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RUNNING THE RACE AGAINST INJURIES: A REVIEW OF THE LITERATURE

by

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Abstract:

Running is one of Australia's most popular sporting and leisure activities. While running is promoted by health professionals and has a wide variety of medically and socially related benefits, it needs to be recognised that, as with any sport, injuries can occur. Between 70-80% of running injuries are from the knee downward; knee injuries typically account for 25% of all cases. The majority of injuries are musculoskeletal in nature and associated with overuse. The constant repetition of the same movements required to run, along with factors related to the runner and their environment, are obvious contributors to the aetiology of running injuries. The overall aim of this report is to critically review both the formal literature and informal sources that describe injury prevention measures, or countermeasures, for running. In doing so, it provides an evaluation of the extent to which these countermeasures have been demonstrated to be effective. This report discusses the full range of countermeasures for preventing running injuries including: warming-up and stretching, correction of training errors, attention to the running environment, correction of running technique, footwear, use of orthotics, preventing runner and transport collisions, adequate treatment and rehabilitation. Specific factors associated with children's and women's running injuries are also discussed. Recommendations for further countermeasure research, development and implementation include additional research into the biomechanics of running and the mechanisms of injury; improved epidemiological studies to identify risk factors; further controlled evaluation of the effectiveness of countermeasures; professional fitting of shoes; professional testing for biomechanical abnormalities and the fitting of orthotic devices; further research into the role of dietary factors; and provision of first aid at running events.

Key Words:

running, injury prevention, overuse injuries, countermeasures, evaluation

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EXECUTIVE SUMMARY

Running is one of Australia's most popular sporting and leisure activities. One of the reasons for its popularity is that it is highly promoted as a preventative and therapeutic activity with considerable health benefits. Another reason for the popularity of running, may be the fact that there are few costs associated with the sport in terms of necessary equipment and membership of clubs, with the only real requirement a pair of running shoes. Additional factors such as the ability to participate at any time without the worry of scheduled organised events may also add to the sport's popularity. Recreational joggers are not restricted by age or sex barriers. Joggers may also participate for competitive reasons, as a source of relaxation, for personal fitness and self esteem, as a social activity, as a time to be alone or simply because they enjoy spending time outdoors.

While running has been promoted by health professionals and has a wide variety of medically and socially related benefits, it needs to be recognised that, as with any sport, running related injuries can and do occur. Running injuries are diverse, ranging from overuse injuries and metabolic abnormalities to extrinsic hazards such as dog bites and traffic collisions.

A significant amount of literature has been published about the epidemiology and biomechanics of running injuries. This has often included informed and expert conclusions on the causes of specific running injuries and how to prevent them. There is however, a notable lack of formal, controlled evaluations of the effectiveness of injury prevention countermeasures in running.

The overall aim of this report is to critically review both the formal literature and informal sources that describe injury prevention measures, or countermeasures, for running. In doing so, it provides an evaluation of the extent to which these countermeasures have been demonstrated to be effective. Unlike other literature describing running injuries, this report does not specifically focus on the epidemiology of running injuries and neither does it provide a detailed description of their aetiology. Rather, this report presents a detailed examination of the range of countermeasures promoted to prevent running injuries.

Little Australian data exists on the incidence and types of running injuries occurring in various populations of runners. The epidemiology of running injuries therefore needs to be viewed on a international scale. A review of the literature found that knee injuries typically account for 25% of all running injuries. Other commonly injured body regions are the feet (2-22% of injuries), the ankles (9-20%), lower leg (2-30%), shin (6-31%), upper leg (3-18%), back (3-11 %) and the hip/pelvis/groin (2-11%). In general, the majority of running injuries are located from the knee downward (ie 70-80% of cases). In terms of the nature of injury, 50-70% of running injuries are predominantly musculoskeletal in nature and associated with overuse. The constant repetition of the same movements required to run, along with factors related to the runner and their environment, are obvious contributors to the aetiology of running injuries.

This report has discussed the full range of injury prevention activities for preventing running injuries. Recommendations for further countermeasure research, development and implementation have been based on the review presented here and discussions with experts acknowledged in this report. Separate sections on overuses injury and injury risk in children and women are also presented because of the particular risk factors involved.

Many of the recommended countermeasures have yet to be proven to be effective and more attention to controlled studies "in the field" are needed. More effort directed to basic scientific studies to better understand the biomechanics of running, the mechanisms of injury and the role of various risk factors in injury causation are also required. Indeed, the evidence for the effectiveness of certain countermeasures such as warming-up and shoe design remains controversial. A summary of the countermeasures reviewed in this report and the accompanying recommendations for further research, development and implementation are given below.

OVERUSE INJURIES

Overuse injuries are the most common type of injury to runners. They result from repeated stress to the tissues involved due to repetitive episodes of trauma overwhelming the body's ability to repair itself. Overuse injuries in runners usually begin with pain and stiffness. Depending on the severity, the runner will suffer pain and stiffness at the beginning, during or after the run, or a combination of these. Continuous pain and stiffness will eventually lead to the cessation of running. The majority of the overuse injury risk factor studies have been based on competitive athletes.

Recommendations

- More research into the aetiology of stress fractures, particularly at the recreational runner level needs to be undertaken.
- Further development of three dimensional modelling of the foot and lower limb during running should be undertaken to gain a greater understanding of the biomechanics of running and the associated injuries.
- More research into the role of a low fat diet, restrictive eating patterns and the risk of stress fractures needs to be undertaken.
- The role of conditioning (both to improve strength and flexibility) in the prevention of stress fractures should be further explored.
- Runners should choose their running shoes carefully, preferably with professional advice.
- Runners should avoid running on very hard surfaces.
- Runners with potential biomechanical abnormalities (eg. leg length discrepancies) should have these assessed by a professional who can recommend corrective actions.
- Runners with prolonged and severe shin pain should consult a podiatrist to determine whether the cause of the pain could be treated with orthotics.
- Runners should be educated about the risk of and the severity of the consequences of stress fractures.

WARMING-UP

"Warming-up" is a term which covers activities such as light exercise, stretching and even psychological preparation before undertaking major sporting activity. Warm-ups, including stretching, have been recommended as a means of reducing musculoskeletal injury because they improve the range of motion of the joints and improve muscle elasticity, thereby removing some of the physical stresses associated with running. Sound epidemiological and experimental evidence for the preventive effect of warming-up is scarce and inconclusive.

Recommendations

- More research into the effectiveness of warming-up as an injury prevention measure is needed.
- Research should be undertaken into the benefits of different types of warming-up, cooling-down and stretching practices.
- Research into the optimal duration and frequency of warm-up should be undertaken.
- The specific needs of the injured runner, versus the non-injured runner should be considered when setting up a warming-up program. Injured runners should seek professional advice, from a physiotherapist for example, about the appropriate exercises to perform.
- Information about warm-up, cool-down and stretching techniques should be developed and widely promoted to improve specific knowledge of techniques.
- Consideration should be given to disseminating this information at the point of sale of running shoes, to reach a wide audience.

CORRECTION OF TRAINING ERRORS

A major contributor to running injuries is inadequately designed training programs which lead to training errors. Training errors include running too far, increasing the distance or time too quickly, high intensity, hill work, poor technique and fatigue. Training errors may lead to specific overuse type injuries.

Recommendations

- Runners should undergo a graduated running progression, guided by initial fitness testing results.
- Simple fitness testing prior to amateur running competition to ensure fitness for competition should be conducted. For instance, a 20m shuttle run score is easily and (relatively) safely obtained, and could be used as one criterion for admission to a competition or training programme, or for determining level of participation.
- Appropriate education and monitoring of runners regarding the nutritional and hydration demands of running, particularly as intensity increases with a training

programme, and particularly emphasising complex carbohydrate intake should be conducted.

- A study should be conducted to determine the maximum distance that should be run by runners of specific characteristics eg. recreational. This needs to take into account differences in individual goals and abilities.
- Recreational runners should not run excessive distance per week if fitness is the overall goal, running could be interspersed with other activities.
- Runners should consider some form of cross-training (eg bicycling) to improve their fitness levels whilst remaining injury free.
- Running speeds and distances should be built-up gradually
- More research is needed to determine the threshold levels of the various training factors under which runners are likely to remain injury free
- A campaign aimed at increasing runners' awareness of the injury consequences of training errors should be developed and promoted

RUNNING ENVIRONMENT

Running takes place predominantly in an outdoor environment. It is not surprising, therefore, that the runner is influenced by factors such as running surface, terrain and weather.

Recommendations

- More research into the role of running terrain is required to assess the impact of gait asymmetry on injury risk.
- Running tracks should be regularly checked for hazards such as potholes, loose debris, rubbish etc. and properly maintained.
- Track surfaces should be checked before each meeting for dangerous articles (eg broken glass, used syringes, etc)
- Runners should avoid soft sand, concrete or other hard rigid surfaces.
- Runners should avoid slippery surfaces such as can occur during wet, cold weather.
- If runners, particularly long-distance runners, are planning to run in events likely to be conducted when it is hot or humid, they should undergo a process of acclimatisation.
- Running events should not be planned for times when there is a likelihood of hot, humid conditions. Whenever possible, such events should be cancelled if such weather conditions eventuate.
- Drinking water should be provided at all running events, club meetings and competitions.
- Runners should ensure they drink adequate water.

- Runners should wear appropriate clothing when running and not run bare topped.
- Runners should always use a broad spectrum sunscreen and wear a hat and/or sunglasses if appropriate.

CORRECTION OF RUNNING STYLES

Each runner has their own running style, based on both natural and acquired habits. Correction of style is a complex matter which needs to be treated on an individual basis. Sometimes a runner's style will change to protect a previous injury site from further damage. Problems of malalignment such as leg length differences may often be an underlying cause of incorrect running technique and the use of orthoses is required to correct this.

Recommendations

- More research is needed to demonstrate the relationship between running style imperfections and injury risk.
- Research into the role of malalignment of the lower limbs in injury causation is needed.
- Studies to determine whether correction of running style leads to injury reduction should be conducted.
- Sporting organisations should continue to promote and teach correct running techniques.

FOOTWEAR

The process of running involves the gait cycle and this cycle can produce ground reaction forces of two to three times the runner's own body weight. The impact forces must be distributed by the body, and it is generally accepted that these forces contribute to the occurrence of running injuries. The logical approach to prevent these injuries would, therefore, be to attenuate the impact forces - for example by using shock absorbing shoes, shoe inlay orthoses or even good socks. When a runner selects a shoe it must provide cushioning, support and stability, and must maintain reasonable flexibility, softness, and lightness.

Recommendations

- Purchasers of running shoes should be encouraged to look for certain characteristics of shoes and not to be unduly influenced by price.
- Runners should choose their shoes carefully, preferably with professional advice.
- Further research is needed to adjust for confounding factors such as previous injury when looking at the relationship between shoe design and injury.

- Development of shoes to overcome the relatively short life of shoes, in terms of their impact absorption, should be investigated.
- Runners with potential biomechanical abnormalities (eg leg length discrepancies) should have these assessed and treated by a professional who can recommend corrective actions.
- Ongoing development of orthotic devices needs to continue.

TREATMENT AND REHABILITATION

Many running injuries are re-injuries or aggravation of a pre-existing injury. A runner with a previous injury may be more likely to be injured again because the original cause remains, the repair of tissue may function less well or be less protective than the original tissue, or the injury may not have healed completely. This leads to the conclusion that complete and controlled rehabilitation of an injury needs to be achieved, and sensible preventive precautions taken, before the person begins to run again. This procedure may involve prompt first aid attention, taping or bracing of joints and general rehabilitation.

Recommendations

- Runners should seek prompt attention to their running injuries from a person with first aid qualifications.
- Organisers of events should ensure that there are qualified first aid personnel at all events.
- Injured runners should ensure that they allow enough time for adequate rehabilitation before returning to their pre-injury level of activity.
- Research into the effects of rehabilitation programs for runners needs to be undertaken.
- Taping or bracing of joints could be considered by professionals in their management of injuries.
- Research into the benefits of taping or bracing specifically for the repetitive actions of the runner should be undertaken.

RUNNER AND TRANSPORT COLLISIONS

One of the most obvious, yet often undiscussed causes of running injuries is collisions with various forms of transport. Many runners run on footpaths or roadways, and most need to cross roads at some point in their running session. Collisions between runners and motor vehicles are uncommon but they do occur and may be catastrophic. The most effective way of preventing collisions is to separate runners and vehicles, and the provision of running tracks is an excellent way to do this.

Recommendations

- Planners and traffic engineers should continue to develop ways of preventing collisions between runners and vehicles, eg by providing more running tracks.
- Continue to educate runners and other road users about good road safety practices and enforce these.
- Traffic volumes in residential areas where people are likely to run should continue to be monitored and reduced.
- Runners should wear bright and/or reflective clothing so that they are readily noticed by motorists.
- Running shoes with reflectors, should be highly promoted for night-time runners.

FACTORS ASSOCIATED WITH CHILDREN'S RUNNING INJURIES

Injury prevention strategies for children should be considered separately to those for adults, despite the fact that their injuries may be attributed to many of the factors associated with adult runners (eg. training, environment, warm-up, technique, footwear). The Australian Little Athletics Association has taken these factors into consideration and developed sporting activities (including running) appropriate for children.

Recommendations

- Safety regulations and adequate training programs specifically for children need to be developed and implemented.
- Continue to support the activities of the Little Athletics Association for organised running events for children.
- Provide up-to-date information to the Little Athletics Association to inform them of the latest progress in injury prevention and to support their activities.
- School running programs should include more information about injury prevention.

FACTORS ASSOCIATED WITH WOMEN'S RUNNING INJURIES

Over the last several decades, there has been an increase in the number of women participating in many sports. Coinciding with this has been an increase in the recognition of their ability and needs as athletes. Female and male runners, in general, have an equal chance of injury occurring. There are factors present in the female athlete, however, which can increase their risk of injury above that of their male counterparts. These factors include anaemia, disturbances of the menstrual cycle and dietary behaviours.

Recommendations

- More research into the role of menstrual disturbances and the risk of overuse injuries needs to be undertaken.
- In particular, the exact relationship between menstrual health, bone health and stress fractures is yet to be elucidated.
- The impact of dietary behaviours and habits on the incidence of injuries, particularly in women, needs to be determined.

ADDITIONAL RECOMMENDATIONS

- Guidelines for minimum safety requirements for Little Athletics meetings and other running events (including the need for mobile phones, telephone contacts, first aid kits, etc) should be developed and widely disseminated.
- Improved data collection about the occurrence of running injuries and their associated factors needs to be developed and maintained.
- Data about injuries and their associated factors in recreational runners needs to be collected.
- Data collections should conform to guidelines for sports injury surveillance being developed and promoted nationally.
- Information about preventing running injuries should be disseminated widely through shoe points of sale, running magazines and more general magazines.

1. INTRODUCTION

Running is one of Australia’s most popular sporting and leisure activities (Brian Sweeney & Associates, 1991). A population survey conducted by the Australian Bureau of Statistics (ABS) indicated that in 1994/95, 49,000 Australians participated in the activity of jogging (ABS, 1996). It has been estimated that more than one in five (22%) Australian’s aged 16-65 currently jog, while one in seventeen (6%) attempt the more exhausting marathons or “fun run” events (Brian Sweeney & Associates, 1991). In comparison, 18% of Canadians (Stephens & Craig 1990) and approximately 11% of Americans participate in running (Rzona & Baylis, 1988).

The statistics quoted above do not include the large number of people involved in running as the basis of another sporting activity (eg. baseball, track and field, football, etc). Indeed, the action of running alone is difficult to interpret as the differences in pace running and distance running are often not stipulated. Pace and distance running are more commonly referred to as:

- Sprinting: to run a short distance at full pace;
- Jogging: to run at a slow pace;
- Distance running: to run at a slow pace over a long distance.

Why is it that running, or jogging, is such a popular sport? It is likely that this is because the association of running as a preventative and therapeutic activity with considerable health benefits is highly promoted. For example, higher levels of physical fitness have been attributed to lower rates of cardiovascular disease, reduced risks of cancer, weight loss, lower blood pressure, improved psychological status, better control of elevated blood sugar and prevention of osteoporosis (Blair et al., 1989; Marti 1991; Paffenbarger et al., 1993; U.S. Centers for Disease Control and Prevention, 1993). In the pilot survey of the fitness of Australians (Commonwealth Department of the Arts, Sport, the Environment and Territories, 1992) people were asked to nominate activities they would prefer to take up if they were to exercise more. A higher proportion of males (15.1%) than females (6.3%) nominated jogging or running as their preferred activity.

Another reason for the popularity of running, may be the fact that there are few costs associated with the sport in terms of necessary equipment and membership of clubs, with the only real requirement being a pair of running shoes. Additional factors such as the ability to participate at any time without the worry of scheduled organised events may also add to the sports’ popularity. Recreational joggers are not restricted by age or sex barriers. Joggers may also participate for competitive reasons, as a source of relaxation, for personal fitness and self esteem, as a social activity, as a time to be alone or simply because they enjoy spending time outdoors.

While running has been promoted by health professionals and has a wide variety of medically and socially related benefits, it needs to be recognised that, as with any sport, running-related injuries can, and do, occur. Running injuries are diverse, ranging from overuse injuries and metabolic abnormalities to extrinsic hazards such as dog bites and traffic collisions (Powell et al., 1986).

A significant amount has been published about the epidemiology and biomechanics of running injuries. This has often included informed and expert conclusions on the causes of specific running injuries and how to prevent them. There is, however, a notable lack of formal, controlled evaluations of the effectiveness of injury prevention countermeasures in running.

2. AIMS

The overall aim of this report is to critically review both the formal literature and informal sources that describe injury prevention measures, or countermeasures, for running. In doing so, it provides an evaluation of the extent to which these countermeasures have been demonstrated to be effective. The full range of countermeasures widely promoted to prevent running injuries are discussed.

Unlike other literature describing running injuries, this report does not specifically focus on the epidemiology of running injuries and neither does it provide a detailed description of their aetiology. Rather, this report presents a detailed examination of the range of countermeasures promoted to prevent running injuries. Nevertheless, a brief overview of the epidemiology of running injuries, particularly from an Australian perspective, is given to set the scene for the subsequent discussion of countermeasures.

3. METHODOLOGY

The sources of information used to compile this report were:

- Medline CD-ROM search for published medical literature (over the past 10 years)
- Sport discus CD-ROM search for published sports literature (over the past 10 years)
- injury conference proceedings scans
- discussions with key Australian researchers and sporting organisations
- correspondence with relevant state and national sporting organisations
- correspondence with relevant researchers registered by the National Sports Injury Research Centre
- a posting to the Injury List on the Internet
- scanning of other Internet and world wide web sites.

This review is based on English-language material only. It is acknowledged, however, that some of the relevant running information is published in foreign languages.

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 of the strength of the evidence presented in the identified literature was developed. This is shown in figure 1.

Figure 1: Grading scale for assessing the extent to which countermeasures have been fully evaluated

STRENGTH OF THE SCIENTIFIC EVIDENCE	TYPE OF SCIENTIFIC EVIDENCE
least ↑	anecdotal or informed/expert opinion
	laboratory-based/equipment testing
	data-based evidence (uncontrolled)
↓ **most**	controlled evaluations

This scale reflects an epidemiological and rigorous scientific approach to injury prevention that considers demonstration of the effectiveness of a countermeasure's performance in the field to be the highest level of 'proof'. This is particularly important for sports injury countermeasures where any change to the nature of the sport is an important factor to be considered. In general, changes to factors such as how the sport is played or undertaken, the behaviour of the participants and the level of enjoyment can only be measured during "in-the-field" evaluations.

At the lowest level of proof (ie. the "least" evidence end of the scale) are anecdotal reports of injuries and their prevention and comments based on informed or expert opinion. This category would include, for example, statements like "I treated 5 cases of Achilles tendinitis during last year and all would have been prevented if they had adequately warmed-up" or "none of the children I treated last year were wearing shock absorbing footwear". Of course, some expert/informed opinion carries more weight than other, particularly when it is based on a critical review of available information.

Laboratory-based evidence is a very important source of information about sports injury countermeasures. This category includes reports that have explored equipment design and testing, development of standard testing procedures and biomechanical research, including that performed on animals, cadavers and simulated body tissue such as crash-test dummies. Such information provides detail about the extent to which countermeasures such as protective equipment and properly designed running shoes perform under certain stress and/or impact conditions. This research is generally performed under laboratory conditions which are often controlled. However, such conditions may not be a good representation of actual running environment or conditions.

Data-based evidence can take a number of forms. Case-series studies or routine surveillance activities document the incidence of new injury cases over periods of time. Patterns in data can be examined over time to draw conclusions about the impact that countermeasures may have on injury rates. Cross-sectional epidemiological studies provide some information about injury prevalence at a given point of time but are unable to assess the influence of countermeasures on injury rates. Quasi-experimental studies are not controlled evaluations but do enable a comparison of pre-intervention with post-intervention data to examine the effects of some countermeasures.

Controlled evaluations provide the most definitive evidence for the impact of countermeasures. Case-control studies and longitudinal (cohort) studies are common forms of controlled studies. Neither study type allows random assignment of people (or injuries) to test and control groups, though they are examples of natural experiments. A randomised controlled trial is considered to provide the best evidence. In such studies, the units of interest (ie runner, surface, type of shoe, etc) are randomly assigned to test and control groups.

Another important aspect of countermeasure implementation is the extent to which they are accepted or adopted by the users for whom they were intended. Countermeasures should be acceptable to those they were designed to protect. Community consultation and awareness programs must therefore be considered in any implementation process. It is also important to assess barriers towards use of injury countermeasures and an examination of attitudes, knowledge and behaviours is crucial to this. Studies looking at these factors are generally conducted after implementation of a countermeasure and can highlight the need for behavioural or educational change at either the individual or organisational level. Because of the importance of this sort of research, the literature describing these studies is also included in this review.

Another measure of the success of countermeasures is a demonstration of their cost/benefit ratios. This information is often need by regulatory bodies and those involved in policy or rule making, to inform their decisions about countermeasures. Unfortunately, there have been no studies of the economic benefits of running injury countermeasures to date.

In the following sections the relevant literature for the effectiveness of each countermeasure is critically reviewed. Based on the studies reviewed, and discussion with the experts acknowledged in this report, recommendations for future countermeasure research, development and implementation are also given.

4. AN OVERVIEW OF THE EPIDEMIOLOGY OF RUNNING INJURIES

Little Australian data exists on the incidence and types of running injuries occurring in various populations of runners. The epidemiology of running injuries therefore needs to be viewed on a international scale. Internationally, there is considerable epidemiological literature on the incidence of running injuries (see van Mechelen, 1992 for an overview). Assessing the level of agreement between these studies is difficult, however, given the presentation of the data in various forms and differences in the study populations. A description of hospital emergency department presentation data for running related injuries in Victoria is given in Section 4.1.

A recent major review of the epidemiological literature found that if studies were restricted to samples of more than 500 subjects, average recreational runners, who train steadily and occasionally participate in long distance runs, have an annual running injury incidence rate that varies between 37% and 56% (van Mechelen, 1992). In terms of hours of participation, one study found an injury incidence of 3.6 injuries per 1000 hours of running in an overall population survey (van Galen & Diedricks, 1990). This is not too different from the incidence rate amongst competitive athletes which was found to vary from 2.5 to 5.8 injuries per 1000 hours of running, depending on the specialisation of the athlete (Lysholm & Wiklander, 1987).

Table 1 summarises the distribution of running injuries according to major medical diagnosis. Across the range of runners, overuse injuries are the most common type of injury. In the competitive athlete, tendinitis, a common overuse injury, was the most frequently recorded injury (Lysholm & Wiklander, 1987). In boys and girls periostitis/stress fractures were the most common injury (Watson & DiMartino, 1987) and in a normal jogging population strain and tendinitis were frequently reported (Marti et al., 1988; van Mechelen, 1992).

Table 1: Distribution of running injuries according to medical diagnosis

	Population		
	Lysholm & Wiklander 1987 [n=55]	Watson & DiMartino 1987 [n=41]	Marti et al., 1988 [n=877]
	Competitive	Boys & Girls	Normal joggers
Tendinitis	33%	10%	17%
Inflammation (other than tendinitis)	4%	15%	NA
Strain	15%	15%	18%
Periostitis/stress fracture	15%	22%	12%
Sprain	11%	17%	14%
Chondromalacia (roughening of cartilage)	1%	5%	NA
Other	9%	17%	39%

NA = not applicable; the figures in the table give percentage of injuries of each type
Source: van Mechelen, 1992.

Van Mechelen’s (1992) review of the literature found that knee injuries typically account for 25% of all running injuries (Table 2). Other commonly injured body regions are the feet (between 2 and 22% of injuries), the ankles (between 9 and 20%), lower leg between (2 and 30%), shin (6 to 31%), upper leg (3 to 18%), back (3 to 11 %) and the hip/pelvis/groin between

(2 and 11%). In general, the majority (ie 70-80%) of running injuries are located from the knee downward (van Mechelen, 1992)

Table 2: Bodily location of running injuries

Body region	Percentage range across all injuries
Knee	25%
Feet	2-22%
Ankle	9-20%
Lower Leg	2-30%
Shin	6-31%
Upper Leg	3-18%
Back	3-11%
Hip/Pelvis/Groin	2-11%

Source: van Mechelen, 1992

In terms of the nature of injury, 50-70% of running injuries are musculoskeletal in nature and associated with overuse (van Mechelen, 1992). This is hardly surprising given that a runner strikes the ground approximately 1000 to 1500 times per mile with forces of 2 to 3 times their body weight (Knutzen & Hart, 1996). The constant repetition of the same movements required to run, along with factors related to the runner and their environment, are obvious contributors to the aetiology of running injuries (Powell et al., 1986).

Running injuries were found to contribute 12.3% of all cases of injury presenting to a Sports Medicine Clinic in Melbourne over a twelve month period (Baquie & Brukner, 1995). In terms of frequency, running injuries were second only to Australian football (13.3%), while track running injuries contributed 5.6% of all injuries (Baquie & Brukner, 1995). Matheson et al. (1989) also concluded that running injuries made up the majority of sports related injuries in the young (31.5%) and the old (40.5%).

A Podiatric Sports Medicine Clinic reported that 32% of sports-related injuries were as a result of running (Agosta, 1994). Of all sports covered, runners contributed to 26% of all patella-femoral joint pain, while teno-periosteal shin pain in runners contribute to 42% of sports-related injuries.

Running injuries are associated with significant costs to the individual and society. For example, they result in the reduction of training or training cessation in about 30-90% of all cases. Between 20 and 70% of running injuries lead to medical consultation and up to 5% resulted in absence from work. Furthermore 20-70% of injuries are likely to re-occur (van Mechelen, 1992). This is obviously not the desired outcome for a recreational or competitive runner and injury prevention methods need to be reviewed. One possible explanation for the range of statistics given could be the range of different running populations surveyed (i.e. marathon vs sprint runners, elite vs recreational etc.).

4.1 Emergency department presentations

The Victorian Injury Surveillance System (VISS) collects detailed information on emergency department presentations from seven campuses of five Victorian public hospitals: Royal Children's Hospital, Western Hospital - Footscray and Sunshine campuses, Preston and Northcote Community Hospital, Royal Melbourne Hospital and LaTrobe Regional Hospital - Traralgon and Moe campuses. Self reported information on almost 170,000 cases has thus far been collected.

Of these, VISS has recorded 8,053 sports injuries to children, representing 10% of total child injury cases, and 7216 sports injuries to adults, representing 11% of all adult injury presentations. Due to differing hospitals and periods of collection the children's and adult data are best considered separately and the following two sections will present this data.

It is recognised that the VISS database may not be the best source of data about running injuries since most cases would not be severe enough to warrant treatment at an emergency department. Nevertheless, it can shed some light on the more serious cases and case narratives contained on the files are useful for elucidating some valuable information for injury prevention.

4.1.1 Child injuries

The VISS children's data is based upon five years of data collection, 1989 to 1993, at three hospitals: Royal Children's Hospital, Western Hospital, and Preston and Northcote Community Hospital, and four years of data collection, July 1991 to June 1995, at the LaTrobe Regional Hospital - Traralgon and Moe campuses.

There were 59 recorded cases of running injury to children, aged less than 15 years, on the VISS database, representing 1% of all sports injury emergency department presentations amongst children. Almost 70% of those injured were aged 10-14 years and 53% were female. Injuries were most common in the months of November (19% of total), August (17%) and October (14%).

Almost 60% of injuries occurred at areas for organised sport, while another 37% occurred at school. Ninety-five percent of participants were taking part in organised competition. The remaining 5% did not specify the type of running they were doing when injured.

An examination of the case narratives for the running injuries identified that 10% of the injured runners were "sprinting" when the injury occurred and 8% were running in a relay team when the injury occurred. Twelve percent of the injured runners specified the distance of the event they were participating in, of which the most common distances were <100 metres (17%); 100 metres (17%); 200 metres (8%); 400 metres (8%) and 800 metres (8%). A further 3% of cases were participating in a cross country event. Surface conditions such as loose stones, cracks and slippery tracks, were a contributing factor in 15% (n=9) of cases and these factors often caused the runner to slip (4 cases), twist an ankle or foot (2 cases) or fall (1 case).

Forty-two percent of runners were injured when they fell, slipped or tripped, e.g. "*Running and fell over at the finish line*" or *"Practising for cross-country run, slipped on loose stones and fell* *over".* Another 31% of cases related to overuse, e.g. *"Competing in cross-country, overexerted self, complained of sore knee".* Of the remainder, 10% of cases involved contact with another runner eg., *"Competing in race, back of heel was touched by person from behind"* and another 10% of injured cases were associated with incorrect running techniques e.g. *"Running, had to pull up quickly, injured knee."*

Table 3 summarises the most common injury mechanisms for child running injuries and compares them with the adult injury cases. Overuse was the most common mechanism in about one third of cases, followed by falls in 29%.

Only 8% of the child runners had sustained injuries serious enough to warrant hospital admission after emergency department presentation. Forty-seven percent of cases required further review or referral and almost half of these cases (the equivalent of 24% of the total) were referred to an outpatient clinic. A further 27% of injured runners required only minor treatments and 17% required no treatment.

Forty-four percent of the total number of injuries sustained were strains and sprains. These were mostly to the ankle (11% of total injuries sustained), knee (10%) and wrist (7%). Fractures of the radius/ulna accounted for another 16% of total injuries.

Table 3: Comparison of the most common mechanisms for child and adult running injuries presenting to emergency departments

	Child injury cases (N = 59) %	**Adult injury cases (N =13) %**
Over-use	31	61
- knee	7	8
- leg	7	0
- foot	3	8
- hip	0	15
- neck	2	8
- ankle	2	0
- unspecified	10	22
Fall	29	23
Contact with another runner	10	15
Incorrect technique	10	0
Slip	10	0
Trip	3	0
Other	7	1
TOTAL	**100**	**161**

4.1.2 Adult Injuries

The VISS adult injury collection is based on nine hospital years of data. The collection periods for each participating hospital are as follows: Western Hospital (11.12.90 to 31.12.92 - 2 years), Preston and Northcote Community Hospital (1.3.92 to 28.2.93 - 1 year), Royal

Melbourne Hospital (1.3.92 to 28.2.94 - 2 years) and LaTrobe Regional Hospital - Traralgon and Moe campuses (1.7.91 to 30.6.95 - 4 years).

During the total data collection period, VISS recorded only 13 cases of injuries to runners aged 15 years or over, representing 0.2% of adult sporting injuries. Almost half of the injuries were to runners aged 15-19 years. All cases were aged less than 35 years. The majority (n=12) of the injured cases were males.

Seventy percent of adult injuries occurred in the months from June to September (inclusive).

Sixty-two percent of adult running injury cases occurred at areas of organised sport, with another 15% at parks and 15% on the road or footpath. Almost 70% of runners were participating in formal competition or training, another 23% of cases did not specify the nature of the running they were doing when injured.

One third of runners were training when injured and one injured runner was participating in a cross-country event. Almost two-thirds of cases were related to overuse, eg. "*Running, over-exerted while on long run 7 km in 27 minutes".* Another 23% of runners had fallen and 15% of cases involved contact with another runner, eg. *"Running, stepped on another runners' heel, rolled ankle".*

Table 3 shows that like child running injuries, overuse was the major injury cause, followed by falls. Overuse appeared to be more of a problem for adults than children in terms of the relative proportion of injuries (61% versus 31% respectively). It is possible that this difference can be explained by the type of running activity (i.e. distance). Unfortunately the VISS database does not give further information about the type of running undertaken at the time of injury. This means that the role of running type cannot be determined. Unlike the child cases, no adult running injuries were due to technique, slips or trips. This may be due to the fact that these are probably not such a problem for the experienced runner.

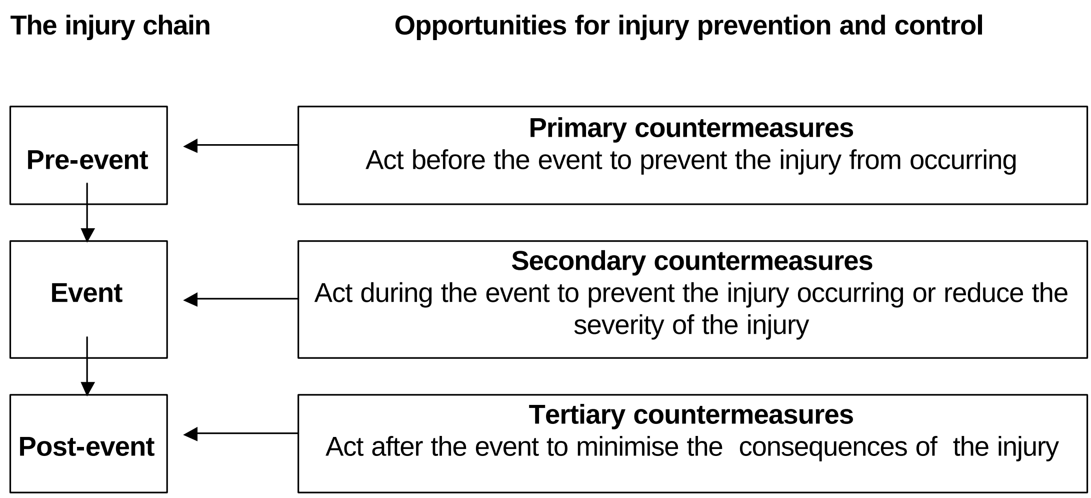
Only one runner sustained injuries serious enough to warrant admission to hospital. Sixty-nine percent of cases required further review or referral. Almost forty percent of total cases were referred to an outpatients department for follow up and 17% to a general practitioner. Another 23% required no treatment.

Sixty-two percent of the total number of injuries sustained were strains or sprains, particularly to the foot (15% of total injuries) and hip (15%). More than half of the injuries sustained were to the legs.

5. AN OVERVIEW OF INJURY COUNTERMEASURES FOR RUNNING

Injuries are considered to result from the culmination of a set of circumstances and pre-existing conditions that may best be understood as a chain of events: pre-event, event and post event (Robertson, 1983). Injury countermeasures are measures that can "counter", that is prevent or reduce, the risk of injury. A number of researchers have described how countermeasures should be targeted at the different links in the chain of events leading to injury (Haddon, 1972; Ozanne-Smith & Vulcan, 1990; Watt & Finch, 1996). Such injury countermeasures can be equated with primary (pre-event), secondary (event) and tertiary (post-event) prevention in the chain of events associated with injury (Figure 2). Primary countermeasures act before an event or incident that could potentially lead to injury to prevent the event from occurring in the first place. Secondary countermeasures act during the event or incident to prevent the injury occurring or to reduce the severity of the injury. The third level of countermeasures act after the chain of events/incidents leading to injury and help to minimise the consequences of injury.

Figure 2. Countermeasure opportunities in the injury chain



Source: Watt & Finch (1996)

Before further considering running injuries and the appropriate countermeasures for preventing them, it is important to review the biomechanics of running. The process of running involves a motion called the gait cycle. This cycle is divided into three phases - stance, float and swing (Ting, 1991). The stance phase occurs when the feet are in contact with the surface, the float is when neither of the extremities are in contact with the surface, and the swing stage occurs when one foot is off the ground. The speed at which this cycle occurs can affect the joint range of motion, muscle activity and ground reaction forces (Ting, 1991). The impact forces resulting from the gait cycle can be two to three times body weight (Knutzen & Hart, 1996). These impact forces must be distributed by the body, and it is speculated that these forces contribute to the occurrence of running injuries, particularly overuse injuries. Although the tissues and anatomic sites of overuse injuries may vary, the cause is the same: repetitive episodes of trauma overwhelming the body's ability to repair itself (Herring & Nilson, 1987).

Other injuries that can occur during running are associated with dehydration, sunburn, falls, traffic hazards, pre-existing medical conditions or simply being ill prepared for the event (Powell et al., 1986).

In his review of the literature, van Mechelen (1992) developed the following table to summarise the factors related to the incidence of injuries to runners.

Table 4: Factors related with running injuries: a summary of results from the literature

Factors significantly related with running injuries	Factors not significantly related with running injuries	Factors related with running injuries that are not clear, or are contradictory or based on scanty information
previous injury lack of running experience running to compete excessive running distance	age gender body mass index hill running running on hard surface participation in other sports time of year time of the day	warming up stretching exercises body height malalignment restricted range of motion running frequency intensity of performance stability of running pattern shoes in-shoe orthoses running on 1 side of the road

Source: van Mechelen, 1992

As summarised in the table above, there are a multitude of factors that may contribute to the risk of injury in runners. Generally, more than one factor is involved in each injury. Consequently, there are numerous countermeasures aimed at the primary, secondary or tertiary levels of prevention which can be used to help prevent these injuries. These are summarised in Table 5.

Table 5: Running injury countermeasures

Primary	Secondary	Tertiary
training pre-season conditioning warm-up technique footwear surface nutrition environment strapping/bracing adequate water intake distance orthotics	environment surface footwear orthotics	rehabilitation availability of first aid equipment rest, ice, compression, elevation, referral strapping/bracing orthotics

Sports injury risk factors can also be described as intrinsic and extrinsic (Kannus, 1993). Intrinsic or internal factors are related to the physical and mental health of the athlete. Extrinsic or external factors are those which impinge externally on the athletes' performance (i.e. running when fell over due to a uneven surface). Different countermeasures are used to address the intrinsic and extrinsic risk factors. Table 6 describes which of the given running countermeasures given in Table 5 address the intrinsic and extrinsic factors respectively.

Typically, the intrinsic factors are addressed by primary prevention activities, while extrinsic factors involve prevention at the primary, secondary and tertiary levels.

Table 6: Intrinsic and extrinsic factors associated with running injuries

Intrinsic factors	Extrinsic factors
pre-season conditioning	training
technique	warm-up
nutrition	footwear
strapping/bracing	surface
orthotics	environment
rehabilitation	strapping/bracing
	orthotics
	rehabilitation
	adequate water intake
	distance
	first aid
	rest, ice, compression, elevation, referral

The literature assessing the effectiveness of the various countermeasures listed in Table 5 and 6, for the prevention of running injuries, is reviewed in the following sections. For each countermeasure, the rationale for its use as a safety measure is presented followed by a critical review of the extent to which it has been evaluated.

6. PREVENTING OVERUSE INJURIES

6.1 Rationale and background

An overuse injury results from repeated stress to the involved tissues - bone, ligaments or tendons. The tissues and anatomic sites of overuse injuries may vary but according to one study, the cause is the same: repetitive episodes of trauma overwhelming the body's ability to repair itself (Herring & Nilson, 1987). This may be associated with the forces and repetitive nature of the gait cycle. Alternatively, an overuse injury could be the result of a previous injury for which the body compensates, by increasing the stress on another part of the body, eventually leading to tissue breakdown and overt injury at the vulnerable site. Overuse injuries in runners usually begin with pain and stiffness. Depending on the severity, the runner will suffer pain and stiffness at the beginning, during or after the run, or a combination of these. Continuous pain and stiffness will eventually lead to a cessation of running.

Once an overuse injury develops, the condition remains until physiological equilibrium is re-established between the stresses of athletic activity and the body's healing ability (Ting, 1991). Overuse injuries contribute to 50-75% of all running injuries and are multifactorial in causation (van Mechelen, 1992). Training, technique, footwear, surface, rehabilitation and warm-up are all factors contributing to overuse injuries with numerous primary, secondary and tertiary factors playing a role in prevention (see Table 5). Due to the range of factors contributing to overuse injuries, reference also needs to be made to all the countermeasures reviewed in other sections of this report.

Overuse running injuries can occur anywhere from the toes to the lumbosacral spine (see Table 2). They also vary in severity and frequency.

Common running injuries associated with overuse are shown in Figure 3.

Plantar fasciitis: an inflammation of the thick band of tissue from the heel to the base of the toes in the bottom of the foot. When placed under stress, the plantar fascia stretches and tears, leading to inflammation.

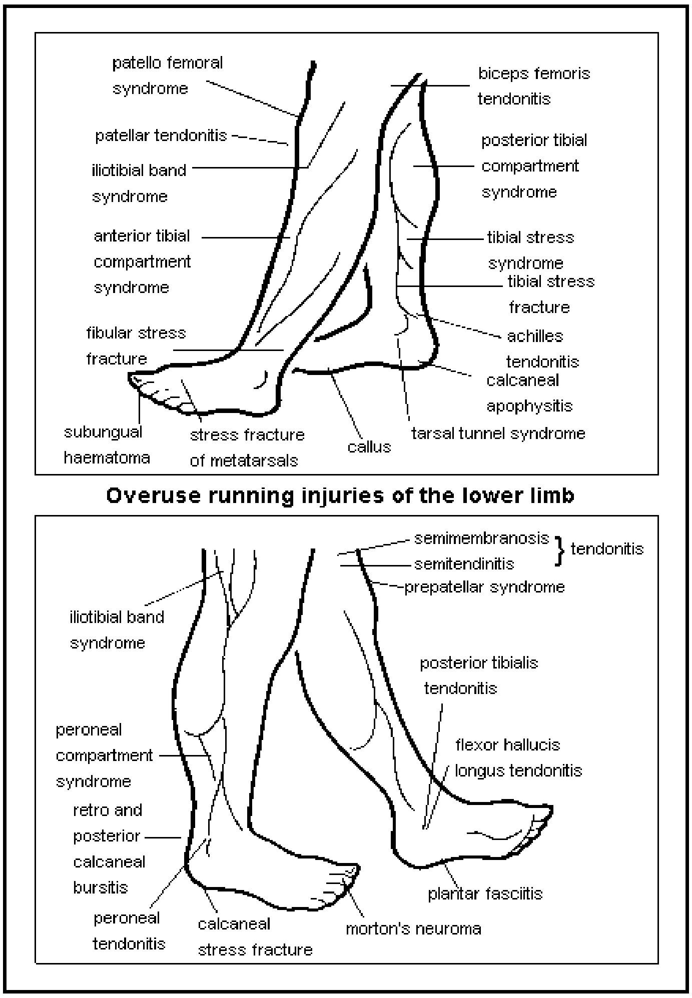
Shin splints: the inflammation of the tendons on the inside of the front of the lower leg, i.e. the shins.

Achilles tendinitis: occurs when the Achilles tendon, a large tendon connecting the two major calf muscles (gastronemius and soleus), is placed under too much stress causing inflammation. If the inflamed Achilles continues to be stressed, it can tear or rupture.

Chondromalacia: a cracking or wearing away of the cartilage under the kneecap, resulting in pain and inflammation.

Iliotibial band syndrome: inflammation and pain on the outside of the thigh, where the iliotibial band rubs against the femur.

Figure 3: Common overuse running injuries of the lower limbs



Reproduced with kind permission of Sports Medicine Australia from Common Running Problems in Sport: their assessment, management and prevention. (Larkins, 1990)

Other less common overuse injuries are also detailed in Figure 3 and may be referred to later in the text. For further information refer to Common Running Problem in Sport: their assessment, management and prevention (Larkins, 1990). In this context overuse injuries can also be prevented despite the fact that there isn't a single event that causes the injury. However, appropriate countermeasures can prevent this accumulation therefore preventing overuse injuries.

6.2 Shin pain

A number of studies have dealt specifically with one of the most frequent, severe and disabling overuse injuries known in general as shin pain. Shin pain in runners is a very common overuse injury. The classic "catch-all" term for shin pain is "shin splints". Shin pain can be caused by shin splints, stress fractures, tendinitis, periostitis, teno-periostitis, tenovaginitis, tibio-fibular joint sprain and compartment syndrome (Rennie, 1993).

In a review of the literature, Cook et al. (1990) concluded that running on a hard surface or with an inadequate arch support, flat feet, or excessive pronation would produce shin splints. It is for this reason that many authors have recommended improved footwear or the use of orthotics. Further discussion of the use of orthotics is provided in Section 7.5.3. Other studies worth mentioning here, however, include a military study of 237 randomly selected new recruits (Schwellnus et al., 1990). In this study, new recruits who were given insoles (experimental group) reported fewer overuse injuries (86.4%) than a control group of 1151 recruits without orthotics (90.7%). The incidence of tibial stress syndrome was found to be significantly lower in the experimental group. The incidence of stress fractures was also lower in this group but not significantly so.

Further support for the use of orthotics was produced by Gross et al. (1991) who conducted a survey of 347 members of a New York Road Runners Club, all of whom were treated with orthotic shoe inserts. Shin pain had lead to the use of orthotics in 14.1% of cases. Of these, 68.8% reported complete cure or a great improvement, 18.8% reported a slight improvement and 12.5% reported a new problem.

6.3 Stress fractures

Reeder et al. (1996) conducted a review of the literature focusing on stress fractures. These authors found that the current concepts of diagnosis and treatment for stress fractures had been described in relation to many sports but they are most commonly reported in runners. This review also concluded that running-related stress fractures can be attributed to many factors, including: training surface, training technique, inappropriate footwear, biomechanical abnormalities and poor conditioning.

Table 7: Possible factors predisposing to stress fractures

Training and equipment
Type of surface (ie. hard surface)
Abrupt change in intensity, speed or distance
Insufficient recovery periods
Inappropriate shoes
Biomechanics
Leg length differences
Increased knee valgus
Foot pronation
Femoral anteversion
Decreased tibial bone width

Source: Reeder et al. (1996).

An Australian study of 53 female and 58 male competitive track and field athletes aged 17-26 years, studied the incidence and distribution of stress fractures prospectively over a 12 month period (Bennell et al., 1996a). These athletes were all registered members of a Victorian Athletics Club and competed in sprints, middle distance, hurdles, jumps or multi events. Twenty athletes sustained 26 stress fractures, with an overall 12 month incidence rate of 21% for men and women combined. The incidence rates did not differ significantly by gender. The most commonly diagnosed musculoskeletal injury was a stress fracture (20%), with the majority of these occurring in the tibia (46% of all stress fractures). The authors concluded that a detailed investigation of the etiological risk factors was needed.

In this same cohort, Bennell et al. (1996b) prospectively investigated the risk factors for stress fractures. Total bone density, regional bone density and soft tissue composition were measured using dual energy x-ray absorptiometry and anthropometric techniques. Menstrual characteristics, current dietary intake and training were assessed by questionnaires. A clinical biomechanical assessment was preformed by a physiotherapist. Of the risk factors evaluated (total bone mineral content, regional bone density and soft tissue composition, dietary intake, training assessment and biomechanical assessment), none were found to predict the occurrence of stress fractures in men (Bennell et al., 1996b). In the female athletes, however, lower bone density, a history of menstrual disturbance, less lean mass in the lower limb, a leg length discrepancy and a lower fat diet, were significant risk factors associated with the incidence of stress fractures. Multiple logistic regression revealed that age of menarche and calf girth were the best independent predictors of stress fractures in women. Odds ratios revealed that for every additional year of age at menarche, the risk of stress fractures increased by a factor of 4.1 and that for every one centimetre decrease in calf girth, the risk increased four fold.

In a retrospective twelve month study aimed at evaluating the incidence, distribution and type of musculoskeletal injuries sustained by 95 track and field athletes, a total of 72 athletes sustained 130 musculoskeletal injuries giving an athlete incidence rate of 76%. Of these injuries, stress fractures were common (20%). The majority of these fractures occurred in the tibia (46%). Stress fractures comprised a greater proportion of overuse injuries in females than in males (Bennell & Crossley, 1996).

In a survey of running injuries in 1505 competitive and recreational runners, similar results to those reported above were found. Females (13.2%) were more susceptible to stress fractures than males (8.3%) at higher mileage (Brunet & Cook, 1990). These studies also found that a higher mileage lead to an increase in stress fractures for both men and women. The cause of this increased incidence may be attributable to lower bone mineral density levels as a result of hormonal factors. According to this study factors such as running surface, age and stretching techniques do not appear to play a significant part in the pathogenesis of running stress fractures. This study also found a significant increase in stress fractures in patients with known leg length inequalities. Men with leg length inequalities reported stress fractures in 17% of cases, compared to 7% for those without leg length inequalities. Likewise in women, 26% in those with leg inequalities and 11% in those without inequalities respectively (Brunet & Cook, 1990).

6.4 Recommendations for futher research, development and implementation

The majority of these risk factor studies reviewed here have been undertaken on competitive athletes. However, they are based on prospectively collected information about the athletes. Based on the above studies, and discussion with the experts acknowledged in this report, the following set of recommendations for future research, development and implementation can be made:

- More research into the aetiology of stress fractures, particularly at the recreational runner level needs to be undertaken.

- Further development of three dimensional modelling of the foot and lower limb during running should be undertaken to gain a greater understanding of the biomechanics of running and the associated injuries.
- More research into the relationship between a low fat diet, restrictive eating patterns and the risk of stress fractures needs to be undertaken.
- The role of conditioning (both to improve strength and flexibility) in the prevention of stress fractures should be further explored.
- Runners should choose their running shoes carefully, preferably with professional advice.
- Runners should avoid running on very hard surfaces.
- Runners with potential biomechanical abnormalities (e.g. leg length discrepancies) should have these assessed by a professional who can recommend corrective actions.
- Runners with prolonged and severe shin pain should consult a podiatrist to determine whether the cause of the pain could be treated with orthotics.
- Runners should be educated about the risk of and the severity of the consequences of stress fractures.

7. DETAILED REVIEW OF RUNNING INJURY COUNTERMEASURES

Through the extensive literature search conducted, seven articles were found to be particularly relevant to this report and are mentioned throughout. Firstly, an extensive review of the literature conducted by van Mechelen (1992) provided an informed opinion on each of the countermeasures topics, along with good epidemiological evidence on injury incidence and severity. Powell et al. (1986) also reviewed the epidemiological literature, providing an informed opinion focusing on the causes of running injuries rather than the frequency of injury. The causes and associated factors focused on, were age, gender, structural abnormalities, body build, running experience, past injury, distance, pace, warm-up habits, running environment and collisions with vehicles. A more recent review of the literature, from 1975 onwards, conducted by Knutzen and Hart (1996), also provided an informed opinion relevant to most aspects of this report.

Recent investigations of injury risk factors were also very important to the report. Brunet and Cook (1990) studied 1505 competitive and recreational runners who completed a 33 item multiple choice questionnaire, focusing on training, injuries sustained and medical care. Results of this epidemiological study dealt with the incidence of injury, location of injury, mileage, running surface, stretching habits and leg length discrepancies. In a similar epidemiological study, Walter et al. (1989) studied a cohort of 1680 runners who were enrolled through two community road race events and monitored during a 12 month follow up period for the occurrence of musculoskeletal injuries. All subjects were requested to complete a baseline questionnaire distributed on race day and were followed up by phone calls scheduled 4, 8 and 12 months after the event. The results from this survey focused on mileage, training days, warming-up habits, running surface, training pace, running shoes, injury incidence and site, as well as other factors such as car and runner collision.

The final two epidemiological studies were based on entrants in competitive running events. Firstly, Jacobs and Berson (1986) investigated 451 (355 men and 96 women) randomly sampled entrants in a 10 km race. This investigation examined the incidence and site of injury, mileage, running pace, stretching habits, running surface, hill running and treatment of the injury. The second study by Marti et al. (1988) was based on a survey questionnaire designed to investigate the incidence, site and nature of running and jogging injuries (surface, shoes, pace and mileage) among 4358 male participants in a popular 16 km race. The response rate for this survey was 83.6%.

These studies form the basis of much of the material in the following sections. Because of the particular importance of overuse injuries, the review of countermeasures will begin with an overview of these injuries.

7.1 WARMING-UP

7.1.1 Rationale and background

“Warming-up” is a term which covers activities such as light exercise, stretching, and even psychological preparation, before undertaking major sporting activity (Best & Garrett, 1993).

Warm-ups, including stretching, have been recommended as a means of reducing musculoskeletal injury because they improve the range of motion of the joints and improve muscle elasticity, thereby removing some of the physical stresses associated with running. Warm-ups are also believed to be beneficial in mental, as well as skill, preparation. Stretching or cooling-down after exercise may be more physiologically effective. This is because there is an increased amount of heat generated in the soft tissues after exercise and this is necessary for the increased elasticity that would enhance stretching (McQuade, 1986).

7.1.2 Evidence for the effectiveness of warm-up

Sound epidemiological and experimental evidence for the preventive effect of warming-up is scarce and inconclusive (van Mechelen, 1992).

McQuade (1986), conducted a case-control study of 214 community runners to assess the effect of stretching. Based on a small number of cases and controls, it was found that the risk of injury for the runner who did not stretch was twice that for the runner who stretched. It is difficult to assess how well this finding generalises to other runners, as there is no evidence of how participants were recruited into the study.

In contrast, Walter et al. (1989) found no significant positive benefit from stretching. During a 12 month cohort study of 1680 runners who were enrolled in a community road race, it was found that runners who ‘sometimes’ stretched had a significantly increased risk of injury compared to runners who ‘always’ stretched (average relative risk of 1.56 males and 1.78 for females). Runners who ‘usually’ or ‘never’ stretched had lower risks of injury than those who ‘always’ stretched but these were not statistically significant. It was also found that runners who -up had a significantly lower risk of injury than runners who ‘always’ warmed-up (average relative risk of 0.37 for males and 0.55 for females).

Jacobs and Berson (1986) obtained a similar finding in their study of 451 runners involved in the 10,000 metre National Championships in New York. Based on the information runners gave in a self-report questionnaire, a positive correlation between injury and stretching was found. This study, however, gave no indication of how long runners had been using stretching techniques prior to their injury. The authors suggested that these findings were probably biased in that injured runners were found to stretch significantly more before running than non-injured runners.

While stretching has been found to be associated with runners who have a previous injury, it has also been associated with the mileage run per week. A survey of running injuries in 1505 competitive and recreational runners indicated that runners who stretched “never or occasionally” averaged more miles per week and had fewer injuries than those who stretched on a regular basis (Brunet & Cook, 1990). A limitation of this study, however, was that it was based on a multiple-choice questionnaire, which tended to restrict responses or to lead people to respond in a given direction.

In comparison to the above, other studies have found neither a significant positive nor negative effect of stretching, warm-up or cool-down (van Mechelen et al., 1993; Pope et al., 1996; Blair et al., 1987).

Van Mechelen et al, (1993) evaluated the effect of a health education intervention, focusing specifically on warm-up, cool-down and stretching on running injuries. During the 16 week study, 326 participants were randomly assigned to a control or intervention group and matched for age, weekly running distance and general knowledge of sports injury prevention. The intervention group received information and a standardised program with regard to warm-up, cool-down and stretching exercises. The control group received no such information. At the conclusion of the study period, there were 23 injuries in the control group and 26 injuries in the intervention group. The intervention proved to be ineffective in reducing the number of running injuries. It was demonstrated, however, to be significantly effective in improving specific knowledge of techniques. On the basis that 90% of runners performed warm-up and cool-down in both the intervention and the control groups, 58% conducted daily stretching exercises, and similar numbers were injured, it is questionable as to whether the intervention really would have been able to change behaviour.

Pope et al. (1996) conducted a controlled randomised trial of 1538 male Australian army recruits aged between 17-34 years, to determine whether pre-exercise stretching prevents injury. This study found that stretching had no significant effect on the incidence of lower limb bone or soft tissue injuries, despite good statistical power.

Further evidence, indicating that running injuries are not associated with stretching habits comes from a study conducted by Blair et al., (1987). This involved a retrospective survey of running practices and orthopaedic injuries conducted on 438 men and women at an aerobics activity centre in Texas. Study participants reported at least 10 miles of running during at least one week within a 3 month period. Blair et al. (1987) reported that the frequency of stretching was not reported to be associated with running injuries.

Taken together, these studies suggest that warming-up and stretching has either no effect or a negative effect on the risk of sustaining a running injury but the evidence is inconclusive. In the studies reviewed the characteristics of warm-up were rarely fully investigated as to the type and duration. It may well be that certain warming-up, cooling-down or stretching practices are effective in preventing injuries while others are not.

The Australian Little Athletics Association (1995) has produced a poster to educate children about correct stretching techniques. Unfortunately, however it is not clear how widely this has been distributed and whether it has influenced participants. At present, a coaching video is being produced by Australian Little Athletics on the benefits of warm-up and techniques for warming-up. Once completed, the video will be available for purchase to members and coaches of Little Athletics along with schools and other interested people (Vincent, 1996). Another coaching video is being produced on the subject of sprinting by the Australian Little Athletics Association.

The Little Athletics Association gives all persons aged 15 years and over the opportunity to participate in an “Orientation to Coaching Course”. This course dedicates an entire component to warm-up. The course indicates that the first part of every training session or preparation for competition should be the warm-up, for the benefits already outlined previously (Section 7.1.1). Table 8 summarises the appropriate warm-up techniques recommended for children at various ages.

Table 8: Suggested sample warm-up for Little Athletics

Activity	Purpose	Time (Minimum)
AGED 7-10		
Running game	Increase muscle temperature	5 mins
Flexibility	Increase range of movement	5 mins
AGED 14+		
Easy aerobic run/jog	Increase muscle temperature	5 mins
Flexibility	Increased range of movement	10 mins
Event specific drills	Co-ordination and preparation for sessions/competition	10 mins

Source: (Australian Track and Field Coaches Association, undated)

In Little Athletics, cooling down is emphasised as being as important as warm-up. This is in order to gradually reduce the body's temperature and heart rate, and speed up the recovery process before the next training session or competition (Australian Track and Field Coaches Association, undated).

Guidelines for stretching are also stipulated within the orientation to coaching course. It is indicated that athletes should start stretching relaxed, be systematic, progress from general to specific activities, encounter active stretching before passive stretching, use a variety of stretches, do slow progressive stretches, not to hold the breath, allow for individual differences and to stretch regularly (Australian Track and Field Coaches Association, undated).

7.1.3 Recommendations for futher research, development and implementation

Taken together these studies suggest some areas requiring further attention:

- More research into the effectiveness of warming-up as an injury prevention measure is needed.
- Research should be undertaken into the benefits of different types of warming-up, cooling-down and stretching practices.
- Research into the optimal duration and frequency of warm-up should be undertaken.
- The specific needs of the injured runner, versus the non-injured runner should be considered when setting up a warming-up program. Injured runners should seek professional advice, from a physiotherapist for example, about the appropriate exercises to perform.
- Information about warm-up, cool-down and stretching techniques should be developed and widely promoted to improve specific knowledge of techniques.
- Consideration should be given to disseminating this information at the point of sale of running shoes, to reach a wide audience.

7.2 CORRECTION OF TRAINING ERRORS

7.2.1 Rationale and background

There is no doubt that a major contribution to athletic injury is inadequately designed training programs, in which what is commonly know as training errors occur (Best & Garrett, 1993). Lysholm and Wiklander (1987) reported errors in training alone, or in combination with other factors, to be responsible for 72% of the injuries sustained to high level runners. A sudden increase in weekly running distance or other training habits has also been shown to be associated with running injuries because the capacity of the tissues to adapt is lacking (Powell et al., 1986).

Training errors include, running too far, fast progression (i.e. increasing distance or time too quickly), high intensity, hill work, poor technique and fatigue. Pope et al. (1996), in a cohort study of 1538 male army recruits, found a significant relationship between pre-training 20 meter shuttle run test score (Leger, 1989) and risk of lower-limb injury during training. The 20 meter shuttle run score is a valid and reliable indicator of fitness (VO2 max) and running performance (Paliczka, Nichols & Boreham, 1987; Leger & Gadoury, 1989). Poor fitness (or relatively low VO2 max) leads to an increased rate of muscle glycogen depletion during physical activity, and hence to earlier fatigue (Burke & Deakin, 1994). This fatigue could leave the individual at increased risk of sprains or strains due to reduced control of excessive joint motion. Moreover, running performance tends to be related to previous running experience. Hence a low 20 metre shuttle run score, indicating a poor running performance, will also indicate lower levels of prior running experience. This is one of the confirmed risk factors for overuse injury in runners noted by van Mechelen (1992).

It should also be noted that fatigue may also result from poor hydration, causing a reduced blood flow, and hence impairing availability of muscle fuels (Burke & Deakin, 1994). Fatigue may also occur because of inadequate nutrition, leading to early muscle glycogen depletion (Burke & Deakin, 1994). Such nutritional deficits are not uncommon in runners, who often restrict their diet in order to maintain a body weight acceptable to them (Larkins, 1990). Inexperienced runners are also more prone to dehydration or inadequate nutrition due to a sudden increase in demand on fuel and water stores.

Other training errors include the wearing of inadequate shoes, poor running surface, climatic conditions and rehabilitation. These latter factors, are discussed separately in future sections of this report.

Training errors may lead to specific injuries. Knutzen and Hart (1996), in reviewing the literature concluded that stress fractures followed interval training (ie. sets of exercises which change in intensity). Matheson et al. (1987) identified training errors in 22.4% of all stress fractures and these errors were equally common for all sites of stress fracture. Iliotibial band friction syndrome is often related to single severe training sessions (McNicol et al., 1981) or to up hill running (Jacobs & Berson, 1986; Jones & James, 1987). Nonspecific knee pain has also been associated with hill running and interval training (Pretorius et al., 1986). Similarly, hill running has been shown to be related to plantar fasciitis (Warren, 1990; Knutzen & Hart, 1996).

7.2.2 Mileage

A positive correlation between the incidence of injury and the distance run, has been the most consistently observed result in studies. In a cohort study of 1680 runners followed over a 12 month period, Walter et al. (1989) found that injury risk was higher if individuals ran more than 40 km per week, ran more miles per day on running days, ran longer runs, ran more days per week and ran all year round.

Supporting this finding are the results of a study of 451 runners involved in the 10,000 meter National Championships in New York (Jacobs & Berson, 1986). Based on the information the runners gave in a self-report questionnaire there was a significantly greater proportion of injured runners than non-injured runners who ran more than 30 miles per week (48% vs 67%, p<0.001). The authors suggested that this result could be biased, since injured runners ran a greater mileage than non-injured runners. Given that this study was based on a population of skilled long distance runners, it cannot be generalised to the population of runners as a whole.

High mileage and its relationship with injury was also investigated in a 10 year follow-up of a cohort of runners (Koplan et al., 1995). Five hundred and thirty participants were recruited from an earlier study population of 1,250 competitors in the Peachtree 10 km road race. The aim of this study was to determine the patterns of exercise and associated adverse events, including injuries. The study required respondents to recall their injuries over the previous 10 years and this is a major concern in the reliability of these results. In general, the incidence of injury increased with greater mileage, but exhibited an inverted U-shaped pattern when considered as a percentage of persons reporting an injury. The incidence was highest amongst men who ran 30-39 miles per week and women who ran 40-49 miles per week.

Marti et al. (1988) supported these results. In this study, information about the incidence, site and nature of jogging injuries among 4358 male joggers participating in a popular 16 km race was collected (Marti et al., 1988). Data from a self-administered questionnaire showed that an increase in the weekly training mileage led to an increased incidence in running injuries and medical consultations.

A sudden increase in training mileage has also been associated with the incidence of running injuries, as the body suffers microscopic damage to the tissues as a result of the inability to adapt quickly. Evidence for this has been documented by Lysholm and Wiklander (1987) in a one year study of a small group of sixty runners, belonging to two running clubs. In 38 of a total of 65 injuries sustained, one or more possible factors were identified. A training fault (excessive distance, sudden change of training routines) was the cause in 72% of the injuries, and in 39% the cause was multifactorial.

Given the high correlation between running injuries and weekly mileage, speculation has developed about the effect of dividing total weekly distance into several shorter sessions. This was examined by Marti et al., (1988) in a subgroup of the original 4358 male joggers who participated in a popular 16 km race. The subgroup consisted of 414 runners who had similar overall running distances but who ran 2, 3 or 4 sessions per week. There was no significant difference in the incidence of injury reported across the groups of runners, suggesting that it was the overall mileage which was associated with injury occurrence.

7.2.3 Training pace

Training pace is another training factor often discussed. In one study of 1680 runners conducted over a 12 month period, usual training pace was not found to be significantly related to injury (Walter et al., 1989). In contrast, a study of 451 runners recruited through a 10,000 meter National Championship indicated that amongst those who ran faster than 8 minutes per mile, the incidence of injury was approximately 45%, increasing to 55% amongst those with a previous injury (Jacobs & Berson, 1986). Unfortunately this study did not provide information on those who ran less than 8 miles per day.

In similar studies, Macera (1992) found that running pace had no influence on the rate of injury and Powell et al. (1986) concluded that running pace was not a factor when the number of miles per week was considered.

Marti et al. (1988) found that running speed, calculated from a 16 km race time, was probably related to the incidence of injury. After adjustment for mileage, however, this association was weakened.

7.2.4 Intensity

The intensity of training was found to be significantly related to injury in a cohort study of 1680 runners (Walter et al., 1989). Evidence was produced to indicate that those running at least once a week over a distance of 8 km or more and those running all year round, had a higher risk of injury. This study generalises well to all runners, since the sample encompassed a wide range of ability, from elite, nationally ranked runners to casual, first time fun runners.

No association was found between the use of hard training days (high intensity) and running injuries in the study conducted by Walter et al. (1989). Running sprints or intervals was not related to running injuries in a study of runners in the 10,000 meter National Championship in New York (Jacobs & Berson, 1986). In this same study, 33% of the injured runners had changed their training techniques or running shoes prior to their injury.

7.2.5 Hill running

Hill running, as a training technique, has often been believed to be associated with running injuries. No correlation was found, however, between the occurrence of running injuries and hill work in a study of entrants in a 10,000 meter race (Jacobs & Berson, 1986). Support for this finding comes from a cohort study of 1680 participants of a community road race (Walter et al., 1989). In this study, no significant association between the amount of hill work used during training and the incidence of injury was reported.

7.2.6 Prevention

To prevent training errors, van Mechelen (1992) recommended that training should be built up gradually. Alternate days for running should be suggested for beginning runners, and running speeds should be such that the runner can speak without being short of breath.

Stamford (1984) suggested that a runner should train at one half the distance they plan to race. If a runner wants to increase their mileage, this should be achieved as a gradual process over several weeks to remain injury free. Stamford (1984) also suggested that increasing mileage, should not exceed 10% per week.

7.2.7 Recommendations for futher research, development and implementation

Taken together these studies suggest the following areas requiring further attention:

- Runners should undergo a graduated running progression, guided by initial fitness testing results.
- Simple fitness testing prior to amateur running competition to ensure fitness for competition should be conducted. For instance, a 20m shuttle run score is easily and (relatively) safely obtained, and could be used as one criterion for admission to a competition or training programme, or for determining level of participation.
- Appropriate education and monitoring of runners regarding nutritional and hydration demands of running, particularly as intensity increases with a training programme, and particularly emphasising complex carbohydrate intake should be conducted.
- A study should be conducted to determine the maximum distance that should be run by runners of specific characteristics eg. recreational. This needs to take into account differences in individual goals and abilities.
- Recreational runners should not run excessive distance per week if fitness is the overall goal, running could be interspersed with other activities.
- Runners should consider some form of cross-training (e.g. bicycling) to improve their fitness levels and remain injury free.
- Running speeds and distances should be built-up gradually.
- More research is needed to determine the threshold levels of the various training factors under which runners are likely to remain injury free.
- A campaign aimed at increasing runners' awareness of the injury consequences of training errors should be developed and promoted.

7.3 RUNNING ENVIRONMENT

7.3.1 Rationale and background

Running takes place predominantly in an outdoor environment. It is not surprising, therefore, that the runner is influenced by factors such as running surface, terrain and weather.

7.3.2 Running surface

Running surfaces can vary from sand to concrete. As the impact forces from the gait cycle can be two to three times body weight, it is generally believed that running on hard surfaces increases mechanical shock thereby overloading joints and tendons. Soft surfaces quickly tire the muscles and are thought to increase injury (van Mechelen, 1992), particularly overuse injuries. The ideal running surface is flat, smooth, soft and resilient to running (van Mechelen, 1992). Running surfaces such as soft sand, cement, or other hard rigid surfaces should be avoided. Also of importance to running surface is the possibility of potholes, tree roots and stones, which may cause severe injury if they cause the runner to slip, trip or fall. Of course well designed running shoes are important for all running surfaces.

A study of 451 randomly selected entrants to a 10,000 meter National Championship did not find any correlation between running surface and running injury. However, since the majority of participants (89%) in the study ran on hard surfaces such as concrete or asphalt, it may have been difficult to detect any effect (Jacobs & Berson, 1986).

Brunet and Cook (1990) supported this finding when investigating a population of 1505 competitive and recreational runners. While this investigation used a method of self-report multiple choice questionnaires, it found that there was no significant association between running surface (asphalt and concrete) and running injury, although it did report that higher mileage runners were found to run primarily on asphalt.

Further support can be found in a retrospective survey of running practices and orthopaedic injuries conducted on 438 men and women who ran approximately 25 miles per week (Blair et al., 1987). The type of surface (synthetic polyurethane or pavement) the runner ran on was not significantly associated with injury (Blair et al., 1987).

A study involving a good sample, encompassing a wide range of ability including runners from elite, nationally ranked runners to casual, first time fun runners was conducted by Walter et al. (1989). In this investigation, of a cohort of 1680 runners enrolled in two community road races. Over a 12 month follow up period, no significant differences between running on concrete, asphalt, grass or dirt was found in relation to the incidence of injury. However, 10% of those injured stated that their injury was a result of running on a slippery surface.

Another study which involved 4,358 male participants in a 16 km road race, supported this finding (Marti et al., 1988). When investigating predominantly hard, predominantly natural or a combination of running surfaces, no advantage or disadvantage in running surface was detected. The observed slight differences could be explained by differences in weekly mileage. This study, however, was based on a male population and was not therefore representative of the running population as a whole.

The issue of gender is particularly important when considering the results of a one year prospective study of 485 entrants in a 16 km run (Macera et al., 1989). This study found that women had a five times greater risk of injury when running on concrete versus other surfaces, even when mileage was controlled for. For males, however, the running surface did not seem to increase the risk of injury when weekly mileage was controlled for. This finding has not been verified in other studies, and may well reflect other characteristics which place women who run on concrete at a higher risk of injury (refer Section 9).

A number of studies on the specific occurrence of injuries related to the environment reviewed in van Mechelen (1992) have found that running on hard surfaces may contribute to stress fractures (Jackson & Matz, 1986; Hulkko & Orava 1987; Rzonca & Baylis, 1988), Achilles tendinitis (Winter & Bishop, 1992. Nicholos, 1989) and plantar fasciitis (Warren, 1990). Overall, van Mechelen's (1992) review of the literature led him to concluded that running on hard surfaces was not significantly related to running injuries. It has also been speculated that running on sand may be related to injuries such as Achilles tendinitis (Rzonca & Baylis, 1988) and plantar fasciitis (Warren, 1990).

Grounds management is an essential component of providing a safe sporting environment. All grounds, particularly the track surfaces, should be checked for dangerous items such as glass, syringes and gardening tools, prior to each Little Athletics meeting. At present there are no regulations for checking the surface of the running area for objects which may lead to injury, within the Australian Little Athletics Association. There are, however, regulations about the track layout with reference to the width of lanes, boarders and markings. Recently, the Victorian Little Athletics Association has suggested the provision of needle stick bins at grounds to reduce the likelihood of needle stick injuries from syringes left on the ground (Vincent, 1996).

7.3.3 Running terrain

Another environmental consideration is the terrain, which can often be slanted or uneven. Running on a cambered (slanted) road may increase the risk of injury because of the gait asymmetry created (i.e. lack of balance in the style or manner of running). On a slanted road the uphill foot must pronate (i.e. roll in the foot) more, which imposes a change in running pattern. A change in running pattern, excessive pronation (excessive rolling in of the foot) and impact forces are considered factors which could lead to injury.

Bovens et al. (1989) studied the occurrence of running-related injuries, in a supervised training program group of 115 volunteers who had little or no running experience. Their results showed that injuries to the lower leg and Achilles tendon were significantly more localised on the left hand side. The authors suggested that this could be explained by the unequal load of the leg caused by the cambered (sloped) surface of the street. This hypothesis, however, has not been proven. Furthermore, it is not clear if the left lower leg or the Achilles tendon is more sensitive to injury or if athletes ran on one side of the road for safety reasons. This study was based on a very small sample who had little or no running experience, therefore, may not truly represent the general running population.

A cohort of 1680 participants in two community road races encompassing a wide range of running ability was conducted by Walter et al. (1989). This investigation found that 33% of those injured in the previous 12 months had sustained their injury as a result of running on a uneven surface.

In contrast, an epidemiological study of 438 participants who ran approximately 25 miles per week reported that running terrain (flat or combination) was not significantly associated with injury (Blair et al., 1987). This result must be treated with caution, however, as only 1% of the participants reported running on hills. This meant that hill runners were grouped with combination runners in the analyses. This study highlights the fact that despite the size of an overall study population, numbers in subgroups may often be small and thus subgroup analysis must be interpreted with caution.

7.3.4 Temperature

Extremes in temperature are a frequent adjunct to outdoor running. Consequently, the weather becomes a pertinent factor in the risk of injury. Temperature affects both bodily function as well as environmental factors, such as running surface.

Running in a hot environment increases the risk of heat exhaustion, heatstroke, and dehydration (Brodeur et al., 1989; Lee & Bishop., 1990). Likewise, a runner can experience frostbite or hypothermia if running in extremely cold temperatures without taking precautionary steps.

Also requiring consideration is the running surface in different climates. Powell et al. (1986) suggested that climatic circumstances such as snow, may lead to more injuries since they can make running surfaces slippery.

Walter et al. (1989) investigated a cohort of 1680 runners enrolled in two community road races over a 12 month follow up period. Ten percent of those injured twelve months prior to the survey stated that their injury was the result of running on a slippery surface. This slippery surface, although not so indicated, may have been a result of cold climatic conditions (ie. rain).

No further specific evidence of preventive measures related to climate and running injuries was identified in the literature. Suggestions for injury prevention have been based on general recommendations relating to thermoregulation, such as wearing appropriate clothing, using sunscreens, maintaining hydration and undergoing acclimatisation (American College of Sports Medicine, 1987; Ting, 1991; Cross, 1993; van Mechelen, 1992; Vincent, 1996).

Event management has also been stressed and this includes not planning events at times when environmental stresses are most likely to occur or cancelling the event if they do occur.

The Australian Little Athletics Association has no specific regulations concerning competition at high temperatures, where heat exhaustion is most likely to occur. Activities at Little Athletic Centres, however, are scheduled for early morning and/or late afternoon during Summer/Autumn when temperature problems are not such an issue. At Championships when competition runs all day, as much shade as possible is provided and longer distance events are normally scheduled during the cooler parts of the day.

Ultraviolet protection is heavily promoted by the Australian Little Athletics Association. Children are recommended to wear a suitable hat at all times, which may be removed during competition. Parents and the children themselves, are also recommended to apply SPF 15+ and water-resistant broad spectrum sunscreen to all exposed skin every 2 hours (Vincent, 1996). It is also recommended that children wear sleeved clothing to protect them from the sun when they are not competing.

7.3.5 Rationale for futher research, development and implementation

Based on these studies, and consultation with experts in the field, the following recommendations can be made:

- More research into the role of running terrain is required to assess the impact of gait asymmetry on injury risk.
- Running tracks should be regularly checked for hazards such as potholes, loose debris, rubbish etc and frequently maintained.
- Track surfaces should be checked before each meeting for dangerous objects (eg broken glass, used syringes, etc)
- Runners should avoid soft sand, concrete or other hard rigid surfaces.
- Runners should avoid slippery surfaces such as can occur during wet, cold weather.
- If runners, particularly long-distance runners, are planning to run in events likely to be conducted when it is hot or humid, they should undergo a process of acclimatisation.
- Running events should not be planned for times when there is a likelihood of hot, humid conditions. Whenever possible, such events should be cancelled if such weather conditions eventuate.
- Drinking water should be provided at all running events, club meetings and competitions.
- Runners should ensure they drink adequate water.
- Runners should wear appropriate clothing when running and not run bare topped.
- Runners should always use a broad spectrum sunscreen and wear a hat and/or sunglasses if appropriate.

7.4 CORRECTION OF RUNNING STYLES

7.4.1 Rationale and background

Each runner has their own running style, based on both natural and acquired habits. The style of running consists of six elements: the overall action, body angle, arm swing, foot placement, rear leg lift, and length of stride (Subotnick, 1985). Given the large number of elements involved in running, it is obvious that each person’s running style is different. Sometimes a runner’s style will change to protect a previous injury site from further damage. Correction of style is a complex matter which needs to be treated on an individual basis. Unfortunately, correction to running style may not be treated simply. Problems of malalignment (i.e. leg length differences) may often be an underlying cause of style and the use of orthoses is required to correct this. An orthoses is a device, inserted into the shoe to support, align, prevent or correct deformities/malalignments or to improve walking or running function. The use of orthotics are discussed in more detail in Section 7.5.3

7.4.2 Evidence for the effectiveness of correcting running style

In a review of the literature on running shoes and their relationship to running injuries, Cook et al. (1990) found that poor running technique was one of the major causes of running injuries. The authors concluded that running was a complex matter since each unique technique leads to different stresses on a variety of tissues. In other words, one part of the body will work harder to compensate for another.

Support for this statement was also provided by Williams (1995) during the Techniques in Athletics Conference, 1990. The basis of his findings came from work done over five years with two organisations: the US Olympic Committee and the Athletics Congress. Williams' presentation indicated that there was no ideal running style, although it was believed that imperfections in running style should be corrected to optimise performance. An individual's running style can be evaluated in relation to data for other runners if it is done superficially. More importantly, it should be evaluated in relation to his/her own body for maximum effectiveness. William's (1995) work, however, was based on a relatively small sample of 46 elite male and 48 elite female runners. As a result, generalisation to a population of runners should be made with caution. It is also of relevance to note that runners with problems with running style would probably not be found amongst a group of elite athletes because poor technique may have prevented them from reaching this level, or this may already have been corrected.

While running technique is an individual matter, the "Orientation to coaching" course for Little Athletics gives some guidelines on aiding technique in the developing child (Table 9). Sprint activities can be many and varied. It is important, even from an early age, that the correct technique is emphasised (Australian Track and Field Coaches Association, undated).

Table 9: Technique in sprinting

1. Light quick movements
2. Upright carriage of the head and trunk
3. Movement of the feet and limbs in a straight path
4. Use of short arm levers, picoting about the shoulder joint
5. A high pick-up of the leading thigh
6. An extension of the support leg
7. Running 'tall' and with 'high hips'
8. A slightly forward inclination of the trunk
9. Relaxation throughout

Source: (Australian Track and Field Coaches Association, undated)

Technique is also emphasised as an important aspect of the middle distance runner's success. The "Orientation to coaching" course gives the following guidelines on technique for the middle distance runner (Australian Track and Field Coaches Association, undated)"

1. "Style is an individual's concern. Provided an individual can maximise speed, rhythm, balance and general comfort with the least amount of energy expenditure then the best style for the individual has been achieved.

2. Balance - athletes should be relaxed with eyes looking straight ahead approximately 10-20 meters. Chest, abdomen and hips should be kept square to the front with only a little shoulder movement.
3. Arm action - carried low with hands lightly clenched. Arms balance the body and determine leg speed. The faster the arms go, the faster the legs will go. Hands should just cross the body, with little movement of the shoulders.
4. Leg action - knee lift is lower than that when sprinting. Normally in distance running, foot contact will be made around the mid sole-heel area of the foot, and towards the outside edge.
5. Rhythm must be maintained not only during each stride, but also throughout the race. Any change or break in rhythm leads to greater fatigue".

7.4.3 Recommendations for futher research, development and implementation

There has been little research into the role of correcting running styles in injury prevention. Two sources provided anecdotal or informed opinion on this subject and a further study presented data-based evidence.

Taken together these studies suggest some areas requiring further attention:

- More research is needed to demonstrate the relationship between running style imperfections and injury risk.
- Research into the role of malalignment of the lower limbs in injury causation is needed.
- Studies to determine whether correction of running style leads to injury reduction should be conducted.
- Sporting organisations should continue to promote and teach correct running techniques.

7.5 RUNNING FOOTWEAR

7.5.1 Rationale and background

As discussed previously, the process of running involves the gait cycle and this cycle can produce ground reaction forces of two to three times the runner's own body weight. The impact forces must be dissipated by the body, and it is generally accepted that these forces contribute to the occurrence of running injuries. Epidemiological evidence has indicated that 70-80% of all running injuries are located from the knee downwards (van Mechelen, 1992). The logical approach to prevent these injuries would, therefore, be to attenuate the impact forces - for example by using shock absorbing shoes, shoe inlay orthoses or even good socks (van Mechelen, 1995).

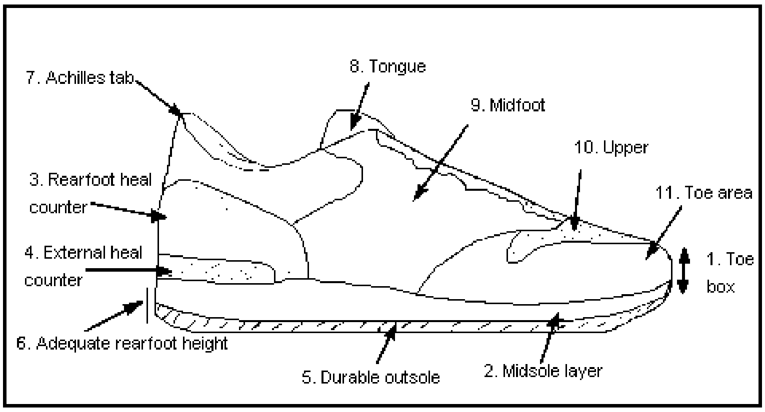
7.5.2 Running shoe design

There are hundreds of pairs of running shoes, produced by various manufacturers in a range of colours and prices, in stores today. One thing remains clear however. When a runner selects a shoe it must provide cushioning, support and stability, and must maintain reasonable flexibility, softness, and lightness (Cook et al., 1990).

Marti et al. (1988) studied 4,358 male joggers involved in a popular 16 km race by means of a survey questionnaire designed to investigate the incidence, site, and nature of jogging injuries. On average, runners were found to choose their shoes according to recommended criteria such as “proper orthopaedic construction” and “proper fit and comfort”. Other factors such as “look” or “price” were not significant factors in their choice. Runners, in general, hold this opinion because of strong advertising campaigns by manufactures and retailers. For example, the Athletes Foot chain of stores, uses slogans such as “choosing the wrong running shoe can affect more than your feet”. Other influences may be attributed to a variety of literature (journals, books, magazines, newspapers, etc.).

From a general review of the literature on the prevention of injuries in sport, Cross (1993) concluded that correct, suitable and safe footwear plays an important role in injury prevention. Figure 4 describes the key features of a running shoe. Cross (1993) also argued that an athlete’s footwear must be able to absorb shock, while maintaining enough stability to prevent excessive pronation (rolling in of the foot). The material of the midsole cannot be too heavy or too inflexible, but must still provide much of the shock absorption. As a result of taking these factors into consideration, shoes are now designed with gel or air inserts in the midsole in order to provide lighter, yet efficient, shock absorption qualities. Traction in wet and slippery conditions requires a good tread pattern on the outer sole of the shoe. The inner sole should be comfortable, cupping the normal heel contour (the rigid material within the counter) during landing and supporting the arch of the foot. The toe box of the shoe should leave sufficient room for foot movement, particularly when running down steep inclines. Blisters, corns, loss of toenails, and so on, can be the result of a too tight fit. It is also important that the material used in manufacturing sports shoes allows the feet to breathe, thus reducing moisture and helping prevent blisters (Cross, 1993).

Figure 4: Anatomy of a running shoe



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Pronation (rolling in of the foot) is a natural function of weight bearing exercise. Excessive pronation, however, is a problem often associated with lower limb overuse injuries, including plantar faciitis, Achilles tendinitis, shin splints and runner's knee. Greater stability of the foot can help prevent hyperpronation (excessive rolling of the foot). This is achieved in shoe design by including a heel counter (a rigid material within the exterior wrap around the heel) that is firmly connected to the midsole. This wedges the midsole and is made with materials of greater consistency (firmness) than those on the lateral side (away from the midline) (Cross, 1993).

Cook et al. (1990) pointed out that all running shoes lose between 30-50% of their shock-absorbing characteristics after about 400 km of running. Excessive wear on the sole must therefore be avoided. This is particularly important at the outer edge of the heel because, when excessive wear occurs, imbalances of the shoe due to excessive wearing result in abnormal stresses transmitted to the foot and lower extremity during heel strike (Cook et al., 1990).

It is generally believed that the potential etiological factors of impact forces and foot pronation, can be influenced by the sport shoe (Cook et al., 1990). The corollary to this is that shoe design can be used to prevent injury. An understanding that poor shoes may contribute to running-related injuries has lead manufacturers to design shoes with added stability and motion control, through the use of various components. In a review of the literature focusing on running injuries related to footwear, however, Cook et al. (1990) indicated that mechanically tested shoes of various brands and prices showed no difference in their ability to absorb shock. The implication of this is that the price of shoes may not directly reflect their quality.

In an study of 4358 male runners, taking part in a 16 km race, no difference in the incidence of injury was found between runners preferring any one of the three most popular running shoes (i.e. Adidas, Puma, Nike). Of note is the finding that only a small percentage wore inexpensive shoes (3%). Runners having no preference for any brand of shoes sustained significantly fewer injuries than runners who had a preference for a specific brand. The authors concluded that no particular shoe has a preventive advantage over other brand names (Marti et al., 1988). Runners wearing inexpensive shoes did not sustain more injuries whereas runners wearing expensive shoes sustained significantly more injuries. A likely explanation, put forward by Marti et al. (1988) is that injury prone runners or high mileage runners choose to wear expensive shoes. Also, the small number of runners with inexpensive shoes may have made a statistical comparison difficult.

This study reinforced the finding of a case-control study of runners with and without injury conducted by McQuade (1986). This study surveyed 214 runners with regard to the brand type of shoe they wore. Of the running shoes worn, those wearing "New Balance" shoes had a greater proportion of wearers reporting some pain or injury related to running in the last two years. Conversely runners who wore "Etonics" shoes, had a greater proportion of wearers in the no pain group. This finding correlated with the authors clinical observations that during the study period, "New Balance" shoes seemed to break down quicker than other shoes and tended to have poor pronation control. The "Etonics" shoes were generally found to have good motion control properties. It is difficult, however, to assess the generalisability of these findings to other runners, as there was no evidence of how participants were recruited into the study.

Williams (1990), investigated 46 male and 48 female elite runners in conjunction with the United States Olympic Committee and the Athletics Congress. He found that injuries often occurred shortly after the runners began intense interval training or track work in either lightweight racing shoes or running spikes. The combination of the body not having yet adapted to the higher than usual forces associated with the intense training, coupled with a lack of cushioning on the part of the footwear may have been directly related to the incidence of injury (Williams, 1990).

It seems evident that a training shoe providing cushioning, support and stability can play an important role in shock absorption, and as a consequence injury prevention (Cook et al. 1990). However, there is also evidence which suggests that modern running shoes provide poor protection from running injuries and may cause chronic overloading (Robins and Gouw, 1990). The question still remains, therefore, as to whether running shoes reduce the risk of injury.

A cohort study of 1680 runners from two community road race events was conducted by Walter et al. (1989). The runners were monitored during a twelve month follow up period, for the occurrence of musculoskeletal injuries. Runners owning two or more pairs of running shoes had a 50% increased risk of injury, compared to those with fewer pairs of shoes. The physical characteristics of the shoes (varus wedge, waffle sole, wear patterns, or personal shoe repairs) could not be related either positively or negatively to risk. The observed effect, therefore, may be associated more with the greater levels of training of those owning more running shoes.

Robbins and Gouw (1991) investigated twenty male subjects from a university population, to examine how plantar tactile events (i.e. when the sole of the foot touches the ground) affect perceived sole discomfort. They found that people who performed activities involving high impact footwear, currently promoted as offering protection in this environment, are at high risk for injury. In the natural situation (i.e. barefoot and natural surfaces) the impact is sensed and, through impact moderating behaviour, is maintained at a safe level. An inadequate understanding of the physiology of human impact control has resulted in footwear which makes chronic overloading inevitable, by providing plantar comfort to the wearer, even when enormous vertical impacts are experienced. These observations are based on the results of laboratory tests, which may not necessarily be representative of a runners environment.

The effects of shoes on the torsion (twisting) and rearfoot motion in running was investigated by Stacoff et al. (1991). A very small sample of nine male subjects were used for this laboratory based study. When running with forefoot touchdown (i.e. with the front part of the foot touching the ground first) at a running speed of 5.3-6.1 ms^{-1}, the following results were obtained for left and right touchdown running with running shoes, with spikes and barefoot. Most torsion (twisting) and the least pronation took place when running barefoot. Torsional shoe sole stiffness seems to play an important role during the touchdown phase in running. In order to decrease pronation and the risk of injury, running shoes may be improved with respect to their torsional stiffness and spikes may be improved with respect to their rearfoot construction. There is still a need to conduct more research into running shoe design.

All child athletes competing in Little Athletics are required to wear suitable shoes as foot covering. The extent to which this is enforced, however, is unclear. Spikes are permitted to be worn by all U12-U15 year old athletes in certain events (Table 10), except where this contravenes any rule of the Organising Body and/or venue with regard to the wearing of spikes (Victorian Little Athletics, 1996). Misuse of spikes by the athlete will be referred by officials to the Chief Referee and may result in disqualification of the athlete or team from further participation in that event (Victorian Little Athletics, 1996).

Table 10: Regulations regarding the use of spikes in Little Athletics

Event	Distance
Track	70m, 100m, 200m, 400m, 60mH, 80mH, 90mH, 100mH, 300mH
Relays	All events, except for the U12 child in the U9-12 mixed age medley

Source: Victorian Little Athletics (1996)

The Little Athletic Association gives all persons aged 15 years and over the opportunity to participate in an Athletics "Orientation to Coaching" course. This course emphasises that one of the key points for safety is that athletes wear suitable footwear. It further indicates that ill fitting and/or non-shock absorbing footwear can lead to both immediate and long term problems (Australian Track and Field Coaches Association, undated).

7.5.3 Orthotics

The use of orthotics to balance the feet in unidirectional and multidirectional sports was introduced after it was observed that small imbalances may have a significant effect on the athlete because of the increased forces of running (Subotnick, 1985). Imbalances often refer to the degree to which one pronates (rolling in of the ankle). Given that everyone pronates to some degree it is the excessive or insufficient pronation that causes problems (Simpson, 1996).

The scientific basis for the use of biomechanical foot orthoses in the treatment of lower limb sports injuries was reviewed by Kilmartin and Wallace (1994). These authors concluded that the biomechanical orthoses will reduce rearfoot movement, but the effect on the knee function is negligible and the clinical significance of excessive rearfoot movement has not yet been proven to positively reduce injury or aid in treatment.

In an attempt to analyse the causes of prospectively registered running injuries retrospectively, Lysholm and Wiklander (1987) found that malalignment was at least one of the factors causing injury in 40% of the cases. Malalignment in this study included foot in-sufficiency, lower extremity muscle stiffness, genu varum (bow leggedness) and high Q-angle (the angle formed between the patella, femur and tibia). The epidemiological study of Walter et al. (1989) is the only study which conducted a baseline physical assessment of the lower extremity. None of the measured variables: femoral neck anteversion (i.e., tipping forward of the femur-thigh bone), pelvic obliquity (i.e., slanting of the pelvis), knee and patella alignment and rear foot valgus (ie. bending outwards) were significantly associated with running injuries. From these scarce and contradictory results, the importance of malalignment as a cause of running injuries is still not clear. However, as stated by Powell et al. (1986), the hypothesis that structural abnormalities are a risk factor for running injuries is too reasonable to deny.

A review of the literature found that many alignment defects were found to be associated with overuse running injuries, for example: differences in leg length, femoral anteversion (tipping forward of the femur); knee anomalies, (i.e. knocked knees or bow legs and too large or too small patella); and foot abnormalities, such as varus (bending inwards) and valgus (bending outwards) of the heel or rear foot, flat feet and high arches (van Mechelen, 1992). All of these are readily treatable with properly constructed orthotics.

In contrast, O'Toole (1992) in a review of the literature established that less than 20% of all injuries can be directly related to structural abnormalities. He stated that foot orthotics are also believed to prevent excessive pronation and as a result may decrease the incidence of injury. It has been previously stated that the use of orthotic devices is capable of correcting minimal alignment abnormalities, in this way creating normal running conditions (van Mechelen, 1992).

Marti et al. (1988) used a survey questionnaire design to investigate the incidence, site and nature of jogging injuries among 4,358 male runners participating in a 16 km race. The use of orthotics to correct alignment abnormalities, thus creating normal biomechanically optimal running conditions, could not be tested. This was because an increased use of orthotics within the sample was positively correlated with both a history of previous injury and with more frequent running-related injuries during the 12 month study period.

The effectiveness of orthotic shoe inserts in the long distance runner was investigated in a population of 347 male and female runners currently using orthotics for symptomatic relief of lower extremity complaints (Gross & Davlin, 1991). Of the runners responding, 76% reported complete cure or great improvement of their injury, while 90% continued to use their orthotics after the injury had gone. Orthotics were found to be most effective in the treatment of symptoms arising from biomechanical abnormalities, such as excessive pronation or leg length discrepancies. This study had the benefit of being undertaken in a clinical setting. Biases may have resulted, however, as the survey was distributed at racing events and therefore only certain types of runners were represented. For example, runners unable to continue running due to treatment failure, would not have been present at the survey site. Also, those with malalignments may not compete at this level due to structural abnormalities preventing them from progressing to a more advanced level.

Donatelli et al. (1988) studied 81 subjects who had worn orthoses for a period ranging from three months to two years. Fifty-three subjects participated in a questionnaire evaluation of their progress with orthoses. Relief from pain was reported by 96%, while 52% of respondents said they would not leave home without the orthoses in their shoes (Kilmartin & Wallace, 1994). Axe and Ray (1988), used biomechanical orthoses in the treatment of ten athletes with resistant sesamoiditis (i.e. a small bone embedded in a tendon or joint capsule). While eight of the subjects had undergone a variety of previous treatments including cortisone injections, metatarsal padding and below knee casting, symptoms had persisted. Once the biomechanical orthoses were prescribed no further practices or competitions were missed by any of the athletes and at 18 month follow up, eight of the ten subjects had sufficient symptom relief that surgical excision of the sesamoids could be avoided (Kilmartin & Wallace, 1994).

The prevention of common overuse injuries by the use of shock absorbing insoles was investigated by Schwellnus et al. (1990) in a sample of 237 randomly selected army recruits fitted with orthotics, and a further 1151 recruits as a control group. A total of 54 (22.8%) and 237 (31.9%) injuries were reported in the experimental and control groups respectively. The majority of these injuries were overuse in nature (experimental group 90.7% and control group

86.4%). The mean weekly incidence of total overuse injuries and tibial stress syndrome injuries was significantly lower in the experimental group. The mean incidence of stress fractures was lower in the experimental group but not significantly so. This study suggests that the incidence of total overuse injuries and tibial stress syndrome during nine weeks of basic military training can be reduced by wearing insoles.

Supporting this finding, Gardner et al. (1988) conducted a twelve week prospective study of 3025 marine recruits to study the effects of insoles and the age of running shoes on the incidence of stress fractures. There was no significant difference in the incidence of stress fractures between recruits wearing polymer or standard insoles.

In these studies, it is often not evident whether the tested strategies for impact reduction were ineffective because their cushioning was minimal or whether the injuries reported resulted from factors other than the impact forces. Alternatively the study groups may have provided a poor representation of the running population (Gardner et al., 1988; Schwellnus et al., 1990).

An overview of the treatment of lower extremity injuries with orthotic shoe inserts indicated that they are an effective way of providing symptomatic relief of lower extremity complaints in running athletes (Gross & Napoli, 1993). Inserts adjust the biomechanical variables associated with running injuries and reduce the effect of high stresses produced by running activities. Successful treatment with orthotic shoe inserts is dependent on careful evaluation of the runner and formulation of a properly fitted orthosis. When correctly utilised, orthotic shoe inserts are beneficial for a broad range of disorders experienced by runners. Problems relating to prolonged pronation are most amenable to orthotic treatment. Finally, it needs to be remembered that orthotics are only one facet in the overall treatment plan for injured runners (Gross & Napoli, 1993).

7.5.4 Running socks

Blistering of the feet is common among runners. Sequela of friction blisters of the feet can lead to compromise of individual performance, local infection and can progress to septicemia (Richie, 1993).

In a presentation to the 1993 Annual Conference in Sports Medicine, Richie (1993) stated that in order to reduce potentially damaging shearing forces, a protective material must be interfaced between the pedal skin (i.e. foot skin) and shoe surface. Moisture (perspiration) is a significant secondary factor contributing to blistering of the feet of humans. A sock can reduce moisture against the surface of the skin by either absorbing or wicking moisture (that is drawing it out e.g. by a gauze) from the skin surface and moving the moisture through the fibre framework of the sock to the shoe upper.

Richie (1993) also presented material from three studies designed to determine the effect of sock fibre composition and density of padding on the formation of friction blister sequelae in running athletes. The first study involved 457 runners who completed a 26.2 mile course wearing randomly assigned popular brands of socks. Three hundred and fifty five blisters were recorded. No significant difference could be found between any of the seven popular brand socks in terms of blister frequency or size. The heavily padded socks, however, had a significantly reduced severity of blistering compared with other socks.

The second study involved a double blind investigation of a relatively small sample of 35 long distance runners completing over 800 run trials. This study compared 100% cotton fibre socks with 100% acrylic fibre socks in a patented padded construction. A significant difference in blistering rate was found between cotton and acrylic. The results showed that acrylic fibre socks were associated with fewer, smaller blisters and less severe blisters when compared to cotton fibre socks.

Richie's (1993) third study was conducted on a generic cushioned sole running sock to identify any superiority of acrylic over cotton. Fifty runners completed over 1000 run trials. No superiority of either cotton or acrylic in terms of reduced blistering frequency or severity was demonstrated. Richie concluded that acrylic fibre socks are superior to cotton fibre socks only when the fibres are arranged in dense padding under the key shearing stress areas of the foot.

These studies of sock composition are based on relatively small sample groups, which may not be representative of the population as a whole. Also of consideration is the fact that no attempt was made in these studies to control for the runners' personal training habits, surface or regime, which are all factors that can contribute to blisters. Shoe fit and condition of the shoes was only controlled to the extent that proper fit and condition of the shoes to be used were confirmed at the time of sock assignment. The studies, also did not investigate the effect of environmental temperature. They did, however, eliminate runners with intrinsic structural or mechanical problems that may contribute to blister formation. The attempt to replicate these results was also not clear in the outcome and as a result these findings should be considered with caution.

7.5.5 Recommendations for further research, development and implementation

Taken together these studies suggest some areas requiring further attention:

- Purchasers of running shoes should be encouraged to look for certain characteristics of shoes and not to be unduly influenced by price.
- Runners should choose their shoes carefully, preferably with professional advice.
- Further research is needed to adjust for confounding factors such as previous injury when looking at the relationship between shoe design and injury.
- Development of shoes to overcome the relatively short life of shoes, in terms of their impact absorption, should be investigated.
- Runners with potential biomechanical abnormalities (eg leg length discrepancies) should have these assessed and treated by a professional who can recommend corrective actions.
- Ongoing development of orthotic devices needs to continue.

7.6 TREATMENT AND REHABILITATION

7.6.1 Rationale and background

A previously sustained running injury is consistently reported as a strong predictor of another running injury occurring (van Mechelen, 1992). In other words, many injuries are re-injuries or aggravation of a pre-existing injury. In a twelve month cohort study of 1690 runners, Walter et al. (1989) found that forty eight percent of runners experienced as least one injury. Fifty four percent of these were new injuries and the remainder were recurrences of previous injuries. In a similar study of 4358 male runners participating in a 16 km race, Marti et al. (1988), found a 74% increased risk of injury amongst runners with a history of previous injury, compared to those without a history. Runners with a history of previous running injuries trained one third more than runners without such a history; even when adjusted for these differences, the increased risk associated with prior injuries was still 65%.

According to Powell et al. (1986), a runner with a previous injury may be more likely to be injured again because the original cause remains, the repair of tissue may function less well or be less protective than the original tissue; or the injury may not have healed completely. This leads to the conclusion that complete and controlled rehabilitation of an injury needs to be achieved, and sensible preventive precautions taken, before the person begins to run again. This procedure may involve, RICER (rest, ice, compression, elevation and referral), taping or bracing, and general rehabilitation. However, the causes of running injuries are so multifactorial and diverse that any specific single measure proposed would probably be of help to only a small minority of runners (Marti et al., 1988). It is likely, therefore, that a combination of preventive procedures may need to be administered. Overall, the treatment goals are pain relief, promotion of healing, decreased inflammation, and a return to functional and sports activities as soon as possible.

7.6.2 Sports first aid

Rest, ice, compression, elevation and referral (RICER), is a well known procedure to initially manage a running injury and thus restrict the possibility of further damage (Knight, 1985; Larkins, 1990). While this procedure is well recognised and widely used, studies indicating the benefits of the procedure, conducted within the last ten years, have been minimal. Nevertheless, it is so widely used and promoted as good first aid practice, that its effectiveness is accepted.

Hunter and Poole (1987), recommend that the treatment of acute running injuries should include rest and ice during the first 72 hours, and application of compression bandaging to reduce swelling, pain, muscle spasm, and inflammation.

Sports Medicine Australian (SMA) in its ‘Sports First Aid Course’ provides guidance on the RICER technique (National Sports Trainers Scheme, 1994). SMA identifies the benefits to be a reduction in the severity of further injury, haematoma and swelling, a reduction in the amount of tissue damage and finally a reduction in recovery time (National Sports Trainers Scheme, 1994).

Medical coverage for Little Athletics events is a requirement at both the state and national level of competition. This may include the requirement that sports trainers, physiotherapists and/or doctors be on duty. At the local level, however, these requirements vary. Medical coverage is often left to parents or associates who may or may not be accredited Sports Trainers, St John's First Aid certified, or may be medical practitioners or qualified nurses.

The Little Athletic Association gives all persons aged 15 years and over the opportunity to participate in the "Orientation Coaching Course", a 15 hour, non accredited coaching course. It highlights injury management and first aid. Again, RICE is recognised and promoted. This course also emphasises the need to ensure full restoration of function, defined as the use of stretching within the limits of comfort when pain and tenderness have almost resolved. Strengthening exercises are recommended to build up wasted muscle, which has occurred as a result of the injury. Finally, reconditioning is recommended (Australian Track and Field Coaches Association, undated).

7.6.3 Taping and bracing

Taping and bracing of a joint helps to reduce the range of movement possible at that joint. It is therefore believed to help reduce the risk or severity of injury (National Sports Trainers Scheme, 1994). Unlike some other sports, taping and bracing are rarely used as prophylactic (preventative) measures for runners. Nevertheless, they can be useful as tertiary prevention measures.

The studies looking at taping and bracing have not focused specifically on running. However, the results are relevant to the issue of taping and bracing for runners and hence, are presented here. The effect of ankle support was investigated by Karlsson and Anderson (1992) in 20 athletes with chronic lateral ankle joint instability. The results from this study suggested that taping was a beneficial measure for reducing the rate of injury, particularly re-injury. The greatest stability was obtained in ankles with the highest degree of mechanical instability before being taped. After exercise, however, the ankle tapes were generally loose, affording only limited protection. Ankle taping is not without controversy (Karlsson & Andreasson, 1992). The prophylactic value of ankle taping has been shown in only some studies, whilst others have pointed out some negative factors (Grana, 1994).

Baker (1990) suggested that prophylactic bracing not only offers little protection for knee joint ligaments but in fact may be the cause of additional injuries in that area. Strapping and bracing can effectively stabilise joints such as the thumb, elbow and ankle as these joints can normally tolerate small losses in movement without affecting function. On the other hand, they are usually ineffective measures in stabilising the knees and the shoulder for the rigours of competitive sport and limiting the function of these joints, even if assisting with proprioceptive control (knowledge of where body part is without looking).

A biomechanical evaluation of taping and bracing on the knee joint translation and rotation was conducted on five randomly selected cadaver specimens (Anderson et al., 1992). This study found that taping and bracing together produced the greatest reduction in both anterior-posterior translation and internal-external rotation, providing objective evidence of the restraining capabilities of these protective systems that may prove to be beneficial in the clinical setting. However, load levels used to test the knee laxity (weakness of supporting structures of the knee) were much lower than those levels anticipated based on in vivo experience. Furthermore, there was a lack of active muscle tension in the cadaveric model. Under normal conditions, the tension produced by muscles across the joint would be expected to decrease the displacement at a given load. The final limitation of this study was in regard to the loosening and slippage of the tape or brace. This is a common problem encountered during activity, which can decrease effectiveness. This situation was not tested and the results may therefore be overly optimistic when considering their actual clinical effectiveness.

Much of the research into the benefits of taping or bracing in sports injury prevention has been conducted in contact or fast turning sports such as football (Grana, 1994). Research specifically focusing on the repetitive actions of the runner needs to be conducted.

7.6.4 Rehabilitation

Van Mechelen (1992) concluded that the complete rehabilitation of an injured athlete should restrict the athlete from restarting activities too soon. A rehabilitation programme cannot be regarded as having been completed until the athlete is free from pain; muscle strength has returned to about the pre-injury level; and articulatory mobility (joint union movement) has recovered to pre injury level.

Often, rehabilitation needs to include the complete cessation of running for a given period of time for the injury to heal. Alternatively, it may include a reduction in the weekly running distance. Van Mechelen (1992) concluded that running injuries result in a reduction in training or training cessation in 30-90% of all injuries. A review of the literature focusing on lower extremity injuries in runners also indicated that a reduction in running distance to below 32km/week would decrease the risk of a recurring injury (Macrea, 1992).

An overview of the prevention and treatment of overuse tendon injuries, recommended that range of motion exercises would be beneficial during the acute phase of an injury to reduce swelling and maintain joint mobility during rehabilitation (Hess et al., 1989). This could be done within the confines of a compression dressing such as athletic tape or elastic bandages, which protect the injured area without restricting active movement. The authors further recommended that mobilisation should begin as early as possible to maintain the range of motion of the joint and to help decrease swelling. Exercise, in conjunction with the mobilisation, will also restore range of motion and increase strength.

Hunter and Poole (1987) believe that the application of heat or a contrast programme of heat and cold would be beneficial. The rationale for this is that heat increases the circulation and promotes healing. The contrast treatment, on the other hand increases circulation as well as decreasing swelling.

In his review, van Mechelen (1992) could not identify any studies into the effects of rehabilitation programmes with respect to running. He did note, however, that Ekstrand (1982) had demonstrated that a whole package of measures including ‘controlled rehabilitation’ can reduce the number of sports injuries in soccer.

A study of 451 entrants in a 10,000 metre National Championship race, found that of those injured, 70% sought professional medical attention for their injuries (Jacobs & Berson, 1986). The most often recommended treatment was complete rest (58%). Muscle strengthening exercises were recommended to 30% of runners, a change in training to 21%, and 20% of runners were advised to wear orthoses. Surgery was a recommended treatment in 3% of cases.

Eighty percent of injured runners who sought medical advice followed their physician's recommendations (Jacobs & Berson, 1986). Of these, 57% described the result as excellent and had returned to running with full pain relief. Only 20% of runners "complied with their doctors somewhat", while 4% "did not comply" at all. The reason given for "somewhat" or "not complying" in 75% of these cases was that the injury was improving on its own. Thirty nine percent of injured runners did not want to decrease their mileage or believed that the recommended treatment was too time consuming, while 28% had a lack of trust in their physician's advice. Of those "not complying" or "somewhat complying" only 47% reported full relief of pain, while 19% had full pain relief but with restricted distance or speed. No data were obtained, however, on the extent to which injured runners recovered if they did not consult a physician.

7.6.5 Recommendations for further research, development and implementation

Taken together these studies suggest some areas requiring further attention:

- Runners should seek prompt attention to their running injuries from a person with first aid qualifications.
- Organisers of events should ensure that there are qualified first aid personnel at all events.
- Injured runners should ensure that they allow enough time for adequate rehabilitation before returning to their pre-injury level of activity.
- Research into the effects of rehabilitation programs for runners needs to be undertaken.
- Taping or bracing of joints could be considered by professionals in their management of injuries.
- Research into the benefits of taping or bracing specifically for the repetitive actions of the runner should be undertaken.

7.7 RUNNER AND TRANSPORT COLLISIONS

One of the most obvious, yet often undiscussed causes of running injuries is collisions with various forms of transport. Many runners run on footpaths or roadways, and most need to cross roads at some point in their running session. Collisions between runners and motor vehicles are uncommon, but they do occur and may be catastrophic (Powell et al., 1986). The most effective way of preventing collisions is to separate runners and vehicles, and the provision of running tracks is an excellent way to do this.

Koplan et al. (1982) sent questionnaires to 1,250 randomly selected male and female registrants of a 10 km road race held in Atlanta, U.S.A. in 1980. Fifty five percent of the men and 58% of the women responded to the questionnaire which was distributed one year after the race. During that year, five males and four females had been hit by motor vehicles. Only one of the nine people injured was sent to hospital, and the severity of that person's injuries was not stated (Powell et al., 1986). In a ten year follow up study of the same population, 535 runners responded (326 men and 209 women). Of these, four men and two women had been hit by a car whilst running, corresponding to 1% of all runners (Koplan et al., 1995).

A cohort of 1680 runners enrolled through two community road race events and monitored during a 12 month follow up period also provided information on the risk of injury associated with motor vehicles (Walter et al., 1989). In the twelve months prior to the baseline study, eight runners had been hit by a motor vehicle whilst running.

Since both of these studies required self reporting of information, often over a long period of recall, the results may be unreliable and they may be underreporting. Also it is possible that fatal collisions may have occurred among non respondents. These studies also give no indication as to where the runners were running, such as whether it was against or with traffic and during daylight or at night.

The issue of runner and vehicle collisions is generally covered by pedestrian (i.e. person travelling by foot) safety guidelines. The Australian National Road Safety Action Plan (1996) recognises pedestrian safety as part of its ten national priority actions. A report on pedestrian safety issues in Victoria, Australia was conducted by Corben and Diamantopoulou (1996). This report found that young adults (aged 17-34 years) were the predominant pedestrian age group involved in crashes of all environment types. It is worth noting that this is also the most common age of runners. Pedestrian activity tended to be associated with strip shopping environments, other commercial/business activities, residential land use and/or public transport. Pedestrians were also found typically to use the shortest and/or quickest route to cross roads and showed a definite reluctance to walk far to use pedestrian signals or other facilities. This is a behaviour common to runners.

Corben and Diamantopoulou (1996) also outlined appropriate countermeasures for preventing pedestrian and motor vehicle collisions. These obviously also apply to protecting runners. For example, they recommended that, in a park setting, roads surrounding the area should have reduced speed limits, either by signage or speed humps. Research by McLean et al. (1994) indicates that pedestrian fatalities would be reduced by 32% if vehicle speeds could be reduced by 5 km/hr from 60 km/hr. A reduction in speed limit may also lead motor vehicle drivers to take alternative routes. Fencing and barriers could be installed to direct runners to the appropriate crossing. In a park or residential area, for aesthetic reasons, garden beds, plantar boxes or outdoor seats may provide higher levels of compliance as they appear as natural elements of the streetscape (Cobern & Diamantopoulou, 1996). Furthermore traffic signals could be placed in areas were a high volume of runners tend to cross, to prevent hazardous crossings. As a runner is easily impatient, these pedestrian signals could have a reduced time cycles.

In general settings, footpaths could be widened and street lighting improved. Median strips could also be a advantage. Kerb extension and improved street lighting would allow an increase in sight distance between the runner and the driver. Medians allow the runner to concentrate on only one direction of traffic at a time. Medians and kerbs used either together or separately are predicted to reduce pedestrian accidents by about 32% (Land Transport Safety Authority, 1996). Residential areas are often areas where a person will be found running. It is therefore recommended that traffic volumes in these areas be reduced, by restricting traffic to residential use only or installing speed humps, which often result in the driver taking an alternative route.

It should be remembered, however, that without adequate police enforcement and publicity programs some of these road safety countermeasures may not be effective (Corben & Diamantopoulou, 1996).

7.7.1 Recommendations for further research, development and implementation

- Planners and traffic engineers should continue to develop ways of preventing collisions between runners and vehicles, eg by providing more running tracks.
- Continue to educate runners and other road users about good road safety practices and enforce these.
- Traffic volumes in residential areas where people are likely to run should continue to be monitored and reduced.
- Runners should wear bright and/or reflective clothing so that they are readily noticed by motorists.
- Running shoes with reflectors, should be highly promoted for night-time runners.

8. CHILDREN

When it comes to sports performance, children must not be thought of as little adults (Stanitski, 1988). Significant differences exist between child and adult athletes, and those interested in injury prevention must understand the difference (Meyers, 1993). Growth and maturation rates in children demonstrate marked variability, along with concomitant gains in coordination and strength, flexibility, and endurance (Stanitski, 1988).

Within the same age groups, physical maturity can sometimes vary by several years (Welford, 1989). This means physical maturity is a more dominant factor in relation to injury than is chronological age. In particular, rapid growth spurts are often associated with diminished strength, agility, coordination and endurance (Backx, 1995).

It is for these reasons that when developing running competitions, injury prevention strategies for children should be considered in a separate category, despite the fact that their injuries may be attributed to many of the factors associated with adult runners (e.g. training, environment, warm-up, technique, footwear). The Australian Little Athletics Association has taken these factors into consideration and developed sporting activities (including running) appropriate for children (Vincent, 1996).

Little Athletics began in 1964, when a small number of children turned up for a few running events in Geelong, Australia. Today there is a total of 88,000 children registered in some 500 Little Athletics centres around Australia. Little Athletics offers a wide range of track and field events. For the purposes of this review, however, we have looked specifically at running events and the associated risk factors, injury prevention methods and recommendations for improvement. In summer, relays and track and field championships are popular. In winter, cross-country events are undertaken by about 15-20% of all Little Athletics participants.

Although the track and field events are not without injury, the Little Athletics Association has no formal policy relating to the prevention of sporting injuries. It does, however, promote certain regulations and recommendations governing safety and procedures to its participating centres (Vincent, 1996). These regulations are primarily aimed at championships and not the club level activities.

Regulations exist that limit the distance that Little Athletics participants of specific ages may run. This is purely for the prevention of over exertion injuries (see Table 11).

Table 11: Events conducted by the Victorian Little Athletics Association

Events	U9	U10	U11	U12	U13	U14	U15
Track events							
70m	*	*	*	*			
100m	*	*	*	*	*	*	*
200m	*	*	*	*	*	*	*
400m	*	*	*	*	*	*	*
800m	*	*	*	*	*	*	*
1500m				*	*	*	*
60mH	*	*	*				
80mH	*	*	*	*	*	* girls	
90mH						* boys	* girls
100mH							* boys
300mH				*	*	*	*
Relays							
4x100m	*	*	*	*	*	*	*
4x100m mixed	*	*	*	*	*	*	*
4x200m	*	*	*	*	*	*	*
mixed sex medley	*	*	*	*	*	*	*
medley	*	*	*	*	*	*	*
mixed age medley	#	#	#	#	+	+	+
Cross country							
1500m	*	*					
2000m			*	*			
3000m					*	*	*

Source: (Victorian Little Athletics, 1996).

(All events for boys and girls, unless stated. m=meters, mH=meter hurdles. Mixed age medley #U9-U12 and +U13-U15 compete against each other).

The Little Athletic Association gives all persons aged 15 years and over the opportunity to participate in the “Orientation to Coaching” course which aims to educate participants in what can be expected from an eight, eleven, and fourteen year olds in regard to both sprints and middle distance running. Further information regarding this can be found in the “Orientation for (Australian Track and Field Coaches Association, undated). The overriding consideration in regard to whether a child can participate in a given event, is that it must not be outside their capabilities (Vincent, 1996). This means that children with disabilities can easily be integrated into Little Athletics activities. Although most children only participate in Little Athletics on Saturday mornings, coaching and training is available for those who want it during the week. This is generally taken up by children involved in state and national championships.

The Victorian Little Athletics Association employs an Athletic Development Officer to run its school program. This is targeted at primary schools in Victoria and aims to teach children about athletics and healthy lifestyles. There is good potential for this program to promote sports safety (Vincent, 1996)

While dealing with injury prevention, the Little Athletics Association, has also considered the hard working volunteers who lift, push, pull and carry heavy equipment on and off the field. The

Association has developed a brochure to introduce safe manual handling techniques, which it is hoped will help prevent injuries.

Asthma is a common medical condition experienced by up to 20% of adolescents and children. The Little Athletics Association has a particular concern with asthma, as some asthma suffers will suffer from what is termed exercise induced asthma. As a result, information regarding prevention and treatment is well publicised through the association, aiding the child, the parent and those assisting with the athletic activities.

Finally, children should equate sport with happiness without fear of getting hurt (Kennedy & Fitzgerald, undated). Therefore good safety regulations and adequate training programs need to be developed. The activities of the Little Athletics Association should be recognised as providing much of the progress in this area.

8.1 Recommendations for further research, development and implementation

- Safety regulations and adequate training programs specifically for children need to be developed and implemented.
- Continue to support the activities of the Little Athletics Association for organised running events for children.
- Provide up-to-date information to the Little Athletics Association to inform them of the latest progress in injury prevention and to support their activities.
- School running programs should include more information about injury prevention.

9. WOMEN

Over the last several decades, there has been an increase in the number of women participating in many sports. Coinciding with this has been an increase in the recognition of their ability and needs as athletes. There are factors present in the female athlete which can increase their risk of injury above that of their male counterparts. The following sections review issues relating specifically to female runners.

9.1 Anaemia

Iron is contained in the haemoglobin molecule of the red blood cells and is necessary for oxygen transport. A normal iron level is especially important in runners, where maximal carrying capacity is needed for maximal energy output (Griffin, 1993). Women are more at risk of developing anaemia than men, due to iron lost via the menstrual cycle, along with strenuous exercise which may further increase their risk by increasing iron loss (through increased destruction of blood cells, and increased losses in sweat, faeces and urine), and perhaps reduced iron absorption (Australian Sports Medicine Federation, undated). Runners may also have a low dietary intake of iron, as many runners tend to be weight conscious and to follow extreme dietary practices (Larkins, 1990).

If a menstruating female runner does not include 18mg of iron in her diet (recommended daily allowance), treatment is recommended (Griffin, 1993). Treatment often involves the addition of iron supplements, however, a successful management plan should also be undertaken to modify excessive iron loses and improve dietary intake (Griffin, 1993). Good sources of iron include lean red meat, poultry, fish, legumes, green leafy vegetables and wholegrain cereals (Larkins, 1990). Dietary disturbances are common in female athletes and are a concern (Bennell, 1996c). It is not clear whether running larger distances pre-disposes runners to eating disorders or whether females with these disorders are more likely to choose running as an activity.

9.2 Amenorrhoea

Disturbances of the menstrual cycle can occur in at-risk female runners. The menstrual cycle varies in length with anything from 23-35 days being considered normal. The average is 28 days from the start of the menstrual period to the start of the next. In a young female runner who has not yet reached puberty, menarche (the onset of the first menstrual period) can be delayed. This is known as primary amenorrhoea if the condition persists beyond the age of 16 (Australian Sports Medicine Federation, undated). In female runners who already have an established menstrual cycle, the cycle can be disrupted, with menstruation occurring at intervals of more than 35 days apart (oligomenorrhoea) (Australian Sports Medicine Federation, undated). When menstruation stops for three or more consecutive months, females who were previously menstruating and who are not pregnant, suffer from what is known as secondary amenorrhoea (Australian Sports Medicine Federation, undated).

Not all female runners suffer from amenorrhoea. However it has been reported that pre-pubertal female runners can suffer a delay in menarche (Australian Sports Medicine Federation, undated). In girls and women who began training after menarche, the incidence of oligomenorrhoea has been reported to be 5% higher than in the general population (Australian Sports Medicine Federation, undated). The incidence of amenorrhoea has been reported in 24-45% of female runners, depending on the amount of training undertaken (Australian Sports Medicine Federation, undated).

Athletic amenorrhoea is thought to be caused by many factors including increased training intensity, loss of body weight and fat, low calorie intake or a combination of these factors, leading to hormonal imbalances and especially, low oestrogen levels (Larkins, 1990). There is no evidence to suggest that amenorrhoea is harmful to the female reproductive system, however runners should be advised of the associated osteoporotic hazards and counselled regarding changes to their diet and training schedules (Larkins, 1990). Osteoporotic hazards are commonly referred to as osteoporosis, a condition whereby the bones become brittle and fragile, often as a result of hormonal change or deficiency of calcium or vitamin D.

Amenorrhoea can, for most runners, be treated by reducing training intensity and increasing weight. This is not an option, however, for most runners. Thus, most runners whose condition is “athletic” in origin will usually be put on the contraceptive or mini pill (Australian Sports Medicine Federation, undated). There is some suggestion the use of the oral contraceptive pill may be associated with a lower risk of injury (Bennell, 1996c)

9.3 Shin Pain

As previously discussed in Section 6.2, women have been shown to sustain more shin pain than their male counterparts. One reason given for this increase is that women who suffer from stress fractures are more likely to suffer from amenorrhoea. The incidence of stress fractures has been shown to be relatively high in women with athletic amenorrhoea (Carbon et al., 1990, Myburgh et al., 1990). Various hormonal and metabolic factors have been implicated, as well as diet and eating disorders such as anorexia nervosa (Wajswelner, 1995).

Myburgh et al. (1990) studied a group of 25 matched female athletes with similar training habits. Those with stress fractures were more likely to have had significantly lower bone density in the femoral neck, lower dietary calcium intake, current menstrual irregularity and lower oral contraceptive use. They found osteoporosis was a risk factors for stress fractures, suggesting that low calcium intake and/or calcium deprivation could increase the risk of osteoporosis in later life, despite regular exercise.

Bennell et al. (1995) conducted a retrospective analysis of the risk factors for stress fractures in 53 female competitive track and field athletes. Forty-five stress fractures in 22 women were diagnosed by clinical findings and bone scan, radiography, or CT scan. There was no significant difference in bone mineral density at the lumbar spine and tibia/fibula or in percentage body fat and total lean mass, when those with and without a stress fracture history were compared. Athletes with a past stress fracture were significantly older at menarche (14.8 years compared to 14 years) and were more likely to have experienced a history of menstrual disturbance (menstrual disturbance ratio of 0.19 for females without stress fracture history and 0.35 for women with stress fracture history). Analysis of dietary behaviour found that athletes with stress fractures were more likely to engage in restrictive eating patterns and dieting (EAT-40 score of 15.2 for those without stress fractures and 18.7 for those with). Athletes with a history of oligomenorrhea were six times more likely to have sustained a stress fracture in the past, while those who were careful about their weight were eight times more likely.

In comparison, Koike et al. (1996) conducted a study of 12 elite female distance runners over two years and 22 sedentary healthy females for one year. The two groups were matched according to age and body size. The purpose of the study was to investigate whether stress fractures occurring in elite female long distance runners were related to decreased bone mass. There were, however, no significant differences in bone mass density between the two groups at any of the sites measured (distal radius, lumbar spine and femoral neck). Thus, the authors concluded that stress fractures in elite long distance runners were largely independent of bone mass density.

In order to prevent stress fractures in female runners, Myburgh et al. (1990) suggested that oral contraceptives appeared to offer some protection, as did an increased calcium intake of more than 120% of Recommended Dietary Allowance (Australian Recommended Dietary intake is 800mg). This was necessary to help repair bone microtrauma and offset the increased requirements of athletes with oestrogen deprivation.

The recommendations also included putting a female on either the contraceptive or mini pill, to counteract amenorrhoea. Amenorrhoea results in a decrease in oestrogen which is believed to lead to lower bone density and increased rate of stress fracture, however there is no evidence to show that oral contraceptive use decreases the risk of stress fractures or increases bone density in athletes with amenorrhoea. (Bennell, 1996c). There is evidence to show that amenorrhoea results in a decreased risk of osteoporosis and a increased risk of stress fractures (Bennell, 1996c). Bennell (1996c) also recommends developing mileage over time, or including rest days or alternative training methods in the runner’s training schedule. This would result in allowing time for the bone to readapt to new stresses.

According to Heinrich et al. (1990), weight training provides a better stimulus for increasing bone mineral content than does running or swimming, so it may be useful for the female runner to participate in alternative training methods for both rehabilitation and prevention of stress fractures in the lower leg.

Caffeine intake increases the urinary excretion of calcium in premenopausal women who habitually consume it (Massey & Opryszek, 1990). For this reason, it has been suggested that the female runner should avoid excessive intake.

9.4 Recommendations for further research development and implementation

- More research into the role of menstrual disturbances and the risk of overuse injuries needs to be undertaken.
- In particular, the exact relationship between menstrual health, bone health and stress fractures is yet to be elucidated.
- The impact of dietary behaviours and habits on the incidence of injuries, particularly in women, needs to be determined.

9. SUMMARY AND ADDITIONAL RECOMMENDATIONS

This report has discussed the full range of injury prevention activities for preventing running injuries. Recommendations for further countermeasure research, development and implementation have been based on the review presented here and discussions with experts acknowledged in this report. Separate sections on overuse injury and injury risk in children and women are also presented because of the particular risk factors involved.

Many of the recommended countermeasures have yet to be proven to be effective and more attention to controlled studies "in the field" are needed. More effort directed to basic scientific studies to better understand the biomechanics of running, the mechanisms of injury and the role of various risk factors in injury causation are also required. Indeed, the evidence for the effectiveness of certain countermeasures such as warming-up and shoe design remains equivocal.

In addition to the specific recommendations in this report, the following set of more general recommendations can be made:

- Improved data collection about the occurrence of running injuries and their associated factors needs to be developed and maintained.
- Data about injuries and their associated factors in recreational runners needs to be collected.
- Data collections should conform to guidelines for sports injury surveillance being developed and promoted nationally.
- Information about preventing running injuries should be disseminated widely through shoe points of sale, running magazines and more general magazines.
- Guidelines for minimum safety requirements for Little Athletics meetings and other running events (including the need for mobile phones, telephone contacts, first aid kits, etc) should be developed and widely disseminated.

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