparison community (Day, 2001; Ytterstad, 1996). The implementation of a *Safe Communities* approach integrated into a system-wide 'top-down' approach may increase compliance and produce better injury reduction outcomes. However, it is important to note that the evidence from evaluations shows that *safe communities* programs work best when the intervention population is cohesive, homogenous and stable, the implemented prevention measures are evidence based, interventions have good reach and high penetration and attention is paid to sustainability through organisational change (Ozanne-Smith, 1998).

8. CHANGING ORGANISATIONAL CULTURAL BEHAVIOUR

Evidence for interventions to change cultural norms in the military context toward safe behaviours and practices, and away from unsafe behaviours and practices were investigated. Among others, "action research" (Kurt Lewin) and humanism-based approaches (eg: obtaining commitments, establishing moral obligations and a sense of duty, establishing states and expectancies which will affect behaviour) will be considered, but with emphasis on evidence-based interventions.

What is an organisational culture? An organisational culture is that set of rules, regulations, common understandings and general practices accepted by most members of an organisation. These elements govern, and allow the organisation to function. It is the very presence of these rules, regulations and common understandings that provide the coherence of an organisation. Consequently, the nature of the organisation itself, its size, rigidity, structure, and its mission bear directly upon its culture (Anderson, 1985; Armenakis & Bedeian, 1999; Baron & Byrne, 1987; Damanpour, 1991; Furnham, 1997; McKenna, 1994; Mullins, 1993; Norman, 1988; Organ & Bateman, 1991; Oxenburgh, 1991; Parker et al., 1999; Robbins, Waters-Marsh, Cacioppe, & Millett, 1994).

Cultural change within organisations involves the organisation at several levels. The executive level provides a direction to the change. The managerial levels control the pace of the change, and the employees implement the change. Consequently, as a pre-condition for successful cultural change, all levels of the organisation must adopt their share of the change. Additionally, the change must consider the nature of the organisation itself. Small, flexible, unstructured organisations are able to rapidly change. Large, complex, hierarchically bound organisations may decide to rapidly change, but will resist themselves. Should a complex organisation also be bound with strict and complex rules, further resistance to change will arise through the complexity of competing requirements and rule structures (Beer, Eisenstat, & Spector, 1990).

8.1 EVIDENCE AVAILABILITY AND LIMITS

It would have been beneficial for this review to consider cultural change within the military context. While it is apparent that the ADF have achieved this in the past, as have other comparable military organisations in other Nation-States, there is a lack of peer-reviewed literature available from which to draw. This review is only able to consider published research, and overarchingly this review will consider cultural change in other mission-specific large organisations.

Due to the nature of organisational change, evidence pertaining to change is largely anecdotal with some limited case study material available. Unfortunately, little evidence of successful change within organisations is actually published for a number of reasons. First, change processes within organisations can rarely be compared due to the differences in circumstances between organisations undergoing change. For instance, differences in client bases, industries, and national and international economies will bias results drastically. Second, organisations are reticent to release confidential aspects of their management and accounts that might reveal to their competitors the advantages they obtain through the change. Third, the information that is made public is usually bound inside other systems and often reported in a manner that will not allow objective external scrutiny of the effect of any changes. Fourth, organisational change occurs within functioning organisations. Consequently, little experimental evidence is available to support or contradict theoretical claims made by practitioners throughout the field. It is simply not practical or ethical to employ controlled experimental designs inside work places where consequences for individuals may be severe, and for organisations, survival itself may be threatened. Thus, work in this field has only been evaluated by case study. Hence, assessing successful organisational change is difficult.

One further problem that complicates assessment of successful organisational change models is that of unfounded theoretical bias. Many practitioners in the field hold assumptions that colour their approach to organisations (Heller, Price, Reinharz, Riger, & Wandersman, 1984). In fact, several texts explicitly state these assumptions as principles required for obtaining successful change, and yet offer no evidence supporting these assumptions (cf: Drench, 1998; Dunnette, 1990; Mullins, 1993). This biased approach has arisen because of both the difficulty in obtaining data, and because the field grew from humanistic psychological approaches that assume certain values, such as “supplementing the authority of role and status with the authority of knowledge and competence, locating decision-making and problem-solving as close to information sources as possible…” (Friedlander & Brown, 1974). It is ironic that the value of knowledge has been supplanted with doctrine through the assumption that knowledge empowers organisational change. It is true that social psychology has found this assumption to be supported at an individual level (Baron & Byrne, 1987), but at that time it had not been assessed as a part of organisational development. Fortunately, this has since been evaluated, and supported, as will be discussed below. Nonetheless, the point here is that much that is claimed to be “true and necessary” in the field has not been subjected to rigorous experimentation or evaluation. Overall, the field of Organisational Development remains one of the most poorly explored areas of modern psychology.

8.2 HUMANISTIC THEORIES OF FACTORS IMPORTANT IN CHANGE

Over the past 50 years several psychological factors and theories have been proposed as being important to cultural change. This has frequently been on the basis of these factors displaying good explanatory power for some behaviour. An important distinction needs to be drawn at this point. Many psychological theories that have excellent explanatory validity (ie. they adequately explain some behaviour or its absence) have poor predictive validity (ie: the measured presence or absence of some factor prior to some behaviour predicts the outcome). A typical example of this is IQ. Children who succeed academically are frequently found to possess high IQ and are rarely found to have low IQ. Nonetheless, children with high IQ often do not succeed in school. In other words, IQ has excellent explanatory power and limited predictive power.

Factors that have been regarded as important in organisational cultural change in the past have included moral obligations, stated intentions, planned actions, self-efficacy, and expectancies. Moral obligation has, in the past, been seen as useful in predicting intentions that in turn precede behaviours (Ajzen & Fishbein, 1980). Nonetheless, work since then has reported only equivocal results in incorporating this dimension as a predictor of behaviour, and recognised that stated intentions are a stronger predictor of behaviour than moral obligation (Gorsuch & Ortberg, 1983). This is not surprising, as measures of moral obligation will strongly correlate with measures of stated intention, and stated intention does not correlate well with behavioural outcome (Den Ouden, 1995). Additional development of this theory suggested intention would have meaning only when associated with a plan of action that in turn relies upon beliefs about self-efficacy (Bandurra, 1986). Self-efficacy in the present context means having specific cognitions about one's ability to undertake the task that is the subject of the belief. Most people have low self-efficacy concerning public speaking, while most people have high self-efficacy about their driving ability. However, the concept of self-efficacy as a predictor of behaviour is mixed (Walker, Burnham, & Borland, 1994). Placed in suitable conditions, most people may attempt, and even succeed at tasks in which they have low self-efficacy and do poorly in tasks where they have high self-efficacy. For instance, most people carry-off a public speaking task no matter what they believe of themselves if it is forced upon them (Phillips, Jones, Rieger, & Snell, 1997), while the great majority of drivers believe that they drive better than the average driver, when clearly, only half the driver population could exceed the average (Harrison, Fitzgerald, Pronk, & Fildes, 1998).

One other parameter, expectancies, is more predictive of behavioural outcomes than moral obligations, intentions to behave, or perceived self-efficacy, though all of these are involved in behavioural outcomes. Research suggests peoples' expectancies about outcomes are predictive of those outcomes (Swann & Reed, 1981), and that this even pertains to how employees perceive the nature of their organisation (Olekalns, 1997). This model suggests what we believe to be true of ourselves, and of others around us, will colour our interactions. Where we believe an organisation seeks to change things, and has consistently failed to implement the right change, or cannot resolve work place issues effectively, the person modifies their behaviour in anticipation of this outcome, frequently leading to the very outcome that was believed in the first place (Olekalns, 1997). If this sounds circular, it is. Nonetheless, examples abound.

However, the strongest predictor of behavioural outcomes remains past behaviour (Baron & Byrne, 1987; Walker et al., 1994). Thus, it must be concluded that as a theoretical approach to behavioural change, either at personal or organisational levels much remains to be elaborated. Presently, the approach to change management offered by methods such as the atheoretical approach of Action Research surpass the theoretical models mentioned above.

8.3 ACTION RESEARCH

Kurt Lewin's (Weiss, 1990) model of change within organisations places the behaviour of individual who is to change as a function of both their environment and their personality, or $B=f(P, E)$. Necessarily this places both the individual and the environment as central to the change process. The environment includes all external influences upon the individual. While much modern theory has evolved from this perspective, and much success has been claimed from this and subsequent models, Lewin's formal model suffers from its infallibility. All forces are either intrinsic (personality) or extrinsic (environmental). The theory could be argued to predict anything. What possible forces acting on or within an individual could be missed? The theory cannot be falsified, and therefore, no evidence for or against it may be meaningfully assembled (Popper, 1959). Nonetheless, others have evolved elements and approaches that stem from Lewin's approach, which involve testable elements.

Stemming from Lewin's work is one of the most widely accepted models in organisational behaviour change, that of Action Research (Badger, 2000; Beer et al., 1990; Kelly & Simpson, 2001; Robbins et al., 1994). Nonetheless, the process is founded on the scientific method, for which the evidence is abundant (Popper, 1959).

Action research postulates that information should be gathered by means such as questionnaire, observation, or direct measurement. Thereafter, analysis of the data is undertaken, which is reported back to the organisation, most particularly to the targeted employees of the change, the change is then implemented, and results evaluated (Robbins et al., 1994). Others authors (Beer et al., 1990; Kelly & Simpson, 2001), suggest that the researchers should add qualitative interpretations and information about the nuances of the process itself to the feedback. Kelly & Simpson (2001) even claim that this improved the outcome. Unfortunately, this claim is not evaluated within their work. What may be concluded is that the basic model of Action Research as specified by Lewin (see Robbins et al., 1994), is sound, and has been extensively tried. Additionally, the principles of social communication, discussed below, suggest that where such a methodology is undertaken, it should be effectively communicated to those undertaking the change. Beer et al (1990) and Armenakis & Bedeian (1999) report results suggesting that regardless of the process used, successful change implementation will, nonetheless, rely upon leadership, and the management of conflict.

Case-based research has revealed that effective change within organisations requires a number of the elements specified in the Action Research model (Armenakis & Bedeian, 1999; Beer et al., 1990; Damanpour, 1991; Mullins, 1993; Organ & Bateman, 1991; Parker et al., 1999; Robbins et al., 1994). These include commitment to change by all involved, a shared end vision with the ability to obtain it, activity toward the change by all sub-units of the organisation involved in the change, and institutionalisation of the changes by reconstructing the formalised aspects of the culture to agree with the change. Throughout the process, evaluation of the efficacy of the implementation must be undertaken.

8.4 ACTION RESEARCH EVIDENCE

One domain where considerable success has been obtained is that of Skin Cancer Prevention (Hill, White, Marks, & Borland, 1993). This program undertook to reduce the alarming rates of melanoma within the Australian population. In order to achieve this goal, the program needed to change Australians' attitudes concerning sun tanning. At the time of the program's commencement, Australians viewed sun tanning very favourably, even to the extent that a sun-tanned skin was taken as a sign of being a "true-blue" Australian.

Over the course of the years 1988 to 1990 this public health program significantly reduced the incidence of sunburn, increased the level of skin coverage, and moved attitudes concerning bronzing and sun-exposure. The program was designed to cost approximately $5m annually, and planned to save approximately 4300 lives. Approaches included changing sporting culture, fashion and the presentation of fashion in the media, thinking in health, social attitudes to sun exposure, and an array of other variables (SunSmart Campaign, Personal Communication).

Among the many measured successes of the Sunsmart campaign (Hill et al., 1993) the proportion of the population receiving sunburn reduced from 11% to 7% over 3 years, while protective clothing use increased (hat wearing and proportion of body surface area covered), and sunscreen use increased from 12% to 21%. Attitudes about tanning being considered healthy fell from 51% to 39%. The belief that prolonged exposure to the sun was not likely to result in skin cancer fell from 41% to 29% and the proportion of people wanting to acquire a deep tan fell from 20% to 12%. Overall, the Sunsmart campaign was extremely successful.

The Sunsmart campaign undertook a series of strategies and steps to implement and obtain its achievements. These included: advertising, media sponsorship, and public relations conveying the SunSmart message; coordination and negotiation with various bodies, groups, institutions, and organisations to enjoin them to advocate the SunSmart message; development of adequate training resources to facilitate advocacy of the SunSmart message, as well as development of resources to support these aspects; training and development of change agents within the community (ie: schools, GPs, health promotion agencies, etc); and lastly, ongoing research to establish the extent of the problem, and to measure the level of success of the campaign.

Initially, it may appear that the SunSmart campaign did not apply standard Action Research principles. However, the steps undertaken all conform to principles as specified above. The media and advertising campaign was sourced from the initial research, which involved focus groups, identifying the nature of the behaviours to be targeted. The media campaign that followed was structured in such a way as to enjoin the population to accept ownership of the problem. While not following the scripture of Action Research, it nonetheless follows the principle. Information about the extent and nature of the problem was gathered from the targeted group (the population), and was returned to them via the media and through advertising. This campaign was designed to enhance principles of problem ownership. Thereafter, the solutions were consistently reported to the population in similar manners, reinforced by information and appeals to behaviour from various advocates. Change behaviour was facilitated and then institutionalised through regulation, and the support of designated behaviours (ie: Sun Protection Factor ratings, shade requirements, hat and body protection clothing in various workplaces and industries, etc). Contradictory institutional strictures were removed. For instance, various Police Forces accepted uniform changes to ensure the wearing of appropriate headwear. Throughout the process, successes and failures of the campaign were monitored through research, reported upon consistently. Consequently, the SunSmart campaign represents an example of the principles of Action Research models achieving widespread change with entrenched societal attitudes.

8.5 APPLICATION OF ACTION RESEARCH MODEL

How should a diagnosis process be undertaken? There are several possible approaches. One of the most frequently used is possibly one of the least successful – guided intuition (Anderson, 1985; Norman, 1988; Walker et al., 1994). When asked to decide on issues, people are found repeatedly perform at or about the level statistical chance would predict. However, there are better processes. Another is building organisation-wide teams, drawn from all strata. The role of these teams is too identify the nature of the problem, discuss solutions, and then make recommendations for their implementation. Where results of these processes have been reported (Beer et al., 1990; Mullins, 1993), they generally failed for reasons such as becoming "too touchy feely", or because the wider body of personnel believed they were too management-centric.

Alternatively, Action Research offers a method loosely based upon scientific method. First the nature of the problem must be identified through data gathering and analysis. This may take various forms (Badger, 2000; Kelly & Simpson, 2001). In the present case the nature of the problem is clear, and the nature of the solution is the basis of much of the present report, and so neither will be commented upon further here.

8.6 COMMITTMENT TO AND ACCEPTANCE OF THE CHANGE

The first step in obtaining commitment to any change is obtaining consensus that there is a problem which needs addressing. If there is no apparent problem, why change? Change for change sake is not usually sufficient reason for people to go through the difficulties the change will entail. Open reciprocal communication between senior management and the rest of an organisation about the change has been shown to be the strongest manner to ensure successful change (Schweiger & DeNisi, 1991).

In order to obtain employee commitment to the change process authorities suggest various theories. However, the two most frequently suggested are that of the Change Grid (cf Robbins et al., 1994), and that of the Three Pillar model of commitment (cf (Mullins, 1993). The change grid suggests people go through a process of shock to denial to resistance to exploration, and finally re-commitment through the change process. This and similar models, are much touted in the Organisational change industry, though evidence to support them is absent. No doubt, the model does describe the features of emotional response to enforced change, but it is difficult to see where it suggests mechanisms to harness in the change process. The model appears to suggest that the process must be traversed, and that careful management may hasten various negative aspects. On the other hand, the Three Pillar model of commitment has ostensibly been supported by extensive case study, though the actual case study data is not widely available. Nonetheless, this model suggests that employees need (1) a sense of belonging to the organisation, (2) a sense of excitement in the job, and (3) confidence in management.

Belonging to the organisation, it is argued, is enhanced through active communication and sharing in organisational success. These principles conform with In-group Out-group theory in social psychology, which has received extensive experimental support. In-group Out-group theory says that those we perceive as within our social group are better on almost any metric when compared to those we perceive as external to our group (Gardham & Brown, 2001).

Additionally, increased communication has been shown to improve change acceptance outcomes. An experimental study of low and high level communication in corporate change by Schweiger & DeNisi (1991) found that where communication was minimal, employee stress was increased, and satisfaction and commitment to the organisation, among other parameters, were decreased compared to the high communication group. The differences in outcomes are not surprising. The high communication group received weekly meetings with managers, a newsletter, a telephone hotline, and personal meetings between managers and affected staff. The low communication group received a newsletter and informal contact. For some time it has been known that where persons participate in forums where they may consider and express one view, yet hold an incongruent personal view, they undergo a process known as cognitive dissonance (Festinger & Carlsmith, 1959). Essentially, people do not like to hold conflicting personal and public positions, and will confabulate, changing their personal view to conform to their apparent public perspective, and even later claiming their views were always consistent. By involving people in assessing the nature of the problem, consensus that there is a problem will be obtained. The more broad the involvement in the diagnosis processes, the more widespread will be the acceptance of the need to change. However, in a meta-analysis of 23 case studies of change Damanpour (1991) did not find that internal communication was a powerful mediator hastening the implementation of change. Initially, it might appear that this finding questions one of the fundamental tenets of both the Three-Pillar model and principles of change specified in Action Research. However, neither the Three-Pillar model nor Action Research specify that internal communication will hasten the process, they both argue that internal communication is needed for acceptance to be achieved, and the change fully implemented.

The Three-Pillar model stipulates that a sense of excitement in the job is enhanced by pride in work, trust in the others we work with, and accountability for results. Such studies as do exist on this question suggest that any relationship between work and excitement is the reverse to that suggested by the Three Pillar model. Research suggests that contentment in work is a result of feeling excited by work, and not that contentment will increase if excitement increases (Ros, Schwartz, & Surkiss, 1999).

The Three-Pillar model suggests confidence in management is related to enhancing respect by attention to authority, dedication and competence. At present no experimental literature addresses this relationship, though a scale incorporating both concepts was developed and validated in 1973 (Guion & Elbert, 1973). This suggests either the area is ripe for research, or others have previously excluded this as an avenue of fruitful investigation. Consequently, this third principle appears to be more a matter of belief than one of developed theory.

Beer et al. (1990) discuss several reasons for culture change failure. Among the most important is the lack of senior management (SM) support. Where SM has failed to support change, it may provide resources toward that change, and ostensibly support it. However, when pressure to perform increases during the reduced productivity of the change period, the same managers and executives return to prior behaviours and patterns. They instruct and expect their staff to adopt the previous behaviours, and thereby, reinforce the sense of futility in the change, and supplant the change (Beer et al., 1990; Oxenburgh, 1991; Parker et al., 1999). On the other hand, instances of SM not actively supporting change have been reported, where middle-level managers have instituted their own change program and succeeded. Nonetheless, where SM actively resists change, or is seen as relevant to the change but not participating, change is frustrated (Beer et al., 1990; Robbins et al., 1994). Consequently, the attitude and commitment of SM to an organisation-wide change is imperative.

Other organisational levels that must commit to the change for it to be successful include the middle-level management of the organisation and the workforce. Both these groups are instrumental in successful change. Research has shown that a perspective or view held by a minority is less likely to change a group's consensus than are views held by the majority (Kerr & MacCoun, 1985). While classic research on compliance with authority shows that SM could exert power to implement change (Milgram, 1974), the individuals are likely to resist if they are required to accept responsibility for outcomes and they don't agree with the change (Hamilton, 1978). Resistance may arise in various forms, ranging from subtle acts of frustration to deliberate acts of sabotage. Consequently, cultural change must involve commitment to the change at all organisational levels. The most powerful means to obtain this commitment is to involve people in diagnosing the need for change, as discussed above, the process to implement change, and the nature of the desired change. This has been demonstrated both experimentally (Kerr & MacCoun, 1985; Schweiger & DeNisi, 1991), and in case studies (Hackman, Oldham, Janson, & Purdy, 1995; Oxenburgh, 1991). Perfect consensus is not required, but rather majority consensus has been shown to be most effective (Kerr & MacCoun, 1985; Schweiger & DeNisi, 1991).

8.7 CHANGE IMPLEMENTATION

Whenever an organisation considers a proposed change, it must first assess both the congruence of the proposed change with its mission, and the suitability of skills and abilities of the personnel who are to undertake the change. Naturally, a change in the mission itself may be part of the change. For instance, New Zealand's armed services have recently had their outwardly stated mission changed from one oriented toward defence toward peace keeping, substantially altering their envisaged forces composition. Less profound changes still require careful assessment prior to their implementation.

The process of measuring ability to change is a process of action research, as discussed above. Essentially, careful assessment of the nature of the problem is required. A carefully assessed change program will need to go beyond this. It will need to involve feedback to the participants of the change and obtain their commitment to participate (Armenakis & Bedeian, 1999; Badger, 2000; Baron & Byrne, 1987; Beer et al., 1990; Furnham, 1997; Kelly & Simpson, 2001; Mullins, 1993; Oxenburgh, 1991; Schweiger & DeNisi, 1991; Weiss, 1990).

8.8 SHARED ACTIVITY TOWARD THE CHANGES

Generally, the Action Research model includes the principle that all elements of an organisation should contribute activity toward the change. Again, few of the authorities actually provide evidence that this is useful. However, social psychological research shows that principles of equity are important in maintaining commitment. Where persons feel that they are carrying an unfair share of the burden, or others are receiving an unfair level of the credit and reward, they will first take steps to rectify the inequity, and that failing, will commence to withdraw from the relationship (Baron & Byrne, 1987). In the present context, this would mean that organisational commitment would fall as people perceive others are not equitably participating within the change.

8.9 INSTITUTIONALISATION OF THE CHANGES

Since Lewin specified the early model that led to Action Research it has been recognised that the final process of change management would involve a refreezing of the now changed organisation into its new configuration. Again, actual evidence for this does not exist. Case studies suggest this should be undertaken (Mullins, 1993), but there are no direct experimental analyses of this question. However, the roles of established rules and norms within organisations have long been recognised as important (Baron & Byrne, 1987). Where groups have fluid rules or norms, that change too hastily and too often, individuals become stressed, and in turn, lose a sense of cohesion with the group (Baron & Byrne, 1987). Re-drafting the formal aspects of an organisations culture, its rules and regulations, to reflect the change is necessary to prevent this loss of commitment, and to give individuals a sense of continued group cohesion (Baron & Byrne, 1987), and to prevent a rapid return to the previous state (Armenakis & Bedeian, 1999; Drench, 1998; Dunnette, 1990; Friedlander & Brown, 1974; Furnham, 1997; Kelly & Simpson, 2001; McKenna, 1994; Mullins, 1993; Organ & Bateman, 1991; Parker et al., 1999; Robbins et al., 1994; Weiss, 1990).

8.10 EVALUATION OF THE CHANGES

This last step in the Action Research model is, in many respects, the most fundamental. Organisational change that is unmeasured may or may not succeed. Without baseline data, and data gathered progressively through the process, the actual process may be subverted, the change become altered, and the organisation become unaware of the failure of their goals. This process should be used to feedback, where needed, required modifications to the process. This is a fundamental aspect of the scientific process

8.11 RECOMMENDED CHANGE PROCESS

1) Identification of the problem and the solution.

a) The ADF should form a large number of focus groups at all levels and strata, encapsulating a significant proportion of the ADF population. These groups should possess rank homogeneity to facilitate openness of communication and trust.

b) Focus groups should be provided with the detail of the problem facing the ADF, and be tasked to develop solutions that:

- Adopt evidence-based countermeasures
- Shares the activity or process necessary to obtain the change across all ranks equitably, and
- Ensures there are specific measurable goals with stated deadlines

2) Committment to and acceptance of the change

a) Within a second round of the focus groups, the set of more common solutions should be assessed against the mission of the ADF. This is necessary as the ADF is not able to redefine its mission without reference to the political process, hence it must limit solutions to those confined within the parameters of its defined mission, and yet obtain commitment to the change process.

b) The proposed solutions should be evaluated and modelled for likely outcomes. The results of this process should be returned to a third round of the focus groups for decision as to which solutions should be adopted.

3) Change implementation

a) A group from ADF command, not previously involved in the focus group processes, should decide which solutions proposed will be carried forward. This should be conveyed to all members of the ADF, along with details of the process. It is essential that this decision is seen as transparent, well reasoned, unbiased, and generally accepted.

b) Institutional barriers will need to be audited and changes implemented. These proposed changes will need to be fully gazetted to all members of the ADF as part of the change process. This will demonstrate the institution of the ADF's preparedness to commit to the change.

c) Following indication of the institutional changes, commitment to participate in changes should be assessed at all levels of the ADF by anonymous questionnaire (however, command responsibility details should be collective). Additionally, the instrument should assess reasons for proposed non-compliance.

d) If general commitment is lower than 60% to70%, or is not supported by 60 to 70% of commanders, the process should return to step 2, with this information and a specific brief to develop solutions that address reasons for non-acceptance.

4) Shared activity toward the change

a) Activity toward the change should be objectively measurable, and this should be reported openly upon throughout the ADF.

b) Success and failure to meet change goals should be reported openly. These should be stated in terms of the original problem.

c) Following completion of the program, all change measures should continue to be reported to the entire ADF, facilitating recognition of the extent to which everyone is continuing to contribute.

5) Institutionalisation of the changes

a) All rules and regulations pertaining to targeted change behaviours must be modified to encourage and reward desired changes, not to debilitate, frustrate or punish these. Additionally, all regulations that reward or support undesirable behaviours must be removed. Should this step be incompletely undertaken, the change will not attain permanency, fading as soon as the ADF's focus moves elsewhere.

b) Regulations designed to punish those guilty of undesirable behaviours will only have limited effect, those designed to reward desirable behaviours are likely to be more easily implemented, and will have considerably greater impact. Regulations that frustrate the desired changes are likely to significantly impair the desired changes.

c) Continual monitoring of the impact of rules and regulations upon the change process will be necessary. Many impacting rules and regulations may not be immediately apparent, and as such this process will require continual monitoring with a view to modification. This process will also require ongoing reporting to the ADF in general.

6) Process reporting

a) It is essential that the deliberations of the focus groups at levels 1, 2, and 3 be openly reported.

b) The results of the commitment survey should be reported. The order and nature of pursuant processes will reveal the nature, if not the detail, of this survey's results, leading to a possible perception of deceit.

c) Goal success and failure should be openly reported, including success or failure in meeting timeline requirements.

Changes to institutional structures to facilitate the changes, and retard undesirable behaviours should also be reported. Where institutional barriers exist, many personnel will be aware of them. They will surmise that unless these have been removed, the process of change will fail, and hence, will not commit themselves to the process.

9. CONCLUSION AND RECOMMENDATIONS

9.1 CONCLUSION

In the context of the Australian Defence Force requirement for a trained, fit and deployable workforce, injury resulting from physical training and sporting activity poses major manpower losses and substantial and rising costs. This report sought to document: the physical and mental health benefits of physical activity in the military, barriers to and interventions for participation in physical activity, adverse effects of physical activity particularly injury, countermeasures for the prevention of injury, and approaches to changing organisational cultural behaviour to promote and maintain safe physical activity. The report also aimed to provide strategic direction and advice targetted to areas of high risk and the greatest potential for gains in safe and beneficial physical activity. The ADF is advised to develop, implement and evaluate a Physical Fitness and Safety Strategy that combines system-wide and local initiatives to increase lifelong participation in fitness activities and reduce related injury in ADF personnel.

The project findings indicate two major issues which the ADF may consider addressing to progress the understanding and resolution of currently identified injury problems associated with physical activity. The first relates to optimising the quality and utility of the Defence Injury Surveillance System and the DEFCARE database to better identify specific injury patterns and mechanisms to inform priorities for injury prevention. The enhanced surveillance system should also provide a powerful device for monitoring injury trends and the evaluation of interventions.

The second issue relates to future possible research areas with the potential to progress the understanding of dose-response health benefits of participation in physical activity, personnel participation rates/exposure levels to specific physical activity, injury causation, scientifically rigorous trials of potential countermeasures for injury prevention, and cost benefit analyses. Expected benefits to the ADF of personnel increasing safe participation in sports include a realistic estimate of reduction in injuries of 25% per annum, which represents a decrease of 51.6 injuries per 10,000 personnel each week.

Substantial research is needed for the following: to study the primary modifiable risk factors for injury such as intensity, frequency and duration of training activities and effects on injury; to determine levels of safe activity to maintain fitness after basic training; to promote safe physical activity for health gain; to evaluate equipment design and other promising strategies for injury prevention; and to reduce barriers to participation in physical activity. Evaluation research should employ a randomised controlled design wherever possible.

Lifelong participation in physical activity is a public health aim and major barriers to participation will contribute to poorer health outcomes. It is essential to establish which particular sporting and physical activities are associated with the greatest health benefits and the least health costs for the ADF. Promotion of vigorous exercise needs to be accompanied by explicit, evidence-based strategies to promote safe participation.

Van Mechelen et al. (1992) proposes a four-stage process for injury prevention based on epidemiological principles:

1) identify and describe the nature and extent of the problem;
2) identify the factors and/or mechanisms related to injury occurrence;
3) introduce measures to reduce the risk and/or severity of injury; and
4) evaluate interventions

The ADF has made good progress on the first stage with the recent introduction of the Defence Injury Prevention Program and associated Surveillance System. The newly established ADF surveillance system (along with the DEFCARE data) has the potential to provide a more complete and detailed picture of the frequency, pattern and mechanisms of injuries related to physical activities in the ADF and will provide some guidance for prevention measures if the pathway between mechanism and injury is well-defined and confirmed in the research literature. However, the ADF would be well-advised to supplement surveillance data by conducting a prospective cohort study to determine the incidence and relative risks of injury in the various physical activities undertaken by ADF personnel and the risk and protective factors for injury. This information is needed to generate and refine prevention measures in the ADF environment. The recently completed Western Australian Sports Injury Study (Sports Medicine Australia, 2001) provides a useful model for the establishment of a large well-designed cohort study in selected sports (that ranked highly for participation and injury rates).

9.2 RECOMMENDATIONS

Recommendations arising from the project encompass three broad areas, injury surveillance and data collection, injury prevention implementation and evaluation, and future research.

9.2.1 Injury surveillance and data collection

- Data on activity-specific participation rates and exposure in physical activity and sports to be part of a refined injury surveillance system. These data would enable the generation of injury rates specific for different categories of physical activity and subsequent ranking for injury prevention priority.
- Refinement of current injury surveillance systems to include, where possible, coding compatible with surveillance systems for the general population so that rigorous comparative studies between populations can be undertaken.
- Improved capture rates for reporting data on activity at the time of injury including differentiation between ADF controlled sports and ADF approved community sporting activities.
- Include the use of 'cause of injury' codes as for the civilian population to better inform injury prevention and allow comparative studies. This would entail coding hospital admissions according to the International Classification of Diseases, 10th Revision, Australian Modification (ICD-10-AM), Second Edition (July 2000).

9.2.2 Injury prevention and evaluation

9.2.2.1 General recommendations for injury prevention

- Develop, implement and evaluate a Physical Fitness and Safety Strategy that combines system-wide and local initiatives to increase lifelong participation in fitness activities and reduce injury in ADF personnel.
- Research studies should focus on populations and environments in the military which have the largest impact on readiness (Kaufman et al., 2000). A strategic research approach to include more than basic training, infantry and special forces.
- Evaluation research to concentrate on the primary modifiable risk factors for injury: intensity frequency, and duration of training; levels of physical fitness and type of activity; and equipment. Use of dose-response designs where possible (Kaufman et al., 2000).
- A prospective cohort study in military training, PT and selected sports (with high injury frequencies associated with WDL) to determine the incidence and relative risks of injury in these physical activities and the risk and protective factors for injury. The study should have the power to determine the relationship between player position and injury and foul play and injury (in sports). Nested case control studies should also be undertaken to determine the risk factors for lower limb ligament injuries (knee and ankle), shoulder injuries, fractures and back injuries. This study would also provide data on the cost of injury.
- Implement, monitor and evaluate effectiveness of prevention strategies and countermeasures.
- Research programs for maintenance of fitness after basic training.
- Cost effectiveness studies for injury prevention programs.

9.2.2.2 Specific recommendations for injury prevention in military training

- Trials of modified military (basic) training to incorporate smooth progression in intensity, duration and frequency of training as demonstrated in the ADF Army Recruit Training Intervention Study (Rodney Pope, personal communication) (Jones et al., 1993b; Pollock et al., 1977).

Modifications to military (basic) training could include trials of:

- pre-selection screening of recruits for injury risk factors and assignment to modified training where needed.
- interval training versus continuous training
- modified risk factors for female recruit training
- equipment design and use
- strength training for injury prevention with emphasis on occupational fitness for specific tasks (Brill et al., 2000; Williams et al., 1999a; Williams et al., 1999b)
- deep water running as a substitute for running
- maintenance of fitness after initial training (Bloomfield & Coyle, 1993; Shephard & Shek, 1995; US Department of Health and Human Services, 1996)

- Research to study the effect of equipment design, especially footwear including insoles, on training and injuries (Kaufman et al., 2000).

9.2.2.3 *Specific recommendations for injury prevention during physical training and sports*

Prevention of knee injuries

<u>For player safety</u>

- Indoor sports should be played on wooden floors (or synthetic floors with similar elastic properties). Playing and running on hard surfaces (for example concrete or lino) should be avoided.
- Serious competitors should use cross training to limit the amount of training involving repetitive stresses on the knee.
- Knee pads should be worn in training and match play in sports such as volleyball to prevent acute knee injuries and the acute exacerbation of overuse injuries.
- All players, especially female players, should be trained to 'land softly' on the balls of their feet with knees and hips flexed prior to and throughout landing.
- Coaches should consider introducing balance board training, particularly for female players and players with knee instability.
- A plyometric (jump training), stretching and strength training program should be considered for all players in jumping sports to decrease peak landing forces and particularly for female players to correct imbalances between hamstring and quadriceps muscle strength. Plyometric training should be under the supervision of a trained coach and programs should be carefully evaluated.
- Players who are already proficient jumpers and players with knee pain are advised to decrease their jump training time and pay close attention to technique.

<u>For further research and countermeasure development</u>

- Population-based studies to determine gender-specific risk factors for non-contact ACL injuries.
- Further epidemiological, biomechanical and laboratory studies to clarify the role of intrinsic risk factors in non-contact ACL injuries and establish countermeasures.
- Research to better identify high-risk player positions and player manoeuvres for ACL injury and to develop protective neuromuscular responses when high-risk situations are encountered.
- Research to better understand the influence of playing surface and shoe-surface interaction on knee injury.
- A randomised controlled trial (in a population with no foot pain) to test the advantage of placing the foot in a supinated or neutral position rather than a pronated position when playing sport. Such a trial should have the capacity to establish the significance of pronation in overuse injury and the clinical value of an orthosis.
- Evaluation studies, preferably controlled trials, to determine the effectiveness of strategies and countermeasures to knee injuries in high-risk sports.

Prevention of ankle injury

For player safety

- Players with ankle sprains should complete supervised rehabilitation before returning to competition.
- Players who have suffered a moderate or severe sprain should wear an appropriate semi-rigid brace for at least 6 months and, preferably, twelve months on return to play.
- Players with unstable ankles should consider prophylactic bracing and taping for training sessions and matches. Research shows that bracing is more effective, cost effective and convenient than taping, and does not interfere with performance.
- Players who are at higher risk of ankle injury because of the position in which they play, for example specialist blockers in volleyball and goal shooters and defenders in basketball and netball should consider prophylactic ankle bracing (or taping).
- Coaches should introduce drills which train players in take off and landing skills that minimise the risk of ankle injury
- Ankle disc (balance board) training should be trialed and evaluated in players with previously injured and healthy ankles.
- Playing shoes should be in good condition.
- For court games, training should be conducted on wooden or other synthetic 'forgiving' surfaces, not concrete or linoleum.
- Playing surfaces (fields and floors) should be diligently maintained and regularly checked for hazards such as hollows, cracks and wear.

For further research and countermeasure development

- Evaluation studies, preferably using a randomised controlled design, should be undertaken to better establish the clinical effects of ankle braces, ankle disc training and specific training drills in ankle sprain injury reduction.
- Further laboratory and controlled field research is needed to determine the optimal safety performance values for sports shoes and playing surfaces.

Shoulder injury prevention

For player safety

- Players involved in overhead sports should include specific exercises to strengthen the shoulder in external rotation and increase the flexibility of internal rotation of the rotator cuff.
- More effective shoulder pads should be developed for full contact sports, for example rugby.

For further research and countermeasure development

- In-depth research on the incidence, patterns, mechanisms and consequences of shoulder injuries in ADF sports with a view to developing specific countermeasures, for example shoulder pads in rugby
- Controlled investigations on the optimal preventive and rehabilitative conditioning programs to prevent shoulder overuse injury and re-injury.

9.2.2.4 Recommendations for touch injury prevention

<u>For player safety</u>

- Restrict participation in touch by banning informal or scratch games OR establish strict conditions under which ADF touch games are played that cover: permitted variations to field dimensions; ground surface material, conditions of ground and surrounds; equipment used, player footwear and identification (colours), size of teams, gender mix, match duration, officiation, player code of behaviour, warm up and cool down and first aid.
- For all ADF-controlled games, provide a safe playing environment, including equipment, field and surrounds and develop and implement a pre-match inspection protocol by the referee prior to game.
- Institute a pre-season injury assessment for all players (6 weeks prior to start of new season) linked to tailored training regimes to ensure that only fully fit and rehabilitated players participate in touch. ADF personnel with knee instability should not compete.
- Provide widespread training of ADF personnel in rules of the game and game skills
- For ADF teams, provide pre-season and in-season team and individually tailored training and conditioning programs so players are physically prepared to meet the rigors of match play and the specific demands of their individual playing position.
- Monitor training hours/length of time players are involved in strenuous physical activity to protect players against overtraining injuries. Institute individual training, injury and rehabilitation logbooks for all personnel.
- Mandate that all coaches in control of ADF touch teams are accredited under the National Coaching Accreditation Scheme to at least Level 2 and fulfill update requirements; institute special seminars on injury prevention for coaches and officials.
- Institute a broad program of accredited referee training so that all ADF matches are under the control of an accredited referee with additional training in injury prevention and first aid.
- Institute an education and awareness-raising program covering all ADF teams to encourage a culture of fair play and safe participation.
- Consider semi-rigid ankle bracing for players with a history of ankle injury/instability.
- Supply shoes appropriate to ground surface conditions.
- Mandate warm-up and cool-down before and after every training and match, stretch need not be included.
- Provide best practice first aid, treatment and rehabilitation services; develop and implement strict return to play rules.
- For further research and countermeasures development include touch in prospective cohort study to identify risk and protective factors for injury.

<u>For further research and countermeasure development</u>

- Include touch in prospective cohort study to identify risk and protective factors for injury

9.2.2.5 Recommendations for rugby injury prevention

For player safety

- Limit/ban ADF personnel from participation in informal/scratch rugby matches.
- Consider reducing the exposure of ADF personnel to organised competition rugby.
- Increase the number of allowable substitutes in matches and encourage player substitution (but players should not be played out of position).
- Provide a safe playing environment, including equipment, field and surrounds; develop a pre-match inspection ground protocol and institute inspections by the referee prior to game.
- Institute a pre-season injury assessment for all players (6 weeks prior to start of new season) linked to tailored training regimes to ensure that only fully fit and rehabilitated players participate in rugby. Players with knee instability should not compete.
- Provide adequate pre-season and in-season team and individually tailored training and conditioning programs so players are physically prepared to meet the rigors of match play and the specific demands of their individual playing position. Include regular balance board training, a special weights program for frail players and physical impact drills prior to the season to match-harden players.
- Monitor training hours/length of time players are involved in strenuous physical activity to protect players against overtraining injuries. Institute individual training, injury and rehabilitation logbooks for all personnel.
- Mandate that all rugby coaches in control of ADF teams are accredited under the National Coaching Accreditation Scheme to at least Level 2 and fulfill update requirements; institute special seminars on rugby injury prevention for coaches and officials.
- Institute a broad program of accredited referee training so that all ADF matches are under the control of an accredited referee with additional training in injury prevention and first aid.
- Institute an education and awareness-raising program covering all ADF rugby teams to encourage a culture of fair play and safe participation.
- Mandate the use of facial grease, mouthguards and shinguards for all players and semi-rigid ankle bracing for players with a history of ankle injury/instability. Consider compulsory headgear, shoulder and chest padding and prophylactic ankle bracing (under trial conditions).
- Supply shoes appropriate to ground surface conditions.
- Mandate warm-up and cooldown before and after every training and match, stretch need not be included.
- Provide best practice first aid, treatment and rehabilitation services; develop and implement strict return to play rules.

For further research and countermeasure development

- Include rugby in a prospective cohort study to identify risk factors for rugby (union and league) injuries in ADF personnel using outcome variables that measure rate and severity. This study should have the statistical power to specifically investigate injury by player position.

- Further research into injuries related to tackles in rugby to inform preventive measures (such as changes to techniques, refereeing, rules of the game and personal protective equipment).
- Research to develop fitness tests specific to the demands of particular player positions (to inform tailored training regimes).
- A study to determine whether rugby players who are adequately conditioned for impacts at the beginning of the season are at less risk of sustaining injury through the early part of the season when the injury rate is apparently higher.
- Laboratory and epidemiological research to develop and trial rugby headgear that is effective in reducing the risk of head and facial injuries and concussion.
- Research to investigate whether headgear use in senior rugby places the wearer at greater risk of injury through altered player behaviour.
- Research to determine why senior rugby players currently choose not wear headgear.
- Laboratory and field research to identify the most desirable qualities of shoulder and thigh pad construction for rugby shoulder and thigh injuries and trials to determine the effectiveness of new designs.
- Research to investigate the role of footwear (condition, studs, alternative types) and ground conditions in rugby injury incidence.
- Further research to investigate the observed downward trend in the rate of injury during the rugby season (extending the research conducted by Alsop et al., 2000).
- A study of related injury rates to ground wetness and mechanical compliance or 'give'.

9.2.2.6 Recommendations to prevent soccer injuries

<u>For player safety</u>

- Consider ways to reduce the exposure of ADF personnel to soccer if an in-depth analysis of injury surveillance and exposure data show that this action is warranted.
- Increase the number of allowable substitutes in matches and encourage player substitution.
- Provide a safe playing environment, including equipment, pitch and surrounds; develop a pre-match inspection ground protocol and institute inspections by the referee prior to game.
- Institute a pre-season injury assessment for all players (6 weeks prior to start of new season) linked to tailored training regimes to ensure that only fully fit and rehabilitated players participate in soccer. Players with knee instability should not compete.
- Provide adequate pre-season and in-season team and individually tailored training and conditioning programs so players are physically prepared to meet the rigours of match play and the specific demands of their individual playing position.
- Monitor training hours/length of time players are involved in strenuous physical activity to protect players against overtraining injuries. Institute individual training, injury and rehabilitation logbooks for all personnel.
- Mandate that all soccer coaches in control of ADF teams are accredited under the National Coaching Accreditation Scheme to at least Level 2 and fulfill update

requirements; institute special seminars on rugby injury prevention for coaches and officials.

- Institute a broad program of accredited referee training so that all ADF matches are under the control of an accredited referee with additional training in injury prevention and first aid.
- Institute an education and awareness-raising program covering all ADF soccer teams to encourage a culture of fair play and safe participation.
- Mandate the use of mouthguards and shin guards for all players and semi-rigid ankle bracing for players with a history of ankle injury/instability. Consider prophylactic ankle bracing (under trial conditions).
- Supply shoes appropriate to ground surface conditions.
- Mandate warm-up and cool-down before and after every training and match, stretch need not be included.
- Provide best practice first aid, treatment and rehabilitation services; develop and implement strict return to play rules.

<u>For further research and countermeasure development</u>

- Include soccer in a cohort study to identify risk and protective factors for soccer injuries in ADF personnel using outcome variables that measure injury rates and severity. This study should have the statistical power to specifically investigate injury by player position.
- Further research into injuries related to foul play to inform preventive measures (such as changes to techniques, refereeing standards and education and rules of the game).
- Research to develop fitness tests specific to the demands of particular player positions (to inform tailored training regimes).
- Research to investigate the role of footwear (condition, alternative types) and ground conditions in soccer injury incidence.
- A study of related injury rates to pitch conditions, including wetness and mechanical compliance or 'give'.

9.2.3 Future research

9.2.3.1 Benefits to mental health from participation in physical activity

- Research is needed to further elucidate the individual and circumstantial factors that determine the quantitative and qualitative benefits of exercise to mental health in non-clinical populations.
- Randomised controlled trials are needed for clinical populations to demonstrate the efficacy of exercise interventions as treatments for mild or moderate depression, and to establish a causal relationship between exercise and reductions in depression.

9.2.3.2 Benefits to cognitive performance from participation in physical activity

- Research to examine the effects of exercise as a countermeasure to fatigue in military personnel, using varied durations and intensities of exercise as well as incorporating comprehensive performance test batteries. Critically it is necessary to have a number of subject groups with differing levels of physical fitness. These types of studies are necessary to address the potential for exercise to benefit performance and/or delay performance decrements in particular situations, and to determine whether and how physical fitness interacts with performance in extreme situations.

- Research is needed to ascertain how the nature of exercise interventions (type of exercise, duration, intensity, etc) affects performance in the short-term on a range of cognitive and psychomotor tasks. The effects on performance need to be measured during and immediately after exercise, but also in the hours following the bout of exercise.
- Longer-term studies are required to establish whether physical activity has a noticeable effect on cognitive performance over a substantial period of time. Research also needs to address whether the effects of low intensity activity are similar to those for high intensity activity on cognitive performance.

9.2.3.3 Barriers to participation in physical activity

- There is a need to examine whether the psychological and physical determinants associated with physical activity in the general community are also relevant in the military context.
- Using identified determinants of physical activity in the military to evaluate the effectiveness of psychological and resource interventions to increase participation in physical activity in the military.

9.2.3.4 Safe and unsafe behaviour

- Further investigation is needed to determine the nature of the most appropriate and effective type of intervention to reduce unsafe behaviours in the military.

9.2.3.5 The effects of anxiety and stressful situations on performance

- Research is needed to examine the influences of anxiety and stressful situations (likely to be encountered in the military) on behaviour, and in particular on the decision-making processes, in order to gain a better understanding of how safe and unsafe behaviours are affected.

9.2.3.6 Recommendations to increase participation in physical activity

- Results of studies identifying key determinants of physically active lifestyles to be used as a basis for designing effective programs to increase physical activity in the ADF (US Department of Health and Human Services, 1996)
- Research to establish the processes of promoting, developing, maintaining and evaluating healthier habits of physical activity in military personnel by focusing on interventions with the greatest health gain and cost-effectiveness

9.2.3.7 Recommended organisational change process

- Identification of the problem and the solution through focus groups addressing both the problem and solutions with measurable outcomes
- Commitment to and acceptance of the change through contrasting solutions to the ADF’s mission within focus groups

- Change implementation through decision to adopt solutions conveyed to all members, and the removal of institutional barriers, followed by assessment of commitment to change.
- Shared activity toward the change that is objectively measurable, with success of goals being reported openly
- Institutionalisation of the changes by ensuring all institutional rules that impede the change are removed, and relevant rules and regulations function to enhance the change, with continual monitoring.
- Process reporting of the nature of the problem, possible solutions, the adopted solution, and reasons for this, outcomes, rule changes, regulation changes.

9.2.4 ADF Action Plan (Prioritisation Plan)

This report presents a substantial number of evidence based interventions with good potential to achieve both an increase in the physical fitness of ADF personnel and a committment to decrease injuries associated with physical activity. It also provides modeling of outcomes based on these two parameters using measures identified by the ADF. This action plan provides a recommended means for the prioritization of action and timely progress towards implementation.

Step 1

ADF should set targets for physical fitness and injuries prevented, as measured by injury rates, sick days, light duty days, injury retirement rates and compensation costs based on the models on ‘Expected benefits to the ADF of increased sports participation’ presented in Chapter 2 of this report.

Step 2

Develop, implement and evaluate a Physical Fitness and Safety strategy that combines system-wide and local initiatives to increase lifelong participation in fitness activities and reduce related injury in ADF personnel.

Step 3

Select simple to implement, high impact, low cost measures from the menus provided (e.g. under specific sports) for immediate implementation.

Step 4

Enhance the utility of current injury surveillance in the ADF, in order to provide an excellent monitoring and evaluation tool and a mechanism for identifying ongoing and emerging injury trends.

Step 5

Initiate steps to implement the necessary cultural change throughout the organisation to ensure a positive approach to implementation of interventions and further research and development. Wide-spread implementation (*reach)* of interventions will be essential to achieving the desired outcome targets.

(Note: steps 2-5 to be implemented in the same time frame.)

Step 6

Conduct a prospective cohort study in military training, PT and selected sports (with a high frequency of injury associated with Work Days Lost) to determine the incidence and relative risks of injury in these physical activities and the risk and protective factors for injury.

Step 7

Further develop, pilot and implement factorial designed randomised controlled trials to evaluate the effectiveness of important selected countermeasures to training injuries, employing measures for which there is an evidence base in the literature.

Step 8

Undertake similar randomized intervention trials for physical training and selected sports injuries.

Step 9

Undertake or commission research studies to produce new knowledge on important questions raised in this review, for which current knowledge is inadequate.

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11. APPENDICES

Appendix 1. Model 1: Assuming increased sporting participation through improved fitness to the desired level of 95%

MODEL	Current level	Improvement	New level
Fitness (based on Table 4-4 of ADF Health Status (2000) report)	91%	4%	95%
Safe sport behaviour	0%	0%	0%

Improvement in ADF deployment status (Poisson model, available n)	Deployable	Restricted deployable	Employable	Not employable	Unclassified
ARA	625	-233	-66	-58	-268
RAAF	368	-243	-112	-11	-2
RAN	408	356	258	279	-1,301
ARA reserves	582	246	808	897	-2,533
Total	1,983	126	888	1,107	-4,104

Improvement in ADF deployment status (Poisson model, available %)	Deployable	Restricted deployable	Employable	Not employable	Unclassified
ARA	3.1%	-9.4%	-9.4%	-13.7%	-44.4%
RAAF	2.5%	-14.6%	-31.3%	-37.9%	-50.0%
RAN	4.5%	50.0%	36.8%	962.1%	-44.4%
ARA reserves	2.7%	15.5%	354.4%	197.1%	-44.4%
Total	2.4%	0.2%	1.1%	1.3%	-4.9%

Casualties	Full-time				Part-time			
	Reported	Estimated sports related	Outcome cost in injuries (n)	Change (n)	Reported	Estimated sports related	Outcome cost in injuries (n)	Change (n)
Work days per year				230				34
Manpower				54,244				29,328
Total work days				12,476,120				982,488
Casualties	5,038	3,281	3,425	144	1,067	695	726	31
Days Hospital	1,216	792	827	35	181	118	123	5
Sick days	6,287	4,094	4,274	180	689	449	469	20
Light duty days	25,141	16,373	17,093	720	1,810	1,179	1,231	52
Total days lost	32,644	21,259	22,193	934	2,680	1,746	1,823	77
Injury as % of total work days				0.007%				0.008%
Injury retirements	19	12	13	1	0	0	0	0
Retirements WDL per annum				230				0
Retirements WDL as % of total work days				0.002%				0.000%
Total work days lost as %			-0.178%	0.009%			-0.186%	-0.008%

Sport Injuries while deployed	Current rate per 1000/week	Current rate per 100/week	Outcome rate per 100/week	Rate change
Sports injuries Admissions Rate	0.5	0.05	0.052	0.002
Sports injuries WDL Rate	10.8	1.08	1.127	0.047

Appendix 2. Model 2: Assuming no increased sporting participation through improved fitness, but safe sporting behaviour increased to 100%

MODEL	**Current level**	**Improvement**	**New level**
Fitness (based on Table 4-4 of ADF Health Status (2000) report)	91%	0%	91%
Safe sport behaviour	0%	100%	100%

Improvement in ADF deployment status (Poisson model, available n)	**Deployable**	**Restricted deployable**	**Employable**	**Not employable**	**Unclassified**
ARA	8	-5	-1	-1	-1
RAAF	4	-3	-1	0	0
RAN	8	-1	-1	0	-6
ARA reserves	14	-3	0	-1	-10
Total	34	-12	-3	-2	-17

Improvement in ADF deployment status (Poisson model, available %)	**Deployable**	**Restricted deployable**	**Employable**	**Not employable**	**Unclassified**
ARA	0.0%	-0.2%	-0.1%	-0.2%	-0.2%
RAAF	0.0%	-0.2%	-0.3%	0.0%	0.0%
RAN	0.1%	-0.1%	-0.1%	0.0%	-0.2%
ARA reserves	0.1%	-0.2%	0.0%	-0.2%	-0.2%
Total	0.0%	0.0%	0.0%	0.0%	0.0%

Casualties	**Full-time**				**Part-time**			
	Reported	**Estimated sports related**	**Outcome cost in injuries (n)**	**Change (n)**	**Reported**	**Estimated sports related**	**Outcome cost in injuries (n)**	**Change (n)**
Work days per year				230				34
Manpower				54,244				29,328
Total work days				12,476,120				982,488
Casualties	5,038	3,281	0	-3,281	1,067	695	0	-695
Days Hospital	1,216	792	0	-792	181	118	0	-118
Sick days	6,287	4,094	0	-4,094	689	449	0	-449
Light duty days	25,141	16,373	0	-16,373	1,810	1,179	0	-1,179
Total days lost	32,644	21,259	0	-21,259	2,680	1,746	0	-1,746
Injury as % of total work days				-0.170%				-0.178%
Injury retirements	19	12	0	-12	0	0	0	0
Retirements WDL per annum				-2,760				0
Retirements WDL as % of total work days				-0.022%				0.000%
Total work days lost as %			0.000%	-0.193%			0.000%	0.178%

Sport Injuries while deployed	**Current rate per 1000/week**	**Current rate per 100/week**	**Outcome rate per 100/week**	**Rate change**
Sports injuries Admissions Rate	0.5	0.05	0.000	-0.050
Sports injuries WDL Rate	10.8	1.08	0.000	-1.080

Appendix 3. Model 3: Assuming increased sporting participation through improved fitness to the desired level of 95%, and safe sporting behaviour increased to 100%.

MODEL	Current level	Improvement	New level
Fitness (based on Table 4-4 of ADF Health Status (2000) report)	91%	4%	95%
Safe sport behaviour	0%	100%	100%

Improvement in ADF deployment status (Poisson model, available n)	Deployable	Restricted deployable	Employable	Not employable	Unclassified
ARA	634	-238	-68	-59	-269
RAAF	373	-247	-113	-11	-2
RAN	416	355	257	279	-1,307
ARA reserves	597	243	807	897	-2,544
Total	2,020	113	883	1,106	-4,122

Improvement in ADF deployment status (Poisson model, available %)	Deployable	Restricted deployable	Employable	Not employable	Unclassified
ARA	3.2%	-9.6%	-9.7%	-13.9%	-44.6%
RAAF	2.6%	-14.8%	-31.6%	-37.9%	-50.0%
RAN	4.6%	49.9%	36.7%	962.1%	-44.7%
ARA reserves	2.8%	15.3%	353.9%	197.1%	-44.6%
Total	2.4%	0.1%	1.1%	1.3%	-4.9%

Casualties	Full-time				Part-time			
	Reported	Estimated sports related	Outcome cost in injuries (n)	Change (n)	Reported	Estimated sports related	Outcome cost in injuries (n)	Change (n)
Work days per year				230				34
Manpower				54,244				29,328
Total work days				12,476,120				982,488
Casualties	5,038	3,281	0	-3,281	1,067	695	0	-695
Days Hospital	1,216	792	0	-792	181	118	0	-118
Sick days	6,287	4,094	0	-4,094	689	449	0	-449
Light duty days	25,141	16,373	0	-16,373	1,810	1,179	0	-1,179
Total days lost	32,644	21,259	0	-21,259	2,680	1,746	0	-1,746
Injury as % of total work days				-0.170%				-0.178%
Injury retirements	19	12	0	-12	0	0	0	0
Retirements WDL per annum				-2,760				0
Retirements WDL as % of total work days				-0.022%				0.000%
Total work days lost as %			0.000%	-0.193%			0.000%	0.178%

Sport Injuries while deployed	Current rate per 1000/week	Current rate per 100/week	Outcome rate per 100/week	Rate change
Sports injuries Admissions Rate	0.5	0.05	0.000	-0.050
Sports injuries WDL Rate	10.8	1.08	0.000	-1.080

Appendix 4. Model 4: Assuming increased sporting participation through improved fitness to the desired level of 95%, and safe sporting behaviour increased to 50%.

MODEL	Current level	Improvement	New level
Fitness (based on Table 4-4 of ADF Health Status (2000) report)	91%	4%	95%
Safe sport behaviour	0%	50%	50%

Improvement in ADF deployment status (Poisson model, available n)	Deployable	Restricted deployable	Employable	Not employable	Unclassified
ARA	630	-236	-67	-58	-269
RAAF	370	-245	-112	-11	-2
RAN	412	356	257	279	-1,304
ARA reserves	591	244	807	897	-2,539
Total	2,003	119	885	1,107	-4,114

Improvement in ADF deployment status (Poisson model, available %)	Deployable	Restricted deployable	Employable	Not employable	Unclassified
ARA	3.2%	-9.5%	-9.6%	-13.7%	-44.6%
RAAF	2.5%	-14.7%	-31.3%	-37.9%	-50.0%
RAN	4.6%	50.0%	36.7%	962.1%	-44.6%
ARA reserves	2.8%	15.4%	353.9%	197.1%	-44.5%
Total	2.4%	0.1%	1.1%	1.3%	-4.9%

Casualties	Full-time				Part-time			
	Reported	Estimated sports related	Outcome cost in injuries (n)	Change (n)	Reported	Estimated sports related	Outcome cost in injuries (n)	Change (n)
Work days per year				230				34
Manpower				54,244				29,328
Total work days				12,476,120				982,488
Casualties	5,038	3,281	1,713	-1,568	1,067	695	363	-332
Days Hospital	1,216	792	414	-378	181	118	62	-56
Sick days	6,287	4,094	2,137	-1,957	689	449	235	-214
Light duty days	25,141	16,373	8,547	-7,826	1,810	1,179	616	-563
Total days lost	32,644	21,259	11,097	-10,162	2,680	1,746	912	-834
Injury as % of total work days				-0.081%				-0.085%
Injury retirements	19	12	7	-5	0	0	0	0
Retirements WDL per annum				-1,150				0
Retirements WDL as % of total work days				-0.009%				0.000%
Total work days lost as %			-0.089%	-0.091%			-0.093%	0.085%

Sport Injuries while deployed	Current rate per 1000/week	Current rate per 100/week	Outcome rate per 100/week	Rate change
Sports injuries Admissions Rate	0.5	0.05	0.026	-0.024
Sports injuries WDL Rate	10.8	1.08	0.564	-0.516