MONASH UNIVERSITY

ACCIDENT RESEARCH CENTRE

SPIKING INJURIES OUT OF VOLLEYBALL:

A REVIEW OF INJURY COUNTERMEASURES

by

Erin Cassell

June, 2001

Report No. 181

Funded by

SPORT AND RECREATION VICTORIA

MONASH UNIVERSITY ACCIDENT RESEARCH CENTRE
REPORT DOCUMENTATION PAGE

Report No.	Date	ISBN	Pages
181	May 2001	0 7326 1480 5	110

Title and sub-title:
Spiking injuries out of volleyball: A review of injury countermeasures

Author(s)
Erin Cassell

Type of Report & Period Covered:
Critical Review, 1985-2000

Sponsoring Organisation(s):
Sport and Recreation, Victoria

Abstract:

The Australian Bureau of Statistics (ABS) estimates that in 1999-2000 approximately 150,000 Australians aged 18 years and older (including 46,000 Victorians) participated in organised and unorganised volleyball. Volleyball was ranked 26th in the table of most-played sports and physical activities by adults in Australia (22nd in the table for Victoria).

There is no one comprehensive source of data on injury in volleyball in Victoria or elsewhere. Injury data were extracted from a range of sources for this review including the ABS, Victorian hospital admissions and emergency department databases and Australian and overseas published studies. The weight of evidence indicates that volleyball has a lower risk of injury than all football codes, basketball and some high-risk recreation activities, for example horse riding and skiing. Studies uniformly report that sprains and strains (predominantly ankle sprains) account for approximately two-thirds or more volleyball injuries. The ankle, hand/finger, knee and shoulder are the most common sites of volleyball injuries.

The overall aim of this report is to critically review the formal research literature and informal sources that describe measures to prevent volleyball injury and to assess the quality of evidence supporting claims of effectiveness. There are few formal evaluations of countermeasures to injury in volleyball so our review was extended to include countermeasures in other team ball sports that may be applicable to volleyball.

Recommendations in this report include: extension of pre-participation evaluation; improvements to education and training for players and coaches, particularly at the wider community level; promotion of modified games for children; consideration of conditioning and exercise programs to prevent ankle and knee injuries (ankle disc and plyometric training); training in specific skills and techniques; use of ankle and finger taping and bracing; provision of appropriate and prompt first aid by trained personnel; improvements to injury data collections; and further epidemiological, biomechanical and laboratory research into the causes of volleyball injuries and measures to prevent them.

Volleyball requires a variety of physical attributes (speed, power, flexibility, strength and balance) and specific playing skills. Therefore, participants need to train and prepare to meet at least a minimum set of physical, physiological and psychological requirements to cope with the demands of play and reduce the risk of injury.

Key Words:
Volleyball, injury prevention, overuse, evaluation, countermeasures

Disclaimer
This report is disseminated in the interest of information exchange. The views expressed here are those of the authors, and not necessarily those of Monash University

Monash University Accident Research Centre,
PO Box 70A Monash University Victoria, 3800, Australia.
Telephone: +61 3 9905 4371, Fax: +61 3 9905 4363

Contents

Tables

ACKNOWLEDGEMENTS

This study was funded by Sport and Recreation Victoria.

The author would like to thank Thomas Jones and Terry Jones of Volleyball Victoria for their co-operation and Andrew Shears for his valuable comments on the draft report.

Evert Verhagen (Department of Social Medicine, Vrije Universitiet, The Netherlands) and Assoc. Prof Caroline Finch (School of Health Sciences, Deakin University) are thanked for their expert comments on the draft report

Maria Corbo and Voula Stathakis of MUARC are thanked for their assistance with data provision, as is David Price, Claims Manager, Sportscover Insurance. Ruth Zupo of MUARC is thanked for formatting the final report.

EXECUTIVE SUMMARY

Volleyball is a very popular international sport. The International Volleyball Federation (Federation Internatonale de Volley-Ball - FIVB) claims 800 million participants world-wide who play at least once a week. If this number is accurate then volleyball ranks as the world's most popular participation sport (Briner & Kacmar 1997).

The Australian Bureau of Statistics (ABS) estimates that in 1999-2000 approximately 150,000 Australians aged 18 years and older (including 46,000 Victorians) participated in organised and unorganised volleyball. Volleyball ranked 26th in the table of most-played sports and physical activities by adults in Australia (22nd in the table for Victoria).

Volleyball requires a variety of physical attributes (speed, power, flexibility, strength and balance) and specific playing skills. Therefore, participants need to train and prepare to meet at least a minimum set of physical, physiological and psychological requirements to cope with the demands of play and reduce the risk of injury.

There is no one comprehensive source of data on injury in volleyball in Victoria or elsewhere. Injury data were extracted from a range of sources for this review including the ABS, Victorian hospital admissions and emergency department databases and Australian and overseas published studies.

The weight of available evidence indicates that volleyball has a lower risk of injury than all football codes, basketball and some high-risk recreation activities, for example horse riding and skiing. Studies uniformly report that sprains and strains (predominantly ankle sprains) account for approximately two-thirds or more volleyball injuries. The ankle, hand/finger, knee and shoulder are the most common sites of volleyball injuries.

The overall aim of this report is to critically review the formal research literature and informal sources that describe measures to prevent volleyball injury and to assess the quality of evidence supporting claims of effectiveness. There are few formal evaluations of countermeasures to injury in volleyball so our review was extended to include countermeasures in other team ball sports that may be applicable to volleyball.

The countermeasures that are considered in this report include:

- extension of pre-participation evaluation;
- education and training for players and coaches, particularly at the wider community level;
- modified games for children;
- conditioning and exercise programs to prevent ankle and knee injuries (ankle disc and plyometric training);
- training in specific skills and techniques of the game;
- personal protective equipment, particularly the relative effectiveness of taping and bracing to prevent ankle, knee and finger injuries;
- first aid and rehabilitation;

Data and research needs are also articulated.

SUMMARY OF RECOMMENDATIONS

RECOMMENDATIONS FOR PLAYER SAFETY: GENERAL

Screening, conditioning and fitness programs

Pre-participation evaluation

- Extend pre-participation evaluation (and associated individually tailored conditioning and training programs) to a wider group of higher-level senior and junior players and evaluate the protective effects of these programs.

Training and conditioning

- Simple pre-season fitness testing should be conducted on players participating in competitive volleyball at the inter-club level, four to six weeks prior to the start of the season.
- All competitive and recreational volleyball players are advised to undergo a graduated skills development and training program (which includes cross training) guided by results of an initial fitness test.
- Players should consult an accredited coach on their individual training requirements.
- Coaches should vary training routines and concentrate on developing players' technical skills in training sessions.
- Initiatives to increase the awareness of players and coaches of the injury consequences of training errors (including over-training) should be continuously developed, and refined as new knowledge becomes available.

Warm-up and cool down

- All players should routinely warm-up and cool down before and after every game and training session. On the basis of current research, the inclusion of stretching exercises in warm-up does not reduce the risk of injury.
- The specific needs of the players recovering from injury should be considered when warm-up and cool down regimes are developed.

Environmental safety measures

- Extreme heat policy and rules need to be developed at the association level for both beach and indoor games.
- All beach volleyball clubs and outdoor events managers should provide umbrellas or shaded areas and ice-chests on court, and ensure that water and ‘sports’ drinks (with 4%-8% carbohydrate content) are available.
- Beach and indoor players, particularly when participating in tournaments, should monitor their fluid intake during games by weighing themselves or by noting any reduction in the amount and concentration of urine output in relation to fluid intake (oliguria). Players

should replace fluid and electrolyte loss by consuming 400-600 mls of fluid (2-3 standard glasses) at least 30 minutes before play, 200-300 mls (1-2 glasses) every 15 minutes during play (at change of ends) and more than they are thirsty for after activity (at least 500 mls).

- Education and signage about measures to prevent heat illness should be provided at the club level.
- Players playing outdoors should use a broad-spectrum sunscreen and hat, even on cloudy days.
- Clubs, in association with venue owners and managers, should develop, implement and monitor risk management/sports safety plans. These should include measures to eliminate or ameliorate environmental and other injury hazards. Guidelines and support for the development of these plans should be available from sports associations.
- The playing surface should be checked for cracks, holes and debris prior to play and defects remedied.

Training and education of coaches and officials

- Accredited coaches and sports trainers should be available at every club to advise and monitor the skills development of players at all levels of play (competitive and recreational).
- All coaches and sports trainers should undergo training and re-accreditation through Volleyball Australia and state divisions.

Modified games for children

- Volleyball Victoria should continue to promote the adoption of modified rules volleyball games for children in schools, recreation venues and junior volleyball clubs.

First aid, treatment and rehabilitation

- All players should be taught the RICER, NO HARM regime, through schools and volleyball associations and clubs.
- Players should seek prompt attention for injuries from a sports medicine practitioner and allow enough time for adequate rehabilitation before returning to their pre-injury level of activity.
- Event organisers and clubs should ensure that there are qualified first aid personnel/sports trainers at all training sessions, competition match days and events.
- Clubs should have a well-stocked first aid kit and a supply of ice-packs.
- Players with serious acute and chronic injuries should seek advice from a medical practitioner trained in sports medicine on appropriate treatment and taping or bracing if recommended and rehabilitation regime.

RECOMMENDATIONS FOR PLAYER SAFETY: SPECIFIC TO ANKLE, KNEE, SHOULDER AND HAND/FINGER INJURIES

Preventing ankle injuries

- Associations should consider the introduction of a stricter netline violation rule to reduce foot conflict under the net.

- Players with ankle sprains should complete supervised rehabilitation before returning to competition.

- Players who have suffered a moderate or severe sprain should wear an appropriate orthosis (brace) for at least 6 months and, preferably, twelve months.

- Players with unstable ankles should consider prophylactic bracing and taping for training sessions and matches. There is evidence to suggest that bracing is more effective, cost effective and convenient than taping, and does not interfere with performance.

- Specialist blockers, particularly the middle blocker, should consider prophylactic ankle bracing (or taping).

- Coaches should introduce drills which train players in the following techniques:

  -taking a quick and long last step when trying to reach a 'tight' set rather than trying to 'outjump' the ball (which carries a higher risk of foot conflict under the net with opposing players); and

  -reducing side-to-side movement and using proper take-off technique when setting one-man and two-man blocks.

- Ankle disc (balance board) training should be trialed and evaluated by volleyball clubs.

- Playing shoes should be in good condition.

- Training should be conducted on sand, wood or synthetic 'forgiving' surfaces, not concrete or linoleum.

- Playing surfaces should be diligently maintained and regularly checked for hazards such as hollows, cracks and wear.

Preventing knee injuries

- Indoor volleyball should be played on wooden floors (or synthetic floors with similar elastic properties). Playing on hard surfaces (for example concrete or lino) should be avoided.

- Serious competitors should use cross training to limit the amount of training involving repetitive stresses on the knees.

- Knee pads should be worn in training and match play to prevent acute knee injuries and the acute exacerbation of overuse injuries.

- All players, especially female players, should be trained to 'land softly' on the balls of their feet with knees and hips flexed.

- Coaches should consider introducing balance board training, particularly for female players and players with knee instability.

- A plyometric (jump training), stretching and strength training program should be considered for all players to decrease peak landing forces, and particularly for female players to correct imbalances between hamstring and quadriceps muscle strength. Plyometric training should be under the supervision of a trained coach and programs should be carefully evaluated.

- Players who are already proficient jumpers, middle blockers and players with knee pain are advised to decrease their jump training time and pay close attention to technique.

Preventing shoulder injuries

- All players, especially attackers and beach volleyball players, should include specific exercises to strengthen the shoulder in external rotation and increase the flexibility of internal rotation of the rotator cuff.

- Beach volleyball players should include spike co-ordination training drills with the shoulder joint held in different rotations.

Preventing hand/finger injuries

- All schoolchildren and new players should be introduced to the game progressively with the proper techniques for each of the basic volleyball skills taught and practiced in a controlled environment prior to full participation. Junior players should progress to regular volleyball through the modified "Volleystars" and mini-volleyball programs.

- Players should not wear rings or other jewelry. Coaches and match officials should strictly enforce this ban.

- Hand/finger injuries should be immediately treated with ice and assessed by a medical practitioner within 24 hours.

- Coaches and trainers should be alert to the potential long-term adverse effects of hand/finger injuries and advise players against 'playing on' with hand/finger injuries.

- Buddy taping or, preferably, a finger brace should be worn in both practice and games (if permitted within the rules) until symptoms resolve, which may be several months.

RECOMMENDATIONS FOR FURTHER RESEARCH AND COUNTERMEASURE DEVELOPMENT

General injury data, risk factor identification and risk management research needs

- Volleyball associations should establish an injury reporting system for the documentation of volleyball injuries. All data collections should conform to national guidelines for sports injury surveillance (the Australian Sports Injury Data Dictionary).

- Action needs to be taken to improve the quality and specificity of data on sports injuries collected through the Victorian hospital system.

- Further epidemiological research is needed to determine the risk factors for volleyball injury and to evaluate the effectiveness of countermeasures.

- Current work by volleyball associations on guidelines for minimum safety requirements for organised volleyball should be expedited.

- A cost of sports injury study is required to determine the overall cost of sports injury and the relative cost of injuries for different sports.

Research needs associated with general injury prevention measures

Pre-participation evaluation

- Continue to research assessment measures that are volleyball-specific to improve pre-participation evaluation instruments.
- Systematically evaluate the injury prevention efficacy of the current pre-participation evaluation program for elite players.

Training and conditioning

- Controlled evaluation studies should be conducted to determine 'best practice' conditioning and training programs that develop the skills and fitness necessary for competitive volleyball and protect players from injury.

Warm-up and cool down

- The protective effects of warm-up, stretching and cool-down require further evaluation in controlled trials in specific sports populations.

Environmental safety measures

- Research should continue on player diet and hydration issues.
- The injury prevention effect of the implementation of club and association sports safety plans should be evaluated.

Training and education of coaches and officials

- Continuous systematic evaluation of the effectiveness of coach and sports trainers' education/training programs should be maintained.

Modified games for children

- Research to determine the appropriate age/stage of physical and skills development for children to graduate from modified to full participation in volleyball.
- The pattern of child injury in volleyball needs to be better reported and monitored to enable the development and evaluation of current skills development and modified rules programs.

First aid, treatment and rehabilitation

- Further research and evaluation of first aid and rehabilitation programs are required, to develop optimal regime for recovery and return to play.

RESEARCH NEEDS SPECIFIC TO THE PREVENTION OF ANKLE, KNEE, SHOULDER AND HAND/FINGER INJURIES

Ankle injuries

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

Knee injuries

- Population-based studies to determine gender-specific risk factors for non-contact ACL injuries.

- Further epidemiological, biomechanical and laboratory studies to clarify the role of intrinsic risk factors in non-contact ACL injuries and establish countermeasures to ACL injury.

- Research to better identify high-risk player positions and player manoeuvres for ACL injury and to develop protective neuromuscular responses when high-risk situations are encountered.

- Research to better understand the influence of playing surface and shoe-surface interaction on knee injury.

- A randomised controlled trial (in a population with no foot pain) to test the advantage of placing the foot in a supinated or neutral position rather than a pronated position when playing sport. Such a trial would have the capacity to establish the significance of pronation in overuse injury and the clinical value of an orthosis.

- Evaluation studies, preferably controlled trials, to determine the effectiveness of strategies and countermeasures to knee injuries in volleyball.

Shoulder injuries

- In-depth research on the incidence, patterns, mechanisms and consequences of shoulder injuries in volleyball at all levels of play with a view to developing specific countermeasures

- Controlled investigations on the optimal preventive and rehabilitative exercise programs to prevent shoulder overuse injuries.

Hand/finger injuries

- In-depth research on the incidence, patterns, mechanisms and consequences of hand/finger injuries in volleyball at all levels of play with a view to developing specific countermeasures, for example protective gloves for new players and other players at higher risk of injury.

- Controlled investigations on the optimal treatment and rehabilitation regimes for different types of hand/finger injury including the amount of rest from play that is advisable.

- Controlled trial of the most effective type of protective support for the hand/finger (tape or brace) to prevent re-injury on return to play.

1. INTRODUCTION

Volleyball is a very popular international sport. The International Volleyball Federation (Federation Internatonale de Volley-Ball - FIVB) claims 800 million participants world-wide who play at least once a week. If this number is accurate then volleyball ranks as the world's most popular participation sport (Briner & Kacmar 1997).

The standard (indoor) volleyball game is the six-person team game, now played competitively by both men and women. It was invented in the U.S. in 1895 by William G. Morgan who created the game (at that time called mintonette) by blending elements of basketball, baseball, tennis and handball. Volleyball was designed to involve less physical contact than basketball to suit businessman in Morgan's Young Men's Christian Association (YMCA) physical fitness classes. It became an Olympic sport in 1984 at the Los Angeles Olympic Games. (www.volleyball.org).

Six-person team volleyball is a non-contact team game played by two teams on a hard playing court divided by a net. The object is for each team to send the ball regularly over the net to ground it on the opponent's court, and to prevent the ball from being grounded on its own court. Play is initiated with a serve by the right back-row player to the opponent's court. The opposing team is allowed to hit the ball three times (in addition to the block contact) to return the ball to the opponent's court. The rally continues until the ball touches the ground/floor, goes out of court or the team fails to return it to the opponent's court or commits a fault. (www.volleyball.org).

Under the rally point scoring system, the team winning a rally scores a point and the right to serve if it's the receiving team (players rotate one position clockwise at service). A team wins a game by scoring 15 points with a two-point advantage and wins the match by winning the best of three or five games. (www.volleyball.org).

The game of beach volleyball, played outdoors on sand, originated in the early 1920s on the beach at Santa Monica, California. Over time it has been played as a six- five- four- three- and two- person game. Two-person beach volleyball was added to the Olympics in Atlanta in 1996, when 24 men's teams and 16 women's teams represented their countries. (www.volleyball.org). Park and grass volleyball is also being promoted as a social game.

Sport-specific skills and injury risk

In all variations of volleyball there are six sport-specific basic skills:

- Serve: serves may be overhand or underhand and the ball is hit with the fist (underhand serve only) or the heel of the hand (both overhand and underhand serves).

- Forearm pass/Dig: the basic skill is called a 'pass' when receiving the serve and a 'dig' when handling an opponent's attack. When correctly executed contact with the ball is made with the lower forearms, just above the wrist.

- Set/Overhand pass: the ball is directed towards the net so that it may be spiked or hit by a team mate. In a correctly executed 'set', contact is made with the fingertips of both hands, the contact point is just above the forehead (hairline).

- Hit/Spike: the player jumps high into the air and contacts the ball overhead at the highest point of the jump and strikes it down onto the opposition's side of the net. The contact point is slightly in front of and as high as possible above the hitting shoulder. First contact is made with the heel of the hand, followed by the palm and the fingers which then snap through the ball (the wrist snap provides topspin on contact).

- Block: players on the opposing team will try to block a spike by jumping with hands raised to intercept the spike and force the ball back to the hitter's side of the net.

(www.volleyball.org; Briner & Kacmar, 1997)

These playing skills are associated with different risks of injury. Available evidence suggests that blocking and spiking carry the greatest risk of injury, mainly associated with jumping and landing (Briner & Kacmar, 1997).

This report concentrates on injuries in indoor six-person volleyball because this is the variation of volleyball with most participation in Victoria. Beach volleyball is mentioned, but the literature search revealed only one study of the incidence and pattern of injury in beach volleyball.

2. AIMS

The aims of this report are to document the size and nature of the injury problem in volleyball and to critically review the research evidence on the effectiveness of injury prevention measures.

An overview of the epidemiology of volleyball injury (occurrence, patterns and causes) is given, based on Victorian and Australian data where available, with reference to overseas studies for the purpose of making comparisons. This information sets the scene for the subsequent discussion of countermeasures.

3. METHODS

Three computerised databases - Medline, Sports Discus and Austrom - were accessed for relevant research reports within the period January 1985-December 2000. There is some overlap with an earlier review of the volleyball injury literature that covered publications from 1972-1992 (Lidner & Ferretti in Caine et al., 1996).

Keyword for the initial search was ‘volleyball’ and included beach volleyball. Generally, articles pertaining to treatment were not included. Additional searches were made on specific sports injury types and particular countermeasures, not confined to the volleyball literature. This review is based largely on English language material. With a few exceptions, non-English language articles with English language abstracts have not been included.

3.1 QUALITY ASSESSMENT OF RESEARCH EVIDENCE

Injury epidemiology is the study of the distribution and determinants of injury-related states and events in specified populations and the application of findings to the control of injury problems. The different types of epidemiological research designs are explained in table 3:1, which also includes a rating scale of the relative strength of the evidence they can provide. The rating scale reflects an epidemiological and rigorous scientific approach to injury prevention. In this scale, the most weight is given to positive findings from well-designed randomised controlled trials (RCTs) 'in the field'. RCTs are fairly rare in sports injury prevention research but we are gradually seeing more interventions tested for effectiveness using this methodology.

Countermeasures to injury 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. An examination of attitudes, knowledge and behaviours is crucial to this. Studies of these factors 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, any literature describing these studies is included in this review.

Another measure of the success of countermeasures is a demonstration of their benefit/cost ratios. This information is often required by policy and regulatory bodies to inform their decisions about implementation of injury countermeasures. This is a neglected area of sports injury research.

Table 3.1: Grading scale for assessing the quality of research evidence

Relative strength	TYPES OF EPIDEMIOLOGIC STUDIES
Weaker	**DESCRIPTIVE STUDIES (case series and cross sectional)** **Case series (small, special registry and population-based)** **What are they?** Case series studies identify, define and describe injury problems and patterns. They classify injury cases into homogenous (like) subsets, count them, measure their severity and may specify their concentrations in specific population groups. There are three types of case series: • *Small* for example, cases drawn from a single hospital or a small group of hospitals; • *Special registry* for example, the new Victorian Emergency Department Minimum Database which holds detailed injury data collected from 25 hospital Emergency Departments; and • *State or national data*, for example, studies based on the Victorian Inpatient (hospital admissions) Database (VIMD) which collects a small amount of data on injury cases from all public and private hospitals. **Example:** *A study of 300 volleyball injury cases presenting to Victorian hospital emergency departments 1996-1999.* **Strengths and weaknesses:** Case series can be a rich source of information on injury, especially special registry studies. If the injury hazard from the case series is obvious, there may be little need to carry out more complex and expensive research. However, case series cannot be used to specify causes of injury. Also, the sample of cases may be biased (particularly when drawn from small and registry-based collections) and not representative of all cases, which precludes the calculation of injury rates and trends over time. **Cross sectional studies (surveys)** **What are they?** These studies determine the status quo of a condition during a specified period of time, *for example*, a telephone or postal survey of injuries among a representative sample of volleyball players. Most surveys are cross sectional. **Strengths and weaknesses:** Cross sectional studies examine the relationship between the condition (for example injury) and other variables of interest (for example age, gender, skill level, use of protective gear). They compare the prevalence of the condition in different population subgroups and between those with or without the condition, according to the presence or absence of the variables. They examine a condition at one point in time so cannot determine cause and effect.

Stronger	**ANALYTIC (OBSERVATIONAL) STUDIES (case control and cohort)** **What are they?** These studies test hypotheses (suppositions/conjectures) about the influences that determine that one person is injured while another is not i.e., they provide strong evidence on the causes, risk and contributory factors to injury. • **Case-control studies** The researcher assembles a group of persons with the injury of interest (cases) and a comparison group without the injury under investigation (controls), *for example*, volleyball players with and without ankle injury. The researcher then investigates the history of past (retrospective) exposure to one or more potential risk factors for the injury (for example previous ankle injury, tennis shoe type, playing surface and use of ankle brace or tape). **Strengths and weaknesses:** Case control studies generally require a comparatively short study period, are relatively inexpensive and have the ability to examine association of several risk factors for the given injury. However, the choice and recruitment of appropriate controls can be difficult. Because case-control studies investigate retrospectively from the injury event they are subject to recall and other biases which may affect the results and weaken evidence of cause and effect.
	• **Cohort studies** The investigator begins with a group of persons exposed to the factor of interest and a group of persons not exposed (for example, 15 to 19 year-old males would be a suitable cohort if volleyball injury was the factor of interest) and then follows up the cohort over a number of years and *observes* the association between exposure (volleyball) and outcome (injury). **Strengths and weaknesses*:*** Because they are generally prospective (forward-looking) the likelihood of collecting reliable and valid data is greater. Consequently, results from a well-designed cohort study carry more weight in establishing a cause than results from a case control study. However, cohort studies often involve large numbers (especially if the factor of interest is rare) and/or long study periods and, therefore, are expensive. The other potential problem is the dropout rate ('loss to follow-up') which, if large, results in biased data.

Strongest	**EXPERIMENTAL STUDIES** **(Randomised controlled trial and community trial)** **What are they?** In experimental epidemiological studies, the investigator controls the conditions under which the study is to be conducted by assigning subjects (preferably randomly) to either an experimental (treatment) group which receives the intervention or a control group that does not receive it. • **Randomised controlled trial (RCT)** In a RCT the investigator randomly allocates similar persons to the treatment and control groups. For example, in a RCT to investigate whether or not wearing an ankle brace prevents ankle sprain, the subjects would be recruited into the trial and randomly allocated to the treatment group (who wear an ankle brace) or the control (non-wearing) group and followed-up over time to determine the effectiveness of the countermeasure. • **Community trials (quasi-experimental)** In a community trial the group as a whole is collectively studied. The investigator selects two similar communities. The incidence of the disease or condition of interest (for example dental injury in sports) and prevalence of suspected risk factor/s for which an intervention has been developed are surveyed in both. The intervention (for example compulsory wearing of mouthguards) is then carried out in one community and the other does not receive it. The communities are surveyed again. The net difference in the incidence of the condition and prevalence of the risk factor/s is thereby associated with the intervention. **Strengths and weaknesses:** Well-conducted controlled trials, where the assignment of subjects or communities to the experimental or comparison group is random, are regarded as the strongest epidemiological studies and provide the greatest justification for concluding causation. Obstacles to their use include their great expense and the lengthy research period.

References:

Dawson-Saunders B, Trapp RG. *Basic and Clinical Biostatistics*. Appleton & Lange 1990, Connecticut

Lilienfeld. DE, Stolley PD. *Foundations of Epidemiology*. Third Edition. Oxford University Press 1994, New York.

Robertson LS. *Injury Epidemiology*. Oxford University Press 1992, New York.

4. PARTICIPATION IN VOLLEYBALL

Based on information collected in a quarterly household survey, the Australian Bureau of Statistics (ABS) estimates that 149,700 adults (90,500 males and 59,200 females) participated in organised and non-organised volleyball in Australia in 1999-2000 (ABS 2000). The figures for Victoria were 46,300 adult participants (34,300 males and 12,000 females). Volleyball ranked 26th in the list of most-played sports and physical activities by adults in Australia and 22nd in the list for Victoria (ABS 2000). Non-organised participation refers to participation in volleyball activities not organised by a club or association.

The latest year of available data for child participation in volleyball is 1996-7. In that year the ABS estimated that 14,900 children aged 5-14 years (4,800 males and 10,100 females) participated in volleyball organised by a school or club across Australia (ABS 1998). Data were not given separately for Victoria.

Volleyball Victoria estimates that 15,000 Victorians participated in volleyball at all levels of competition in 2000. These data include participants in informal and school competitions.

5. THE EPIDEMIOLOGY OF VOLLEYBALL INJURIES

There is no one comprehensive source of injury data for volleyball in Australia. A picture of the incidence and pattern of injury in volleyball is, therefore, drawn from many sources (Victorian hospital and sports insurance data and Australian and overseas studies in different settings and populations).

5.1 VICTORIAN HOSPITAL EMERGENCY DEPARTMENT INJURY DATA

The Victorian Emergency Minimum Dataset (VEMD) is an ongoing surveillance database of injury presentations to 25 Victorian public hospital emergency departments (EDs), representing 80% of statewide emergency department presentations. It is the best available source of local data on injuries in volleyball.

The database has several limitations for sports injury surveillance. Players with injuries may present to a range of other practitioners for treatment (for example, GPs and physiotherapists) or self-treat their injuries. Also, hospital data generally underestimate overuse injuries and may be biased towards more serious injuries. The major internal weakness of the VEMD database is that there is no separate code to identify the sport being played at the time of the injury. This information is only available if it is included in the one-line narrative on each sport and recreation case.

These case narratives are completed by staff in the emergency department and are of variable quality. For this review a check was made on the quality of narratives in a random sample of 1,000 sport and recreation injury cases in the latest full year of VEMD data (July 1998 to June 1999). It revealed that only 58% of the 500 one-line case narratives of ED injury cases classified under 'sports' and 40% of the 500 one-line case narratives of injury cases classified under 'leisure, location: place for recreation' specified the sport being played at the time of the injury. Volleyball injury cases are found under each of the two classifications.

Therefore, VEMD data are likely to represent a two- to three- fold under-estimation of sports injury frequency in any specific sport and VEMD data included in this section should be interpreted with caution.

5.1.1 Injury frequency and patterns

There were 291 volleyball injury cases recorded on the VEMD for the three year period July 1996-June 1999, 280 injury cases in indoor volleyball, 10 in beach volleyball and one in recreational volleyball played in a pool.

5.1.2 Age and gender profile

Of the 291 injury cases, 249 were adults (aged ≥ 15 years) and 42 were children (0-14 years). The age groups with the higher proportions of injuries were 25-29 year olds (22.0% of all volleyball injuries), 15-19 year olds (18.2%), 20-24 year olds (15.5%) and 10-14 year olds (12.4%).

Overall, males were more likely to be injured than females in the ratio of 6:4. In adults the male to female injury ratio was 1.6:1, whereas in children the ratio was 1:2.5. ABS participation data suggest that these differences are more likely to reflect the higher participation of males in senior volleyball and females in junior volleyball, rather than indicating gender-related differences in injury risk.

5.1.3 Place where injury occurred

Overall, just over one-half of all injuries occurred at an athletics or sports oval (51.2%), approximately one-quarter occurred at a place for recreation (26.8%) and 10.7% occurred in schools. The remainder were classified under 'other and unspecified' locations. The analysis of child injury cases separately revealed that 45.2% of injuries to children occurred in the school setting.

5.1.4 Major causes of injury

The major causes of volleyball injuries were falls (trips, slips and stumbles) (43.7%), 'struck by or collision with' object (19.9%) and struck by/collision with persons (9.3%). A higher proportion of child injury cases, compared to adult cases, were struck by/collision with injuries. This category, mostly ball strikes to the wrist, hand or fingers, accounted for 40.5% of child injury cases and was the primary cause of child injury. In a small number of cases the child collided with the pole, net winder or got tangled in the net.

Most adult injuries were caused by falls (45.8%), followed by struck by/collision with object (16.5%, mostly the ball) and struck by/collision with person (9.6%).

5.1.5 Injury type and body part injured

Sprains and strains were the most common injury (46.0%) and most frequently involved the ankle, knee and hand including fingers. Other relatively common injuries were fractures (17.5% of injuries, mostly to the hand including fingers, ankle, foot including toes, and wrist), injuries to the muscles or tendon (13.1%, mostly ankle), dislocation (5.5%, mostly hand, including fingers), superficial injuries (3.8%) and open wounds (3.4%).

Overall, the most frequently injured body sites were the ankle (24.7%), hand including fingers (21.0%), knee (10.0%), wrist (7.9%), foot, including toes (5.8%) and shoulder (5.5%). The pattern of injury sites was different for adults and children. Children (aged 0-14 years) were much more likely to present with hand/finger injuries than adults (33.3% vs. 18.9%) and much less likely to present with ankle injuries (9.5% vs. 27.7%).

5.1.6 Mechanism of injury

The one-line case narratives provide some extra information on the mechanism of injury (what happened?) although they vary in quality. These are discussed in detail in Chapter 5 in relation to ankle, knee, hand/finger and shoulder injuries.

5.1.7 Injury severity

Of the 291 patients, 268 were treated and released from E.D. (92.1%), 16 were admitted to the hospital (5.5%), two were admitted within the E.D. (0.7%) and four patients left before seeing a doctor (1.4%). Among the 16 hospital admissions, six were for muscle or tendon injuries, five were for fracture and three were for dislocation. There was one case with intracranial injuries and another with an open wound. The transferred patient also had an open wound. The admission rates for child and adult cases were similar.

5.1.8 Beach volleyball

There were 10 cases of beach volleyball injury, eight of whom were males. Cases were spread fairly evenly across the 5-year age groups from 10-14 years to 35-39 years. The causes of injury were: falls (2 cases), struck by object or person (2 cases) and 'other' causes [6 cases: foreign body in eye (1), hyperextended arm (1), injured toe in sand (3)]. The injuries sustained were: fracture/dislocated/sprained toe (3) sprain/strain to wrist/forearm (2); fracture/dislocation to hand/finger (2); fracture to cheek (1); fracture to shoulder (1); foreign body in eye (1).

5.2 VICTORIAN SPORTS INSURANCE DATA

Sportcover Insurance is the official insurer for players registered with the Victorian Volleyball Association. During the period 24 Jan 1998 to 23 Jan 2000 there were 2,500 senior and 1500 junior volleyball players covered by this insurance company. The Amateur Accident Insurance policy covers athletes for disablement, medical and physiotherapy expenses (only the proportion not covered by the player's public and private medical insurance) and loss of income, injury and death benefits.

There were only 58 insurance claims in the two-year period 1998-1999 (30 claims in 1998 and 28 in 1999) which indicates that insurance claims are a very selective source of injury data. The breakdown of claims by injury site and age of claimants is shown in Table 5:1. The most frequently injured body sites for which claims were made were the ankle (58.6%) and knee (17.2%). The peak age group for ankle injury claims was 30-34 years. Knee injury claims were more evenly spread across the age groups. The overall peak age group for injury claims was 30-34 years (32.8%). Injury claims were fairly evenly spread across the other age groups except for age groups 35-39 years and <14 years which had comparatively low proportions of injury claims (Table 5:1). Overall, more males than females made claims (62% versus 38%) and this was a consistent pattern for all body sites injured (with three or more claims).

Table 5:1. Site of injury by age of injured person (*n*=58)

Body site	**<14 years *n***	**15-19 years *n***	**20-24 years *n***	**25-29 years *n***	**30-34 years *n***	**35-39 years *n***	**>40 years *n***	**All Ages *n* (%)**
Lower limb								
• Knee		3	2	1	2	1	1	**10 (17.2%)**
• Leg					3	1	1	**5 (8.6%)**
• Foot							1	**1 (1.7%)**
• Ankle (inc. Achilles)	2	4	4	6	11	3	4	**34 (58.6%)**
Upper limb								
• Shoulder			1					**1 (1.7%)**
• Hand			1					**1 (1.7%)**
• Finger							1	**1 (1.7%)**
Head/trunk								
• Teeth					1			**1 (1.7%)**
• Back				1	2			**3 (5.2%)**
• Groin		1						**1 (1.7%)**
TOTAL	**2 (3.4%)**	**8 (13.8%)**	**8 (13.8%)**	**8 (13.8%)**	**19 (32.8%)**	**5 (8.6%)**	**8 (13.8%)**	**58 (100%)**

Source: *Sportscover Insurance*

5.3 INJURY DATA FROM AUSTRALIAN AND OVERSEAS STUDIES

5.3.1 Limitations of published studies

Few definitive conclusions about the frequency, incidence and pattern of volleyball injury can be drawn from a comparison of the published studies in volleyball. This is because of differences between the studies in the definitions of sport and sports injury, study populations, sources of data, age and sex of players, level of play (recreational, competition and first grade/elite) and methods of reporting results.

Appendix 1 gives a summary of volleyball studies referred to in this chapter. Most studies are small and the populations closely defined so that injury rates and risks cannot be generalised to different or larger populations of volleyball players.

Many reports lack information on participation and exposure ('time at play'). These deficiencies limit comparisons between sports and within sports for specific populations of players (for example males and females and elite and recreational players). Notwithstanding these caveats some tentative conclusions can be drawn from examining the literature.

5.3.2 Volleyball injury rate compared to other sports

The most reliable studies utilise rate data for comparisons, with participation (the active population) and exposure ('time at play') forming the denominator (for example, injuries/1,000 players or 10,000 hours of exposure to sport).

5.3.2.1 Children and youth

Two European school surveys of sports and active recreation injury to children and youth report comparative injury rates with participation and/or exposure data included (de Loes, 1995; Backx et al., 1991). Volleyball was ranked in the top ten sports for injury in both studies.

de Loes (1995) found an overall injury rate of 3.0 injuries per 10,000 hours of exposure in a large study of sports injury in 350,000 Swiss schoolchildren aged 14-20 years. Backx et al. (1991) used two different methods to estimate sports injury incidence rates in Dutch schoolchildren (per 1,000 young athletes a year and per 1,000 hours practice and games). Volleyball ranked 4th of 19 listed sports and physical education activities on injuries per 1,000 young athletes (548/1,000) and 1st on injury incidence per 1,000 hours in practice (6.7/1,000 hrs). The overall injury incidence rate for volleyball per 1,000 hours in games and practice combined was not published, so these findings cannot be compared to the findings from the Swiss study. In both countries the team ball sports with higher rates of injury than volleyball were soccer, basketball and handball.

By comparison, volleyball was a low-ranked sport for injury (30th out of 37 listed sports) in the only published Australian study, a survey of NSW schoolchildren, that compares injury across youth sport and active recreation activities (North Sydney Area Health Service 1997). The overall ranking for injury in the NSW study was based on proportion of participants injured, with no exposure (time at risk) data factored into calculations. Also, the self-reported injury data included only the most recent injury in the previous six-months. Volleyball ranked behind all other team ball sports except indoor cricket, and a range of individual sports and active recreational pursuits (for example, gymnastics, aerobics, horse riding, martial arts and skiing).

However, this study reported that volleyball was the highest ranked sport and active recreation pursuit for medically-treated injury (23% of injured volleyball players received later treatment from a doctor). Other highly-ranked sports were touch football (21%), soccer, rugby league, netball and gymnastics (all 20%). This finding indicates that volleyball injuries may be more severe than injuries in many other sports that have higher injury rates. By contrast, volleyball was a lower-ranked sport (27th out of 37 listed sports) based on the proportion of injured participants treated later at a hospital (6.8%), although the seven sports ranked just above it had very similar proportions of hospital-treated injury cases (6.8-7.2%).

5.3.2.2 All ages

The only comprehensive study of comparative rates of injury that included exposure data was a Finnish study of six sports covered by a national scheme of compulsory player insurance (Kujala et al., 1995). Volleyball was the lowest-ranked sport for medically-treated injury per 1,000 player years of exposure (estimated) behind karate, judo, ice hockey, soccer and basketball. In another study, based on hospital injury data in a Swedish community, population rate data that included active and inactive community members was used to for rank sports for injury. Volleyball ranked 4th (rate: 8.6 injuries per 10,000 person years) behind soccer, handball and downhill skiing (Ytterstad, 1996).

Aargaard et al. (1997) found an incidence of 4.2 injuries/1,000 volleyball hours in indoor volleyball and 4.9/1,000 in beach volleyball in a prospective comparative study of 295 Danish volleyball players of mixed abilities. Players were followed over one season of beach volleyball and the subsequent indoor volleyball season. Although other sports were not included in this study, the authors compared their findings to those from two earlier Danish studies of sports injuries had used the same questionnaire and definition of injury. They reported that the overall injury incidence in volleyball (4.3/1000 volleyball hours) is comparable to other high performance team sports such as soccer (4.1) and ice hockey (4.7) but lower than European team handball (8.3).

Two other studies provided comparison data. In both of these the ranking exercise was based on frequency of medically treated injury cases drawn from a single or small number of treatment settings (Chan et al., 1993; Solgard et al., 1995). Volleyball ranked in the top five sports for injury in both studies, but neither study included participation data.

5.3.2.3 High grade and elite players

Only one of the published studies with a substantial or whole focus on elite volleyball players directly compared injury rates across sports. Bahr & Bahr (1997) compared the overall injury incidence found in their prospective study of Norwegian high-level volleyball players to those published for other sports that involved players of similar skill level that used the same definition of injury. The authors concluded that the incidence of injury in elite volleyball players (1.7 injuries per 1000 hours of play) is slightly lower than found in basketball (2.5/1,000 hours), and much lower than that found in soccer (8.6/1,000 hours), handball (8.3/1000 hours) and ice hockey (1.4 per 1,000 practice hours and 78.4 per 1,000 game hours).

5.4 PATTERNS OF INJURY

5.4.1 Age, gender and injury

The use of exposure data is especially important when assessing the influence of gender on injury rates because males generally have higher participation rates in sports played by both sexes and also spend more time in training and competition (Aargaard et al., 1997). There is some evidence that females may have higher rates of injury than males in recreational volleyball, perhaps confined to younger age groups, but data are scant and comparisons between studies are complicated by methodological differences.

The Swiss sports insurance-based study of youth sport by de Loes (1995) compared volleyball injury rates in 13,739 male and female players aged 14-20 years. The author found that females had a significantly higher rate of injury per 10,000 hours of exposure than their male counterparts (3.8 versus 3.0). Conflicting findings were reported from a Finnish study by Kujala et al. (1995), that also utilised sports insurance data. The study found only a small gender difference in injury risk in the 15-19 year age group (M52 injuries /1,000 player years versus F50).

Kujala et al. (1995) report that only females in the youngest and oldest age groups (aged<15 years and aged >35 years) experienced higher incidences of injury than males (F6.0 versus M16.0 and F81.0 versus M67.0, respectively). By contrast, young adult males in the five-year age groups 20-24 years and 25-29 years had much higher injury rates than their female counterparts (M236 versus F192 and M 155 versus F125, respectively). The overall sex difference in injury risk was small. Precise data on exposure (hours of training and competition) were not available in this study. Player years of play were aggregated (all registered players were insured) and designated as person years of play.

Several studies in higher level volleyball report that men and women were injured at comparable rates. Schafle et al. (1990) found in a prospective survey of high level competitors in the 1987 United States Volleyball Association (USVA) national tournament that the injury rate per 100 hours of play was higher for females than males (2.2 versus 1.8) but the difference was not statistically significant. Retrospective and prospective studies of injuries in elite and mixed ability volleyball players conducted in Denmark and Norway consistently found no significant difference in injury incidence in male and female players reported per 1,000 hours of competition and training (Aagaard & Jorgensen, 1996; Aagaard et al., 1997, Bahr et al., 1994; and Bahr & Bahr, 1997). Also, no sex difference in injury risk was reported from a prospective study of injury and disability in eight matched men's and women's intercollegiate varsity sports teams, that included volleyball (Lanese et al., 1990).

5.4.2 Anatomical site of injury

The ankle, knee, shoulder, fingers and back are consistently reported as the anatomical sites most at risk for injury in volleyball, although there are marked variations in the proportions of injuries reported for any particular body site in the studies reviewed (table 5:2).

Overall, the ankle is the most common site of injury, accounting for between 17% and 61% of reported injuries, followed by the finger (8-45%), knee (6-59%), shoulder (2-24%) and back (9-18%). The wide range of rates reported for a particular injury site is explained by variations in the size of the studies, the definition of injury used and, particularly, the source of injury data. For example, player surveys generally capture the widest range of injuries in terms of severity and type (acute or overuse), hospital E.D. studies generally underestimate overuse injuries and tend to capture more serious injuries and sports injury clinics capture the more serious injuries including overuse injuries. Most studies reported only the 4-5 major sites of injury.

Table 5:2. Major sites of injury: comparison of published studies on proportions of injuries at specific anatomical sites (for study details see Appendix 1)

Injury site	**Children & youth (recreational)** North Sydney Area Health Service (1997)[1] **Proportion (%)**	**All ages and abilities** Gerberich et al (1987)[2] Bhairo et al (1992)[3] Chan et al (1993)[4] Solgard et al (1995)[5] Kujala et al (1995)[6] **Proportion (%)**	**High grade/elite** Schafle et al (1992)[7] Watkins & Green (1992)[8], elite Rice & Anderson (1994)[9], elite Aagaard & Jorgensen (1996)[10] Aagaard et al (1997)[11], equal elite and recreational, indoor and beach Bahr & Bahr (1997)[12] **Proportion (%)**
Lower limb		90.0 (of severe injuries)[2], 57.4[6]	
• Thigh		2.3[6]	
• Knee	19.0[1]	59.0 (of severe injuries)[2], 6.8[3], 27.3[4], 6.1[5], 19.0[6] 1.8[6]	11.0[7], 30.0[8], 19.4[9] 19.0[10], 17.4[11], 8.0 (acute injuries only)[12]
• Leg			8.6[9] (inc. abdominal); 3.2[10]
• Ankle and foot	27.0[1]	23.0[2] (of severe injuries), 60.9[3], 17.0[4], 36.7[5], 34.6[6]	17.6[7], 35.0[8], 19.8[9]; 16.0[10], 20.6 (ankle only)[11], 54.0[12]
Upper limb		22.4[6]	
• Upper arm and shoulder	25.0[1]	8.0 (of severe injuries)[2], 2.6[3], 23.6[4], 5.0[5], 9.3[6]	8.4[7], 2.0[8], 16.2[9]; 17.0[10], 18.1[11], 8.0 (acute injuries only)[12]
• Forearm and elbow			2.3[11] 2.6[11]
• Wrist		2.3 (inc. palm)[6]	
• Hand/finger	39.0 (hand/finger)[1]	23.4 (wrist/hand/finger)[3] 44.6 (hand/finger)[5], 9.1 (finger only)[6]	10.0 (finger only)[7], 22.0 (finger only)[8], 10.8 (inc. wrist)[9], 22.0 (finger only)[10], 17.7 (finger only)[11], 7.0 (finger only)[12]
Head and trunk		20.2[6]	
• Teeth		2.0[6]	
• Eye		1.9[6]	
• Head and neck		4.3[3], 5.6[6]	4.0[9]
• Thorax and abdomen		0.9[6]	
• Back	14.0[1]	12.3 (lower spine)[4], 8.7[6]	14.2 (low back)[7], 18.1[9], 9.0[10] 8.4[11], 11.0 (lower back)[12]
• Pelvis and hip		0.6[6]	4.2[11]

5.4.3 Type of injury

When studies are compared, sprains (ligament) and strains (muscle) together account for approximately two-thirds or more of volleyball injuries (64-81%) across all age groups and playing levels (table 5:3). Fractures and dislocations account for smaller proportions of injuries (2-14% and 1-5% respectively). The three studies that reported comparatively higher proportions of fractures (9%-14%) sourced their data from hospital emergency departments where you would expect to find higher proportions of more serious sports injury cases presenting (Bhairo et al., 1992; Solgard et al., 1995; Ytterstad, 1996).

Few of the studies in our review report overuse injuries and the proportion of injuries attributed to overuse varied widely (9-33%). In general, current sources of sports injury data (first aid stations, hospital emergency departments, player/population surveys) are biased toward the collection of acute injuries or overuse injuries with an acute exacerbation. Persistent overuse injury cases are more likely to present to different treatment practitioners/facilities, for example sports injury clinics, general practitioners, physiotherapists, chiropractors and masseurs. Data from these sources are sparse.

Table 5:3. Major types of injury: comparison of published studies (for study details see Appendix 1)

Injury site	**Children & youth** De Loes (1995)[1] North Sydney Area Health Service (1997)[2] **Proportion (%)**	**All ages and abilities** Bhairo et al (1992)[3] Chan et al (1993)[4] Solgard et al (1995)[5] Kujala et al (1995)[6] Ytterstad (1996)[7] **Proportion (%)**	**High grade/elite** Schafle et al (1992)[8] Watkins & Green (1992)[9] Aagaard & Jorgensen (1996)[10] Bahr & Bahr (1997)[11] **Proportion (%)**
Sprains & strains	73.9 (sprains and strains)[1], 71.0 (sprains 30.0, strains 41.0)[2]	70.0 (sprains and strains)[3], 72.8 (sprains 55.2, strains 17.6)[4], 80.5 (sprains 72.6, strains 7.9)[5], 74.8 (sprains and strains)[6], 70.3[7]	64.3 (sprains 27.9, strains 36.4)[8], 79.0 (sprains 45.0[9], strains 34.0)[9]
Fractures	5.5[1]	14.0[3], 9.7[5], 5.9[6], 9.0[7]	~3.0[8], 2.0[9]
Dislocations	3.1[1], 5.0[2]	4.0[3], 1.4[6]	~3.0[8], 2.0[9]
Contusions	12.1[1], 47.0[2]	8.0[3], 6.1[4], 8.6[5], 18.3 (including wounds)[6], 13.5 (including wounds)[7]	~5.0[8]
Wounds	1.8[1], 4.0[2]	2.0[3]	~2.0[8]
Inflammation/ overuse	33.0[2]	9.1[4]	20.8[9]

5.4.4 Player position and injury

Only one study identified in our review reported on player position and injury. Schafle et al. recorded injuries in the 1987 USVA national tournament that involved 1,572 skilled and competitive players of both sexes (Shafle et al., 1990). The authors found that net play was three times more hazardous than back row play (2.7 injuries/100 hours of play versus 0.8, P~0.0001). Position 3 and 4 (middle hitter/blocker) and on-side or strong-side hitter had the highest rates of injury (3.9 and 3.1 respectively).

These positions accounted for over two-thirds of all injuries (including 68% of ankle injuries) but comprised only about one third of the possible court positions. In a later article, Schafle commented that similar findings were reported from an Italian study of volleyball injuries published in 1981 (Gangitano et al., 1981 cited in Schafle, 1993).

5.4.5 Player manoeuvres and injury

Six studies, in four different populations of players, report on player manoeuvres/skills and injury (Schafle et al., 1990; Watkins & Green, 1992; Bahr et al., 1995, Bahr & Bahr, 1997; Aagaard & Jorgensen, 1996; Aargaard et al., 1997). It is clear from these that the actions of blocking and attacking (hit/spike) are associated with the majority of injuries in volleyball. Each of these two manoeuvres/skills was uniformly reported to be responsible for one-quarter or more injuries. Field defence was variously reported to be associated with 6% -11% of injuries and sets with 2-4%.

Watkins & Green (1992) included a number of other elements of the game in their analysis of the causes of injury in 86 Scottish elite (first division) male players. Landing (15%), collision with opponent (13%), collision with own team (11%) and general warm-up (6%) were all found to be associated with injury (more than one cause of an injury could be recorded per case). Gerberich et al. (1987) also reported mechanisms of injury using different categories. According to their categorisation *jump, land, and twist upon landing* actions caused over 60% of 35 severe injuries in volley players referred to a sports medicine clinic in the United States. *Spiking* was associated with 9% of injuries and a number of different mechanisms accounted for the remainder (*repetitive motion trauma, sudden sideways twist, stretching* etc.).

Information on player manoeuvre and injury type was sparse except for consistent mention that blocking accounted for over one-half of ankle sprains, mainly caused by foot conflict underneath the net (Schafle et al., 1990; Bahr & Bahr, 1997; Aagaard & Jorgensen, 1996). The most detailed information was given by Aagaard & Jorgensen (1996) from their study of injuries in 137 Danish elite volleyball players over the 1993-4 season. In this population of players blocking injuries (49/177 injuries; 27.6%) were mostly to the finger and ankle/foot, accounting for 74.3% of the 39 finger injuries and 41.0% of the 39 ankle/foot injuries. Spiking injuries (57/177 injuries; 32.2%) were mostly to the shoulder, knee, and ankle accounting for 80.0% of the 30 shoulder injuries and 51.5% of the 33 knee injuries and 17.9% of the 39 ankle/foot injuries. Field defence injuries (12/177 injuries; 6.8%) were fairly evenly spread, involving the finger, knee, ankle/foot and back.

5.4.6 Training versus competition

Four studies compared injury in training to competition. The two studies of sports injuries in school children report conflicting findings (Backx et al., 1991; North Sydney Area Health Service, 1997). Backx et al. (1991) conducted a longitudinal study of sports injury in 1,818 Dutch schoolchildren aged 8-17 years. The authors reported that volleyball had the highest injury incidence rate (6.7 injuries/1,000 hours of practice) of the 18 organised sport and physical education activities studied but was among the lowest ranked sports on injury incidence in games (rate not reported because fewer than five volleyball injuries were registered).

By contrast, the New South Wales sports injury survey of 15,525 schoolchildren aged 11-19 years conducted by the North Sydney Area Health Service (1997) found that 21% of volleyball injuries occurred in training, a lower proportion than occurred in club competition and tournaments combined (26%). The remainder occurred in PE classes (10%), school sport (10%), leisure (10%) and trial matches and selection trials (6%).

Two prospective studies of adult players report that the risk of injury is higher in match play than training but the strength of the findings differ. In a prospective study of 272

Norwegian elite volley ball players followed over one season, Bahr & Bahr (1997) found a greater than two-fold increased risk of injury in match play compared to training for men (3.9 injuries per 1,000 hours versus 1.5 per 1,000 hours, RR 2.7, $P<0.001$), but not for women. Conflicting results were reported from a similarly designed study by Aagaard et al. (1997) in which 295 Danish young adult volleyball players (an equal mix of elite and recreational players) were tracked over one season of indoor volleyball. The authors found only a small and non-significant difference in injury incidence in competition compared to training (4.8 per 1000 hours versus 4.1 per 1,000 hours; n.s.).

5.4.7 Injury severity

Although data are scant, it appears that the majority of volleyball injuries are relatively minor. Two studies, both utilising hospital emergency department data, reported injury severity for recreational volleyball but used different indicators. Solgard et al. (1995) found that four of 278 injuries presentations to one hospital casualty department (1.4%), all to the knee, resulted in admission for inpatient care, 20% of injuries had treatment outside the hospital and 5% received physiotherapy treatment. A follow-up survey of injured patients showed that 39% of injuries resulted in sick leave and 12% of patients suffered economic loss for their injury. In terms of loss of playing time and time needed to reach the previous activity level, 44% of injuries resulted in an absence from play of more than one month.

Ytterstad (1996) used the Abbreviated Injury Scale (AIS) to score injury severity in cases of volleyball and other sports injuries presenting to one Norwegian hospital emergency department over an eight year period. The mean score for the 155 volleyball injuries was 1.116 [on a scale of 1(low severity) to 5 (high severity)] indicating that most injuries were of low severity on a threat to life only scale. Little variability was observed between the mean AIS score for volleyball and other sports, with the exception of downhill skiing that had an AIS score of 1.363.

Three studies of high level/elite players contained information on severity of injuries but, again, findings were not comparable. Schafle et al. (1990) reported that only 8 of the 154 injuries (5.2%) in participants competing in the 6-day 1987 USVA national tournament resulted in more than 5 days of time loss, two of which required surgery. Watkins and Green (1992) investigated injury in first division Scottish male volleyball players over one season and reported that 74% of the 86 injured players were able to resume training and playing within 2 weeks of injury. However, in 10% of cases injured players were unable to train or play for 7-14 weeks. Similar results were reported by Aagaard et al. (1997), from a study that followed a group of 295 Danish indoor and beach volleyball players over one season in each sport. Half of the participants were elite players and half recreational; there were equal numbers of males and females. In 80% of cases, the injured player was able to resume playing within two weeks, in only 7% of cases, the player's disability lasted for more than 7 weeks.

5.4.8 Level of play and injury

The Danish study by Aagaard et al. (1997) included equal numbers of elite and recreational beach and indoor volleyball players. The authors report that elite players played more than twice as many hours as recreational players (334.1 volleyball hours/year/player mean versus 153.7, p=0.01). Although elite players had more injuries per year than recreational players (1.29 versus 0.80), the incidence of injury was significantly lower in elite players compared to recreational players when exposure was factored into the analysis (3.9/1,000 hours versus 5.2/1,000 hours, $p=0.02$).

5.4.9 Indoor versus beach volleyball

Only one study compared the incidence and pattern of injuries in beach and indoor volleyball (Aagaard et al., 1997). The authors found that the incidence of injury was higher in beach volleyball than indoor volleyball, but the difference was not statistically significant [*indoor*: 286 injuries in 277 players (1.03 injuries/player/year) and 4.2/injuries/1000 volleyball hours vs. *beach*: 24 injuries in 137 players (0.18 injuries/player/year) and 4.9 injuries/1000 volleyball hours].

In both types of volleyball the four major sites of injury were the ankle, shoulder, finger and knee, however the pattern of injury was different. Significantly more shoulder injuries ($p=0.04$) and fewer ankle ($p=0.048$) and finger (n.s.) injuries were found in beach volleyball compared with indoor volleyball. The authors suggest that the observed higher frequency of shoulder (mostly overuse) injuries in beach volleyball players is caused by players executing a greater number of spikes and serves in a match because there are fewer players on a beach volleyball team.

The authors speculate, that beach volleyball players are at higher risk of injury because they have to cover a greater area of the court than indoor players and are called on to spike the ball from unpredictable positions using unaccustomed shoulder movements. Another possible explanation may be that in beach volleyball players are unable to generate the explosive and fluid spike approach of indoor volleyball because of the inconsistent playing surface. Players are forced, therefore, to generate power from the shoulder which may make it more vulnerable to injury (Shears, personal communication).

The authors also attribute the lower frequencies of finger and ankle injuries in beach volleyball players compared to indoor players to differences in the two games. Beach volleyball involves fewer blocks (thereby reducing the risk of finger injuries) and more single player blocks (thereby reducing the risk of ankle injury caused by landing on another player's foot). They found that more injuries in beach volleyball, than indoor volleyball, occurred in field defence ($p<0.001$) and fewer in blocking (n.s.).

6. MAJOR VOLLEYBALL INJURIES: EPIDEMIOLOGY AND AETIOLOGY

There are no large, well-designed, longitudinal studies of volleyball injuries at the community level in Australia or elsewhere, so definitive evidence is lacking on the comparative incidence of injury to specific anatomical sites in volleyball and the nature of these injuries. A recent Western Australian prospective cohort study which followed a random sample of 1,391 recreational players competing in four major sports over two seasons did not include volleyball (Stevenson et al., 2000).

The closest studies, in terms of design and methodology, are the overseas prospective studies by Aargaard et al., (1997) and Bahr & Bahr, (1997) that followed cohorts of registered players through one season of volleyball in Denmark and Norway, respectively. However, in neither study was the sample of players representative of registered players in their respective communities. Both cohorts were weighted towards adult and elite players. The Norwegian study included beach volleyball players. In both studies injuries were recorded progressively to minimise recall bias, but only acute injuries were registered in the Norwegian study.

Both prospective studies reported that the ankle, knee, shoulder and hand/fingers were the most vulnerable anatomical sites for injury. This is consistent with findings from most studies included in our review (table 5:2) and results from the analysis of Victorian hospital E.D. data referred to earlier (section 5.1.5). However, the relative proportions of injuries reported to occur at these sites differ considerably in the two prospective studies and in all studies in our review (table 5:2). For example, Bahr & Bahr (1997) identified the lower back as a high-risk site for injury, accounting for 11% of reported injuries in their study (second only to the ankle). It was not among the four major locations for injury identified by Aagaard et al., (1997) but was identified as a vulnerable site for injury in other studies, particularly a number involving high level/elite players (table 5:2). For the most part, conflicting findings are the result of methodological factors such as the definition of injury used, source of data and patterns of participation in the communities studied.

6.1 ANKLE INJURIES

Ankle injuries (predominantly sprains) are the most common acute injury in volleyball both at the recreational and high/elite levels (tables 5:2 & 5:3). They reportedly account for between 17% and 61% of volleyball injuries (table 5:2).

6.1.1 Ankle injuries in children and youth

Only two studies report ankle injuries separately for children and youth. The NSW Youth Sports Injury Report (Northern Sydney Area Health Service, 1997), based on a survey of 15,525 youth aged 11-19 years, found that the ankle and finger were the most frequently injured anatomical sites, each accounting for 27% of volleyball injuries (based on the most recent injury). No detailed information is given on the subset of volleyball ankle injuries. The analysis of Victorian Emergency Department Data (VEMD) conducted for this study showed the ankle injuries accounted for 9.5% of the 42 volleyball injury presentations in children and youth aged 0-15 years. Three of the four injuries were sprains, one was a fracture. The one-line case narratives indicate two scenarios: '*went over on ankle*' and '*fell heavily on ankle*'.

6.1.2 Ankle injuries in adults

The most detailed information on ankle injuries is derived from studies of adult, predominantly elite, players. Two complementary studies involving Norwegian elite players investigated acute ankle sprains (inversions) in volleyball in detail (Bahr et al., 1994; Bahr & Bahr, 1997). The earlier of these studies was a retrospective study conducted after the 1991-92 season involving 318 players in the top two divisions of the Norwegian Volleyball Federation (Bahr et al., 1994). In the subsequent follow-up study, acute ankle inversion injuries were prospectively monitored in a cohort of 272 players over the next volleyball season (Bahr & Bahr, 1997). In both studies only ankle inversions that caused an absence of one or more days from training or match play were included. The other prospective study of volleyball injuries reported in the literature involved 295 Danish recreational and elite beach and indoor volleyball players followed over two seasons, one season in each sport (Aagaard et al., 1997).

6.1.3 Incidence, risk factors and mechanisms of ankle injury

In the Norwegian retrospective study (Bahr et al., 1994), 63 ankle inversion injuries were reported among 318 players during 60,612 hours of training and 928 matches. The authors calculate that the incidence of ankle inversion injuries in volleyball is approximately 1.0 injuries per 1,000 player hours and the risk is about four times greater in competition than training (RR 3.9, $p<0.001$). The subsequent prospective study, the more reliable in terms of methodology, reported a slightly lower ankle inversion injury incidence rate (0.9 injuries per 1,000 player hours) and a much lower, but still significant, increase in risk of ankle injury in competition compared to training (RR 2.1, $P<0.05$) (Bahr & Bahr, 1997). Both studies found that females had a higher risk of ankle injury than males but in neither study was the difference statistically significant.

Aagaard et al. (1997) found that 63 of the 64 ankle injuries reported in two seasons of Danish volleyball competition were acute injuries associated with indoor volleyball (representing 22.0% of all indoor volleyball injuries). Extrapolating from data given in the article, the risk of ankle injury in indoor volleyball was 0.9 injuries/1,000 player hours, the same as reported by Bahr & Bahr (1997). However, the Danish study reported only a small, non-significant difference between the injury incidence in training and competition (4.8/1000 player hours versus 4.1), although these data represent all injuries not just ankle injuries. Although the authors found a higher overall injury incidence in males than females (4.4 versus 4.1), the difference was not statistically significant. The finding of a non-significant difference in risk of injury in the sexes concurs with the findings from the Norwegian studies referred to previously and an earlier U.S. study by Schafle et al. (1990).

All four Scandinavian studies report that the majority (52-79%) of ankle injuries in volleyball players are recurrences of earlier similar injuries at the same site (Bahr et al., 1994; Bahr & Bahr, 1997; Aagaard & Jorgensen, 1996; Aagaard et al., 1997). Bahr & Bahr (1997) reported from their prospective study that the relative risk of injury was 3.8 ($P<0.001$) for previously injured ankles vs. non-injured ankles. The relative risk of injury in an ankle that had suffered an ankle sprain in the previous 6 months was particularly high (42.0±7.0%; risk ratio: 9.8 vs. uninjured ankles; $P<0.000001$)

By contrast, Schafle et al. (1990) reported that only 36% of ankle sprains treated by the on-site medical team in the 1987 US National Amateur Volleyball Tournament were in players that had a previous history of ankle sprains. In relating the pre-tournament histories to tournament injury reports, the authors found no significant difference in the risk of an ankle injury in ankle-injured players who had positive histories of ankle injuries prior to the tournament and uninjured players who also had positive histories (36% versus 24%, p=~0.4). The proportion of ankle injuries reported in the US tournament study is low compared to most other studies (table 5:2). It may be that some players with a history of ankle injuries self-treated their injuries during the US tournament event. Schafle et al. (1990) present anecdotal evidence of widespread self-treatment of overuse and chronic injuries of the knee, back and shoulder with ice during tournament breaks. This leads one to suspect that a proportion of chronic ankle injuries may also have been self-treated by players keen to continue competing.

Several studies have found that ankle injury mainly occurred in the net zone and that most ankle inversion injuries (48-87%) result from landing on the foot of a team mate or, less commonly, an opponent after blocking or spiking the ball (Schafle et al., 1990; Watkins & Green, 1992; Hell & Schonle, cited in Watkins and Green 1992; Aagaard et al., 1997; Bahr et al., 1994; Bahr & Bahr, 1997).

With reference to other potential risk and contributory factors, Bahr and Bahr (1997) found no significant relationship between the risk of ankle injury and age, experience (total number of years playing volleyball or years playing on the same level), skill level (national team vs. others) or player function (setter, middle blocker, outside hitter or utility player). Also, the authors found no relationship between the incidence of ankle injury and training level (number of hours of training per week or match to training ratio). These findings need to be confirmed in further prospective studies in recreational volleyball populations covering different age groups and ability levels before unequivocal acceptance.

The other interesting finding in the literature was the reportedly lower incidence of ankle inversion injuries in beach volleyball compared to indoor volleyball (Aagaard et al., 1997). The authors suggest two explanations. First, beach volleyball is played in 2- or 3- person teams which reduces the risk of stepping on another player's foot during play. Second, sand is a softer and more forgiving playing surface then the hard surfaces on which indoor volleyball is played (Aagaard et al., 1997).

6.2 KNEE INJURIES

In the literature, knee injuries are reported to comprise between 6.1% and 59.0 % of volleyball injuries, the wide variation explained by the source of data and definition of injury used (table 5:2). Gerberich et al. (1987) report the highest proportion of knee injuries in our review (59%) but their data was confined to 'severe' injuries (defined as injuries referred to an outpatient sports medicine clinic for rehabilitation). Knee injuries accounted for 59% of injuries to 106 volleyball players referred to the clinic for treatment and 97% of cases requiring surgery

There is sparse information on the incidence and pattern of knee injuries in the general population of volleyball players. Rice & Anderson (1994) found that 19.4% of the 222 musculoskeletal injuries in members of the US National Volleyball team referred to the team's primary care clinic from 1981-91 were knee injuries, predominantly patellar tendinitis. (There were few recorded knee derangement injuries but a small number may have been treated directly by the team orthopaedist.) Schafle et al. (1990) report that 17 knee injuries occurred in the six day USVBA tournament in 1987 that involved 1,520 high-level participants during 7,812 hours of play. Approximately two-thirds (64.7%) of the knee injuries were inflammation/overuse problems (jumper's knee and patellofemeral dysfunction) and one-quarter (23.5%) were ligament sprains. The authors comment that overuse injuries were probably more common than reported to the tournament first aid post because it was not unusual to see players self-treating knees with ice between and after matches.

Three other studies give some additional information but are biased towards serious knee injuries because they utilise retrospective data from specialist sports medicine clinics. Gerberich et al. (1987) analysed data on serious volleyball cases treated at one hospital sports medicine outpatient clinic in Minnesota. The study found that the knee injuries primarily involved patellofemoral (32.9%), ligament (30.0%) and meniscus (21.4%) damage. The authors report a different age pattern in males and females. In males the majority of knee injuries occurred in players aged 30-39 years (55.0%), whereas in females the majority occurred in younger players aged 15-24 years (63.0%).

Kujala et al. (1996) report from another retrospective study that volleyball players accounted for 11.6% of the 886 patients with knee disorders treated at a sports medicine clinic, ranking behind soccer (20.8%) and long-distance running (13.1%). The distribution of the most common serious knee disorders in their series of volleyball players were: patellar apicitis and peritendinitis (jumper's knee, 37.9%), patellar chondropathy (13.6%), meniscus tear (5.8%), knee sprain (1.9%), Osgood-Schlatter's Disease (1.0%), knee contusion (4.9%) and other knee disorders (22.3%). In this study males appeared to be more at risk of ligament damage than females (36.1% versus 23.5%), and females more at risk of patellofemoral involvement (38.2% versus 32.9).

A different gender-related pattern is reported from a retrospective series of volleyball players with severe knee ligament injuries treated at the Orthopaedic Clinic of Rome University (Ferretti et al., 1992). The series was confined to cases that required surgery. Forty-two of the 52 cases of serious ligament injuries were female (81%). The proportion of women in the Italian Volleyball Federation was 61% over the period of case capture (1979-89), indicating that females are over-represented in knee ligament injury cases. Studies of injury patterns in other sports played by both sexes that involve cutting and jumping, such as basketball and soccer, have shown that females are at higher risk for knee ligament injuries than their male counterparts.

The most detailed research on serious knee injuries in Italian volleyball has been undertaken by Ferretti and colleagues that include an investigation of jumper's knee in a random sample of 407 volleyball players competing in different divisions of the Italian Championship and follow-up in-depth studies, and a case series of traumatic injuries of the knee ligaments that required surgical intervention (Ferretti, 1986; Ferretti et al., 1990; Ferretti et al., 1992). Their data indicate that overload knee injuries (predominantly jumper's knee) are slightly more frequent than traumatic knee injuries, primarily ACL tears (Ferretti et al., 1990).

6.2.1 Jumper's knee

Jumper's knee (patellar tendinitis) is an overuse syndrome that is characterised by lesions (microtears) or degeneration in the patellar tendon, perhaps with inflammation, that may progress to complete rupture, although this is rare (Ferretti, 1986; Cook et al., 1997). It is usually described as tendinitis but some researchers consider that tendonosis is the more accurate description because of the absence of inflammatory cells on histopathological examination (Cook et al., 1997). Jumper's knee is commonly found in athletes involved in repetitive jumping sports (for example, basketball, volleyball, soccer and high jump), weight lifting and bicycling. The usual symptoms are anterior knee pain with jumping and landing, dull aching pain after sports participation which progresses, in chronic cases, to constant pain during activity and at rest, and point tenderness at the site of the damage (the bone-tendon junction of the knee).

Nearly one-quarter (22.8%) of the 417 volleyball players interviewed in the random survey of Italian players by Ferretti and colleagues were currently suffering, or had suffered in the past, from the typical symptoms of jumper's knee (Ferretti, 1986). The author comments that the only comparable statistic for an overuse injury is epicondylitis (tennis elbow) in tennis players. The high proportion of affected players in volleyball is attributed to the high frequency of jumping in games and training sessions, exacerbated by modern developments in the game including two- and three- man blocking and the execution of the service in mid-jump.

The survey found a positive relationship between the number of weekly training sessions and the onset of jumper's knee. The proportion of players affected increased as the amount of weekly training increased, in a direct relationship, peaking in top level players who trained more than 4 times a week (40% of whom reported suffering jumper's knee at some time in their careers). However, training that included weight lifting and plyometric (rebounding and jumping) exercises did not appear to increase the risk of jumper's knee. Years of play had only a very slight effect, there was a peak incidence around the third year of play but sudden onset was common after many years of play.

The other factor that was reported to have a significant impact was the type of playing and training surface used regularly. Over one-third (37.5%) of players that regularly played on cement and one-quarter (23.2%) of players who played on linoleum were affected compared with only 4.7% of those who played and trained regularly on wood (parquet).

Intrinsic factors were studied in follow-up investigations of affected players (*n*=93). No relationship was found between the incidence of jumper's knee and age and sex. Also, no consistent relationship was found between jumper's knee and the morphology of the knee extensor mechanism and derangement to it, including the alignment of the knee, extensor mechanism, position of the patella, characteristics of the tibial tuberosity, rotation of the femur and of the tibia, contracture of the knee flexure, degree of constitutional instability and characteristics of the foot and morphotype (body form including height). Evidence from other studies suggest that the most proficient jumpers are at higher risk (Lian et al., 1996; Richards et al., 1996).

Ferretti (1986) concludes that, contrary to his original expectations, extrinsic factors appear more important than intrinsic factors in the development of jumper's knee and recommend that preventive efforts concentrate on these. In players with symptoms, conservative treatment (rest, stretching, physical therapy and anti-inflammatory drugs) is usually successful and most athletes completely resume sports activity at their previous level of play.

6.2.2 Knee ligament injuries

Ferretti and co-researchers also reported on a case series of 42 volleyball players that were surgically treated for knee ligament injuries between 1978 and 1988 in one Italian university hospital (Ferretti et al., 1990). Thirty cases were acute injuries and the remainder involved chronic instability. All cases had experienced anterior cruciate ligament tears, some with additional damage to the menisci cartilage and one case also involved the posterior cruciate ligament. The most frequent mechanism of injury was landing from a jump in the attack zone, with no physical contact with their own team-mates or opponents involved. More knee ligament injuries occurred in match play than in training (55% vs. 45%), despite the greater length of time spent in training. (On average, three times as many hours per week were spent by injured players in training compared to match play.) The authors suggest two possible explanations. First, more effort is expended by players in competition and, second, an individual player's time at risk is actually greater in matches than in training.

A striking finding was that the risk of serious ligament injuries was much higher in women than men (80% vs. 20%). Similar findings have been reported for volleyball in one study of knee injuries in youth sports (de Loes et al., 2000) and in several studies of ACL injuries in other sports that involve jumping, quick stopping and cutting, for example basketball and soccer, and in military training (Harmon & Ireland, 2000; Gwinn et al., 2000). In sports in which males and females both participate with similar rules and equipment, the likelihood of sustaining an ACL injury reported to be two to eight times greater for females than for males, although the absolute number of ACL injuries is higher for males due to their higher participation rates (Griffin et al., 2000). There is some evidence that ACL injuries in females are predominantly non-contact injuries, whereas ACL injuries in males mostly occur in contact situations.

A number of gender differences in anatomy and structure have been suggested as contributory factors to the apparent higher risk of ACL injury in females. These include lower limb alignment, ligamentous laxity (related to hormonal influences) and ligament size, intercondyal notch dimension and body weight (Harmon & Ireland, 2000). Research on these potential risk factors is sparse and their relative contribution to ACL injuries is unclear (Harmon & Ireland, 2000). In general, intrinsic factors are not amenable to change so preventive efforts should focus on modifying extrinsic factors.

Extrinsic factors include differences in muscle strength and conditioning, muscle recruitment pattern, experience, skills and landing techniques (Harmon & Ireland, 2000). In a recent review, Harmon & Ireland (2000) conclude that there is little current evidence that shows that experience and skill differences make any contribution to the higher ACL injury rate in females and that many questions remain unanswered on the role of conditioning, muscle strength and recruitment. Early data on the effect of neuromuscular training programs (balance board and plyometric training) suggest that they may have some value in reducing ACL injuries in females (Hewett et al., 1996; Hewett et al., 1999).

6.3 SHOULDER INJURIES

Shoulder injuries, predominately overuse injuries, are fairly common in volleyball. They are variously reported to account for between 2.0% - 23.6% of injuries in the studies included in our review (table 5:2). Two of the three volleyball studies that report comparatively low proportions of shoulder injuries (≤5.0%) were based on hospital casualty data that generally underestimate the frequency of chronic overuse injuries. The other study to report a low proportion of shoulder injuries (2.0%) is a survey of First Division male Scottish National League players (Watkins & Green, 1992). This frequency is much lower than reported from other studies involving elite players (Rice & Anderson, 1994; Aagaard & Jorgensen, 1996; Aargaard et al., 1997; Bahr & Bahr, 1993). The highest level of shoulder injuries (23.6%) was reported from a study based on hospital sports injury clinic data (Chan et al., 1993) which would probably capture a higher proportion of overuse injuries compared to other data sources.

Only one study in our review included data comparing the risk of shoulder injuries in female and male players. In a retrospective study of Danish elite players, Aagaard & Jorgensen (1996) found females to be at higher risk of shoulder injury (and more severe shoulder injury) than their male counterparts. Shoulder injuries accounted for 22% of all injuries in females compared to 13% in males, no test of significance was given. This finding requires confirmation in prospective studies in other populations of players.

Aagaard & Jorgensen (1996) also reported on the change in the rate of shoulder injury over time Comparing their results to an earlier similar survey, the authors found that the incidence of overuse injuries in males (predominantly to the shoulder and knee) increased significantly from 0.5 per player per year in 1983-84 to 1.8 in 1993-4 (P=0.001). They attribute this increase to the 50% increase in training over the ten-year period (from 2-4 to 4-6 sessions a week). Females were not included in the earlier survey.

Spiking and, to a lesser extent, serving are identified in a number of reports as the manoeuvres (skills) most associated with shoulder overuse injury in volleyball players (Gerberich et al., 1987; Aargaard & Jorgensen, 1996; Aargaard et al., 1997). It is estimated that an elite level attacker with 16-20 hours weekly practice time spikes the ball 40,000 times in a season (Dubotzky et al., cited in Kugler et al., 1996).

Aagaard et al. (1997) report a significantly higher frequency of shoulder injuries in beach volleyball players compared with indoor players (43% vs. 16%; P=0.004). The authors attribute this discrepancy to higher exposure to movements associated with shoulder overuse in beach volleyball. Because there are only two players in the team, beach players execute many more spikes and serves in a match and hit the ball from more unpredictable positions than their indoor counterparts.

6.3.1 Types of shoulder injury

Detailed information on the type of shoulder injuries in volleyball is also sparse, particularly for lower-level players. Available evidence suggests that among higher level players, 75%-90% of shoulder injuries are overuse injuries resulting in tendinitis of the rotator cuff (impingement syndrome) or biceps tendon (Schafle, 1990; Schafle, 1993; Rice & Anderson, 1994; Aagaard & Jorgensen, 1996; Aagaard et al., 1997; Briner & Kacmar, 1997).

6.3.1.1 Chronic shoulder pain and impingement

Two small studies of higher-level players (from the English national squad and Third Division German teams) indicate that shoulder pain syndrome occurs commonly in players at these levels (Kugler et al., 1996; Wang et al., 2000). In both studies, most players with shoulder pain indicated it was located laterally on the dominant shoulder which is consistent with descriptions of the syndromes of rotator cuff impingement (Wang et al., 2000).

Kugler et al. (1996) investigated muscular imbalances and shoulder pain in 30 volleyball attackers in the third national German Volleyball League (15 subjects with shoulder pain and 15 without) compared to 15 recreational athletes without any overhead sports activities. The authors found differences in the playing and non-playing shoulders of both groups of volleyball players compared to controls whose shoulders were symmetrical. In volleyball players, the playing shoulder was depressed, the scapula lateralised and the dorsal muscles and posterior and inferior part of the shoulder capsule shortened compared to the non-playing shoulder. These differences between the dominant and non-dominant shoulder were more marked in volleyball players with shoulder pain. The authors speculate that these shoulder adaptations may ultimately lead to a disturbance of the gliding and rolling motion of the humeral head, causing pain when the imbalances pass a certain level.

Wang et al. (2000) conducted isokinetic muscle strength tests and examined shoulder mobility to evaluate the differences in strength and mobility of shoulder rotator muscles in the dominant and non-dominant shoulders of ten male players from the England national men's volleyball squad. Six of the ten players reported shoulder pain. The authors found that these elite volleyball players had a lower range of motion (internal rotation) and relative muscle imbalances in the dominant compared with the non-dominant side and suggested that these findings may relate to shoulder overuse injuries. In the visual inspection and strength tests two subjects showed symptoms of supracapular neuropathy (nerve entrapment). This condition has also been found in the dominant shoulder of 4 of 16 members of the Belgian male volleyball team and tests suggested it was associated with increased range of motion of the shoulder joint (Witvrouw et al., 2000).

The aetiology of shoulder pain in the athlete appears to be multifactorial and is still the subject of debate and investigation. Shoulder pain is common in sports that involve repeated forceful overhand arm actions such as baseball, javelin throwing, tennis, and swimming. The conditions that cause shoulder symptoms are usually classified according to the mechanism of overuse injury to the shoulder – primary tensile overload (tensile tendinitis); primary impingement syndrome (compressive tendinitis); and impingement and overload secondary to shoulder instability (Blevins 1997).

There is conflict in the literature about which of the major overuse pathologies (tensile tendinitis, impingement syndrome or shoulder instability) is the primary condition in the majority of sports-related shoulder tendinitis cases, particularly in young athletes, and the sequence of degeneration to rotator cuff injury (Lehmann, 1988; Nirschl, 1992; McCann & Bigliani, 1994; Ticker et al., 1996). However, it is generally accepted that these shoulder pathologies may co-exist and are often inter-related.

Shoulder tendinitis (tensile tendinitis)

On the basis of his own surgical observations and clinical experience, Nirschl (1992) contends that shoulder tendinitis in overhand athletes, particularly young athletes, occurs mostly in the supraspinatus tendon and is caused primarily by intrinsic musculotendinous overload rather than subacromial impingement. He noted an acromial variant sufficient enough to cause primary impingement in only 10% of his patients, usually older patients.

Nirschl (1992) proposed the following continuum of rotator cuff pathology caused primarily by tendinitis:

Tendinitis caused by eccentric loading of supraprinatus tendon

➔fatigue and weakness

➔inflammation, vascular compromise, permanent tendon change (angiofibroblastic degeneration) with occasional progression to rupture

➔loss of humeral head control and upward humeral migration

➔secondary impingement syndrome

➔subteldoid bursitis

➔fibrosis with progression to rupture

➔humeral greater tuberosity exotosis and/or erosion; subacromial exotosis

➔acromial osteoarthritis commonly noted after the fifth decade.

Tensile tendinitis can occur in the tendons of the biceps, triceps, pectoralis major, latissimus dorsi, teres major and teres minor (Allingham 1995). The affected tendon must be identified so that an appropriate treatment and rehabilitation regime is applied.

Subacromial impingement syndrome

Subacromial impingement syndrome (sometimes referred to as 'swimmer's shoulder) is defined as a musculo-tendonous overuse injury in athletes (and non-athletes) who make repetitive movements of the arm/s at or above the horizontal position. There is direct compression forces that cause mechanical trauma (impingement lesions to the superior aspects of the rotator cuff) in addition to any tensile lesions caused by overloading (Allingham 1995).

First described by Neer in 1972, the condition is attributed to the repeated pinching, by the overhand motion, of the soft tissues (most commonly the tendons of the biceps brachii and rotator cuff muscles) between the head of humerus and the space formed between the acromion process of the scapular and the coracoacromial ligaments (McCann & Bigliani, 1994). The fraying commonly seen on the undersurface of the supraspinatus tendon in arthroscopic observation and cadavaric studies is ascribed to impingement rather than to tensile overload (Blevins, 1997).

The progression of primary impingement syndrome as described by Neer (1983) and elaborated in Lehman (1988) and Ticker et al. (1996) is as follows:

Impingement characterised by oedema and haemorrhage in the subocromial bursa and tendon (which typically causes pain after activities and is usually seen in athletes aged 12-25 years)

➔ Thickening and fibrosis of the subacromial bursa and tendinitis (which typically causes pain during activities but may cause pain at night, usually seen in athletes 25 years of age or older)

➔ Subsequent partial or full thickness tears of the rotator cuff tendons and bone spurring (commonly seen in athletes 40 years of age and older)

Athletes that repeatedly perform overhand motions (such as volleyball attackers) may pass through the stages of impingement syndrome more rapidly than indicated above and onset may be earlier (Ticker et al. 1996).

The condition is characterised by inflammation and intense pain especially if the affected arm is lifted vigorously forward and upward (the positive impingement sign). Pain at night and pain in activities of daily living that require the use of the hand at shoulder level and above are also characteristic complaints (Mc Cann & Bigliani, 1994).

Glenohumeral instability

The glenohumeral ligaments are the primary static stabilisers of the shoulder resisting anterior translation of the humeral head. They are grouped into three distinct segments: the superior, middle and inferior ligaments. These ligaments are repeatedly placed under considerable stress in the overhead athlete. The chronic repetitive stresses to the glenohumeral ligaments slowly elongate capsular restraints and cause glenohumeral instability, usually anterior. This results in secondary mechanical impingement and tensile overload. The concept of an instability continuum has been developed to explain the progression of shoulder dysfunction in younger athletes (approximately 18-35 years) who are most commonly involved in sports such as swimming, tennis, baseball or javelin throwing.

Jobe & Pink (1993) defined the following stages to rotator cuff tear when the primary condition is instability:

Instability caused by weakening of the anterior wall muscles through repeated stress

➔Anterior subluxation of the humeral head

➔Impingement

➔Rotator cuff tear

A number of authors suggest that attention to proper technique, body conditioning, strength and flexibility training as well as a gradual increase in the level of play and a balanced pre-season program will help to prevent and control shoulder injuries (McCann & Bigliani, 1994; Mallon & Hawkins, 1994; Ellenbecker, 1995; Kugler et al., 1996; Wang et al., 2000). It is recommended that all volleyball players undertake programs of shoulder exercises to improve muscular function of the dominant shoulder joint and flexibility (Kugler et al., 1996; Wang et al., 2000).

6.3.1.2 Acute shoulder injuries

The only study in the literature search to provide any details of acute shoulder injuries was the study of injuries in the 1987 U.S. National Amateur Volleyball Tournament that involved higher level players (Schafle, 1990). There were three acute injuries, two dislocations (both recurrent injuries) and one sprain.

In the Victorian hospital data analysed for this report there were 15 shoulder injuries to adult volleyball players recorded on the Victorian hospital emergency department database (VEMD) in the three-year period 1996-99. They included 7 sprains/strains, 4 dislocations, 2 fractures and 1 injury to muscle/tendon. The one-line case narratives for these cases are inconsistently completed and provide little extra information on the circumstances of the injury. At least four cases involved falls and one was attributed to hitting the ball. The other cases provided no detail or vague references to sore or painful shoulders after playing volleyball. Only one case of shoulder injury in a child was recorded, with no details on the type and circumstances of the injury.

6.4 HAND/FINGER INJURIES

Several studies report that hand/finger injuries are common in volleyball. Hand/finger injuries accounted for 8.0-44.6% of injuries in the studies included in this review (table 5:2). They may be under-reported, especially in adult competitive volleyball, because players may regard them as minor and '*part of the game*' (Schafle et al., 1992). Also, they may not be fully recorded in studies that use an injury definition based on absence from training and games because, commonly, players tape injured fingers and continue to participate (Bahr & Bahr, 1997).

6.4.1 Frequency and pattern in children and youth

Although evidence is limited, hand/finger injuries appear to be the most frequent injury in junior volleyball. The analysis of the Victorian hospital E.D. (VEMD) data undertaken for this review reveals that hand/finger injuries accounted for one-third of the 42 child volleyball presentations from 1996 to 1999. The NSW Youth Sport Injury Survey also reports that the hand/finger is the primary site of injury in children playing volleyball accounting for 39.0% of all youth volleyball injuries (North Sydney Area Health Service, 1997).

Some additional information on hand/finger injuries is provided by VISS data. The major injuries were: fractures (35.7%), sprain/strains (35.7%) and injuries to muscles and tendons (21.4%). One fracture case required hospital admission, all other cases were treated and discharged. The main mechanisms of hand/finger injuries was 'hit by ball' (42.8%) and 'hit hand/finger against another player' (14.3%).

6.4.2 Frequency and pattern in all ages/adults

The Victorian (VEMD) data for adults shows that hand/finger injuries account for 18.8% of all adult volleyball injuries presenting to Victorian hospital E.D. departments (*n*=249), the second-highest ranked site of injury behind the ankle. Hand/finger injuries were mostly sprain/strains (36.1%); fractures (27.7%) and dislocations (21.2%). Four cases required hospital admission. 'Struck by ball' was the most frequently mentioned mechanism of injury in the case narratives but only 18 of the 47 case narratives provided any additional information on the circumstances of the injury.

Single hospital case series in The Netherlands (Bhairo et al., 1992) and Denmark (Solgard et al., 1995) report that hand/finger injuries account for 23.4% and 44.6% of injuries presenting for treatment, respectively. The Dutch study (Bhairo et al., 1992) concentrated particularly on hand injuries and their long-term sequelae. Data on patient medical records were supplemented with information about the circumstances and sequelae of the injury event gathered in a follow-up telephone survey, conducted three to seven years after the original presentation. Fifty-five percent of the 226 patients with hand injuries could be contacted. In these circumstances recall bias may well have affected findings, but the accuracy of patient recall was described by the authors as 'remarkable' when specific items of survey data was checked for accuracy against similar information on the medical records.

The retrospective review of medical records for the five-year period found that 226 patients sustained a total of 235 hand/finger injuries (Bhairo et al. 1992). Females were over-represented. The mean age of hand-injured players was 26 years, similar for males and females. The injuries were mainly sprains (39%), fractures (25%, mostly to the fingers), contusions (16%) and dislocations (12%). Finger injury accounted for 44% of cases, the thumb and the little finger were most vulnerable to injury. The metacarpophalangeal (MCP) joint (38%) was the most vulnerable joint, followed by the proximalinterphalangeal joint (PIP) joint (17%). Four patients required admission for operative treatment, one patient suffered a ring injury that necessitated amputation.

The follow-up telephone survey (125 respondents) revealed that 57% played at the recreational level, the remainder were competition players (Bhairo et al., 1992). Among recreational players the left hand was the most frequently injured hand. Left-handed players were significantly over-represented in the recreational group of hand-injured players compared to their representation in the general population (20% vs. 11%, P=<0.005). In competition players the right hand was involved more often. The ball was involved in 88% of hand injury cases and most players were injured near the net. The majority of finger injuries were caused by hyperextension when fingers were in spread position when players were blocking or stopping the ball. Competition players were more likely to be injured when blocking the ball, whereas recreation players were more frequently injured attempting to stop the ball.

Hand/finger injuries are often regarded by players as minor. However, the follow-up telephone survey revealed that a substantial proportion of hand-injured players had quite serious repercussions from their injuries (Bhairo et al., 1992). Nearly three-quarters of survey respondents stopped playing volleyball after the injury for a median time of 4 weeks, 20% of these players stopped playing volleyball entirely. One-third did not go to work or school for a median of 4 weeks. While most injured players suffered no long-term effects, 28% reported stiff and crooked fingers with limitations and tenderness in the movements and other discomforts. Twelve per cent suffered a subsequent hand injury in volleyball, 4% to the same site.

In the other hospital case series, conducted in Denmark, Solgard et al. (1995) found that hand/finger injuries accounting for 44.6% of all volleyball injuries, the highest level in our review (table 5:2). The authors suggest that the hospital casualty department data they used may be weighted toward lower level club and recreational (school and leisure) players because higher-level competitive players may seek treatment outside casualty wards. Although their results may be affected by bias, they found that females, especially young females aged 11-17 years, were more at risk of hand/finger injuries than their male counterparts and lower-level club players were more at risk than players competing at the highest levels. Overhand passing, rather than blocks, was the most commonly reported mechanism of injury in this series.

Several studies show that hand injuries are also quite common among high-level players, accounting for 7.0%-22.0% of injuries in elite volleyball (table 5:2). The lowest level (7.0%) was reported from a prospective study of injuries in the 1987 U.S. National Amateur Volleyball tournament (Schafle et al., 1990). The authors comment that many players reporting to the training area had sprains of the interphalangeal joints of the fingers and the metacarphalangeal joints of the thumbs but considered these injuries trivial so did not report them on the pre-tournament injury history survey forms or during the tournament. These same players also reported anecdotally that the accumulation of minor hand injuries was the reason for former team mates retiring from the game (Schafle et al., 1990).

There is little attention to hand injuries in the other epidemiological studies of volleyball injuries, except they mostly confirm that the most common mechanism of finger injuries is hit by the ball in a block (Schafle et al., 1990; Watkins & Green, 1992; Aagaard & Jorgensen, 1996; Aargaard et al., 1996). Aagaard et al. (1997) reported proportionally fewer finger injuries in beach volleyball compared to indoor volleyball (8% of all injuries vs. 18%) and suggested that this was because there were fewer blocks in beach volleyball and most blocks were one-person blocks.

Specific countermeasures to ankle, knee, shoulder and hand/finger injuries are discussed in detail in chapter 9.

7. PREVENTING VOLLEYBALL INJURIES

Effective prevention of volleyball injuries needs to be based on an understanding of the inherent nature of the sport and any particular stresses it may put on the body, its players and the physical and social environment in which it is played.

Often a number of factors may contribute to the risk of injury in sport. A useful framework for the development of countermeasures to injury in volleyball is to view an injury as the culmination of a chain of events and determine the most appropriate intervention points along the chain and then select the most suitable preventive measures (Table 7:1). More attention should be given to implementing measures to prevent injury at the pre-event stage in the continuum. Within this framework, injury countermeasures are identified as either primary, secondary or tertiary measures.

- **Primary countermeasures** are measures that act to prevent the event or incident that may cause injury occurring in the first place, for example pre-season conditioning programs for players, coach training and setting of game rules that minimise the risk of injury

- **Secondary countermeasures** act during the event to prevent or reduce the risk or severity of injury, for example the use of personal protective equipment

- **Tertiary countermeasures** act after the injury event or incident to minimise the consequences of the injury, for example access to prompt and appropriate first aid and rehabilitation

Table 7.1: Potential countermeasures to volleyball injuries

Intervention point	Potential countermeasure
Pre-event (primary prevention)	▪ Development and implementation of sports safety (risk management) plans ▪ Education of coaches, trainers and players in sports injury prevention ▪ Provision of safe playing environment, including equipment, court and surrounds ▪ Pre-participation evaluation to identify at-risk individuals and introduce individualised conditioning programs ▪ Adequate pre-season and in-season training and conditioning ▪ Player skills development by trained coaches, attention to good technique ▪ Appropriate warm-up and cool-down before match play and training ▪ Promotion of good knowledge of game rules in players and officials ▪ Modified rules for junior players ▪ Appropriate hydration and nutrition ▪ UV protection (for beach and outdoor games) ▪ Provision of water, ice and shade for outdoor games
Event (secondary prevention)	▪ Use of protective equipment e.g., knee pads, ankle tape/brace ▪ Attention to correct technique ▪ Knowledge and enforcement of game rules
Post-event (tertiary prevention)	▪ Availability of first aid equipment and ice ▪ Availability of personnel with first-aid training at all games and events ▪ Appropriate and adequate treatment and rehabilitation ▪ Return-to-play rules for injured players

General countermeasures, relevant across the full range of volleyball injuries, are covered in the next chapter (chapter 8). Specific countermeasures to ankle, knee, shoulder and hand/finger injuries are discussed in detail in Chapter 9.

8. GENERAL COUNTERMEASURES TO VOLLEYBALL INJURY

8.1 PHYSICAL PREPARATION

Volleyball requires a variety of physical attributes (speed, power, strength and balance) and specific skills. The game places acute demands on the ability of the player to move quickly in all directions, change directions often, stop and start, while maintaining the balance and control to hit the ball effectively. Therefore, participants need to meet at least minimum set of physical, physiological and psychological requirements to cope with the demands of play and reduce the risk of injury.

8.1.1 Pre-participation evaluation

Pre-participation evaluation (PPE) is essentially a health screening process that is believed to be beneficial to athletes (McKeag, 1989; Kibler, 1990; Vicenzino & Vicenzino, 1995). PPE usually involves a general medical examination and the collection of specific information on the musculoskeletal system to determine whether the potential or practising player can participate safely in sports.

The overall goals of sports-specific PPE include:

- identifying impediments to participation (for example, coronary disease and asthma);
- uncovering conditions predisposing the athlete to injury (for example, musculoskeletal abnormalities and previous injury);
- preventing of injury through a prescribed corrective program; and
- maximising performance

(Vicenzino & Vicenzino, 1996; Kibler et al., 1989).

There is some evidence that PPE performed by multiple examiners in a station situation (for example, a medical practitioner, physiotherapist, exercise physiologist and coach) is a more effective method of identifying musculoskeletal and other risk factors for injury than PPE performed by a single physician (Durant et al., 1985 cited in Vicenzino & Vicenzino, 1996). However, the cost of screening by multiple specialist practitioners is prohibitive for recreational players unless large group screening sessions are organised. PPE should be performed 4-6 weeks before the commencement of pre-season training to give sufficient time for deficits in strength, endurance, power, anaerobic and aerobic fitness and flexibility to be addressed by specific programs (McKeag, 1989; Vincenzino & Vincenzino, 1995).

Because of the cost of PPE, Kibler and colleagues recommend that the focus of the pre-participation examination should include both medical and musculoskeletal examinations. The latter should be based on those aspects of athletic fitness that can be easily and efficiently measured, and confined to measures relating to the sport of interest to the athlete (Kibler et al., 1989).

The authors developed a method of testing for flexibility, strength and endurance and trialed it in a group of 2,107 athletes participating in a variety of sports from junior high school to the college level. Males were significantly stronger than females on all strength tests and females were more flexible than males on all flexibility tests. The tendency in both males and females was that tightness in musculoskeletal areas corresponded to areas of tensile loads applied during a particular sport, indicating sports-specific adaptations. For example, upper body athletes (tennis players, golfers, baseball players and swimmers) were tighter than were lower body athletes (footballers, basketballers, soccer players etc.) in dominant shoulder internal rotations and significantly looser in dominant side external rotations. Kibler et al. (1989) recommend that attention to flexibility deficits in males and strength and endurance deficits in females should reduce the risk of muscle and tendon injury, although research evidence to support these recommendations is lacking. PPE is also used to identify sports-specific maladaptations and guide tailored conditioning programs.

Although there is no current research to show that PPE is an effective method of ensuring safe participation in sport, there is general support for the development of sport-specific PPE in the sports medicine literature (Kibler et al., 1988; Vincenzino & Vincenzino, 1995). It is believed that information from the PPE combined with injury records provide both a better understanding of the specific risk factors for injury in a particular sport and the building blocks for well-designed conditioning programs.

The Australian Institute of Sport, Olympic Athlete Program and the Australian Sports Injury Prevention TaskForce has sponsored the development of a pre-participation examination for all sports.

Recommendations

For player safety

- Extend pre-participation evaluation and tailored pre-season conditioning programs to a wider group of high-level senior and junior players and evaluate the protective effects of these programs.

For further research, development and implementation

- Continue to research assessment measures that are volleyball-specific to improve pre-participation evaluation instruments.

- Systematically evaluate the injury prevention efficacy of the current pre-participation evaluation program for elite players.

8.1.2 Training and conditioning

Fitness is a basic requirement of proper athletic performance and is believed to protect the body against the physical stresses and strains that are a normal part of athletic competition. Although evidence from analytic studies is lacking, it makes inherent sense that athletes in good physical condition are less susceptible to injury.

There is no published information in Australia or elsewhere on the fitness levels of volleyball players at the club and recreational level and the amount of pre-season and in-season training undertaken. The recent prospective cohort study of 1,392 sports participants in Western Australia did not include volleyball players but provides some information on preparation for community-level sport (Stevenson et al., 2000). The amount of preparation undertaken by players appears to be sports specific. Football and field hockey players were more likely to undertake pre-season training than netball and basketball players (92% and 85% vs. 69% and 59%, respectively) and also spent significantly more hours training through the season. The overall injury incidence was elevated for all four sports during the first month of the season but particularly so for Australian football and netball. The authors speculate that the elevated incidence of injury (mostly ankle sprains) in the first month of the season in netball (which was equivalent to the elevated injury rate in football) was in part due to lack of pre-season skills training and match preparation leading to poor proprioception and ankle instability.

Pope et al. (2000) recently reported that the most potent risk factor for injury during basic training in Australian army recruits was the pre-participation fitness level of recruits as measured by performance in a 20 meter shuttle run test. The least fit subjects were 14 times more likely to sustain a lower-limb injury (across all soft-tissue and bone injury categories except ankle sprain) than the fittest subjects.

Well-conducted training programs at any level require advanced planning and good knowledge of the requirements of the sport and the bodies of individual players (Peterson & Renstrom, 1986 in Backx, 1991). For these reasons it is important that club level coaches and trainers are accredited, at least to Australia Coaching Council Level One standard, and continuously update their knowledge and skills. Details of coach training courses are available from Volleyball Victoria.

Schutz (1999) recommends that a well-rounded volleyball training program should include aerobic fitness, flexibility, strength, power and agility components as well as skills instruction and practice. Cross training at the junior level is suggested to build strength while the drills are developing the skills of the game (Schafle, 1993). All training should be conducted on 'forgiving' surfaces, for example wooden floors or synthetic area elastic floors and sand. Coaches, trainers and players should be mindful that overtraining and lack of variation in skills training components (repetitive drills) can cause overuse injuries. Volleyball Victoria recommends that players at all levels should establish a base level of aerobic fitness complemented by a training program that emphasises power, agility and strength with attention to the development of good skills, techniques and game tactics (Shears, personal communication).

Recommendations

For player safety

- Simple pre-season fitness testing should be conducted on players participating in competitive volleyball at the inter-club level, four to six weeks prior to the start of the season.
- All competitive and recreational volleyball players are advised to undergo a graduated skills development and training program (which includes cross training), guided by results of an initial fitness test.
- Players should consult an accredited coach on their individual training requirements.
- Coaches should vary training and concentrate on developing good technical skills in players, especially at the junior level.

- Initiatives to increase the awareness of players and coaches of the injury consequences of training errors (including over-training) should be continuously developed, and refined as new knowledge becomes available.

For further research, development and implementation

- Controlled evaluation studies should be conducted to determine 'best practice' conditioning and training programs that develop the skills and fitness necessary for competitive volleyball and protect players from injury.

8.1.3 Warm-up and cool down

'Warm-up' is a term that is used to cover the light exercise, stretching and psychological activities that are undertaken just prior to sporting activity to increase 'readiness to perform' (Best & Garrett, 1993). The practice is fairly widespread in Australian sport. Stevenson et al., (2000) found that almost 80% of the cohort of 1,390 West Australian sports participants they monitored for a season undertook a warm-up regime before training or playing and 76% completed a cool-down after training or playing. However, the sessions were not comprehensive and lasted less than 10 and 5 minutes respectively. The regime of warm-up to a light sweat followed by slow and relaxed stretching, immediately prior to exercise, is generally recommended to athletes to enhance performance and reduce the risk of musculotendinous injury, particularly muscle tears (Safran et al. 1989).

The injury prevention benefits of warm-up and cool-down are not well established by research outside the laboratory. Literature reviews by Safran et al. (1989) and Best and Garrett (1993) conclude that there exists a body of physiological evidence that shows that warm-up removes some of the physical stresses associated with exercise. Warm-up and stretching have been shown in laboratory studies to improve the range of motion of the joints, increase muscle, ligament and tendon elasticity (thus requiring a greater force and degree of lengthening to tear muscle) and promote heat transfer (Safran et al., 1989; Best & Garrett, 1993). On the basis of available clinical and experimental evidence, Safran and his colleagues were prepared to recommend that warm-up and stretching routines are essential to the prevention of muscle injuries in sport. By contrast, Best & Garret were less inclined to provide an unqualified endorsement. Both review groups recommend that well-controlled epidemiological and experimental studies are needed to fully evaluate whether these regimes prevent injury.

Recent epidemiological evidence throws some doubt on the protective effect of the stretch component of warm-up. A recent critical literature review of epidemiological studies and the basic science literature concluded that there is no convincing evidence from either source that stretching before exercise reduces the risk of injury (Shrier, 1999). Since this review the results of an RCT on stretch and injury risk conducted in Australia were published. Pope et al. (2000) conducted a well-designed randomised trial in a group of 1,538 male Australian army recruits undergoing basic military training. The authors found no reduction in lower limb injury risk from the inclusion of one 20-s static stretch under supervision for each six major leg muscle groups during warm-up routines prior to physical training sessions.

The recruits were randomly assigned to stretch or control (no stretch) groups. There were 158 injuries in the stretch group and 175 in the control group, 214 of the injuries were soft tissue injuries. There was no significant effect of pre-exercise stretch on all-injuries risk (hazard ratio [HR] = 0.95, 95% CI 0.77-1.18), soft tissue injury risk (HR = 0.83, 95% CI 0.63-1.09) or bone injury risk (HR = 1.22, 95% CI 0.86-1.76). As mentioned earlier in this report, the most significant modifiable risk factor emerging from the trial was pre-training fitness, assessed by the test score obtained by participants in a 20 metre shuttle run test (20mSRT). The least fit subjects were 14 times more likely to sustain a lower-limb injury (across all soft-tissue and bone injury categories except ankle sprain) than the fittest subjects. Age and enlistment date also significantly predicted injury risk ($P<0.01$ for each) but height, weight, and body mass index did not.

The authors conclude that a typical muscle stretching protocol performed during pre-exercise warm-up does not significantly reduce the risk of exercise-related injury. These findings confirm and extend the findings from a previous smaller trial that lacked statistical power (Pope et al., 1998). Whether the findings from the large trial can be generalised to populations of (male) sports participants is a debatable question. The principal investigator believes that the sporting history of the army recruits is similar to the range found in the general Australian population, from little sports involvement to elite/professional involvement (Pope, personal communication).

Pope et al. (2000) note that most sports populations are probably at lower risk of injury than the army recruits they investigated and, therefore, the value of stretching may be even less in those populations. Their best estimate of benefit was that a 5-minute stretch completed prior to 40 sessions of exercise during basic training reduced the all-injury risk of the recruits by 5% and, based on these figures, recruits would need to complete an average of 260 hours of stretching to prevent one injury.

Obviously, it would be preferable to confirm these findings in sports populations but it is difficult to envisage that trials could be conducted under the same rigorous experimental conditions that are available in a military setting. The widespread belief in the injury prevention effect of stretch in sports participants would be a major impediment to recruitment to a trial, as would compliance to prescriptive warm-up regimes. Randomised controlled trials are required to investigate whether a longer stretch reduces injury risk (perhaps in elite players as they are more likely to comply with a longer stretch program), the effectiveness and optimal time for warm up and cool down, whether individualised programs are needed for players in different age and sex groups and whether customised warm-ups are required for different sports.

Volleyball Victoria suggests the following warm-up routine for volleyball teams:

- An aerobic activity that involves volleyball skills, for example 'set and run' (10 minutes)

- 'Pepper' - working in pairs for shoulder warm-up then sets of 'dig, set and spike'. (Shears, personal communication)

Recommendations

For player safety

- All players should routinely warm-up and cool down before and after every game and training session. On the basis of current research, the inclusion of stretching exercises in warm-up does not reduce the risk of injury.

- Specific needs of the injured player should be considered when warm-up and cool down regimes are developed.

For further research, development and implementation

- The protective effects of warm-up, stretching and cool-down require further evaluation in controlled trials in sports populations.

8.2 ENVIRONMENTAL SAFETY MEASURES

Environmental conditions that may contribute to injury include hot and humid weather, the condition and type of playing surface, and, using the term in its broadest sense, the total environment that surrounds the sport (injury risk management, policies and practices).

8.2.1 Weather conditions (heat disorders)

Volleyball, especially beach volleyball, is mostly played in summer in conditions that range from comfortably warm to oppressively hot. These conditions would tax even the best-conditioned and fittest players. The amount of water loss depends on a range of individual factors such as environment, intensity of play, acclimatisation, fitness, gender and age but may be as high as 2.5 litres per hour of play (Bergeron et al., 1995).

There are four recognisable heat disorders in the exercising athlete: heat cramp, heat syncope, heat exhaustion, and heatstroke (Murphy 1988). Evaporative heat loss through sweating is the most effective on-court mechanism for dissipating heat in hot weather. If adequate fluid intake is not maintained, a player’s thermoregulatory capacity is diminished leading to premature fatigue, significant loss of performance and ultimately heat exhaustion (Bergeron et al., 1995).

Bergeron et al. (1995) compiled a set of recommendations for fluid replacement and carbohydrate supplementation in tennis players competing in a hot environment that should also be appropriate for volleyball players :

1. Players who intend to play in a hot climate should undergo a process of acclimatisation of at least 7 to 10 days duration which should involve training or competing daily for 1 to 2 hours in the same heat.

2. Players should imbibe sufficient CHO-electrolyte drink at each changeover to feel comfortably full whether or not thirst is satiated. For matches lasting less than one-hour, consumption of water during play should be sufficient provided the player begins the match properly hydrated and with replenished glycogen stores.

3. After a match, a player should replace lost fluids and electrolytes while consuming carbohydrates. The authors recommend the intake of carbohydrate-electrolyte drinks over plain water because they have been shown to better promote fluid absorption.

It should be noted that the recommended 7-10 days acclimatisation period is often not practical, either because of a player's other commitments or the extra expenses involved. In these circumstances careful monitoring of fluid loss and replenishment during tournaments and matches in hot conditions is of crucial importance. Other actions that players can take to minimise heat-related injury include: wearing loose, light, porous and pale-coloured clothing to facilitate evaporation of sweat and to minimise heat absorption; and the use of a sunscreen to prevent sunburn.

Nirschl & Sobel (1994) recommend the following safety measures to competition event organisers, clubs and associations to reduce the risk of injury to players competing in hot weather:

- Cancel or re-schedule matches in hot and humid weather.
- Extend rest periods when environmental factors dictate.
- Make sun-free enclosures available during between-game changeovers.
- Supply plenty of water [and CHO-electrolyte drinks – see discussion above].
- Allow specific accommodation for medical consultation and medical time-outs during the course of play.

8.2.2 Provision of a safe playing environment

Clubs and associations should take a systematic and comprehensive to providing a safe playing environment that minimises the risk of injury. The Victorian 'Smartplay' program, located in Sports Medicine, Australia (Victorian Division) provides support for associations and clubs wanting to develop sports safety (risk management) plans (along with injury prevention education for young players) (www.smartplay.net).

An important aspect of a safe playing environment is the condition of the playing surface. No matter what playing surface is used, the surface should be checked for cracks, holes and debris prior to play and defects remedied. All hard surfaces should be cleaned and maintained according to manufacturer's instructions. Specific injury issues relating to the type and condition of playing surfaces are discussed in the sections on ankle and knee injuries in the next chapter. Guide wires for post should be marked and posts and referee stands padded, the floor should be regularly dried during training and match play and there should be a clear running space around the court. Lighting should conform to the Australian Standard.

Recommendations

For player safety

- Extreme heat policy and rules need to be developed at the association level for beach and outdoor volleyball.
- All beach volleyball clubs and outdoor events managers should provide umbrellas or shaded areas and ice-chests on court, and supply water and ‘sports’ drinks (with 4%-8% carbohydrate content).
- Beach and indoor players, particularly when participating in a tournament, should monitor their fluid intake during games by weighing themselves or by noting any reduction in the amount and concentration of urine output in relation to fluid intake (oliguria). Players should replace fluid and electrolyte loss by consuming 400-600 mls of fluid (2-3 standard glasses) at least 30 minutes before play, 200-300 mls (1-2

glasses) every 15 minutes during play (at change of ends) and more than they are thirsty for after activity (at least 500 mls).

- .Education & signage about measures to prevent heat illness should be provided at the club level.
- Players playing outdoors should use a broad-spectrum sunscreen and hat, even on cloudy days.
- Clubs, in association with venue owners and managers, should develop, implement and monitor risk management/sports safety plans, that include measures to eliminate or ameliorate environmental and other injury hazards. Guidelines and support for the development of these plans should be available from parent associations.
- Equipment, seating and advertising should be kept away from court boundaries, net posts should be padded.
- The playing surface should be checked for cracks, holes and debris prior to play and defects remedied.

For further research, development and implementation

- Research should continue on player diet and hydration issues.
- The injury prevention effect of the implementation of club and association sports safety plans should be evaluated.

8.3 EDUCATION AND TRAINING OF COACHES AND OFFICIALS

8.3.1 Coaches

Coaches are responsible for the design of safe and effective training programs. All coaches should be educated in the general principles of sport and fitness and understand volleyball and its potential injury risks. As much as possible, coaches should prevent players from attempting skill or competition levels for which their maturity, strength or other attributes are insufficient. A coach should be an educator, psychologist, injury prevention and first aid person and provide a role model for good sportsmanship and fair play.

It is important that coaches undertake regular training to update their knowledge of injury prevention, first aid, basic life support and rehabilitation principles and are kept informed on developments in knowledge about training children in volleyball skills.

Volleyball coaches should undertake a variety of training at various levels. These range from the Level 0 coaching course, as a base, to elite level coaching courses provided through Volleyball Victoria. The intensity and educational expectations increase with the level of the course. Clubs and associations should encourage and support coaches to become accredited and to continuously upgrade their knowledge and skills.

8.3.2 Trainers

Sports trainers are also essential to the prevention of volleyball injury and they also need to be well-qualified to deal knowledgeably and efficiently with the prevention, treatment and rehabilitation of injury. The Australian Sports Commission (1997) indicates that education should be undertaken not only by coaches and trainers but also by officials, administrators and facility managers/operators who are often responsible for the overall risk management of the sport.

Recommendations

For player safety

- Accredited coaches should be available at every club to advise and monitor the skills development of players at all levels of play (competitive and recreational).

- All coaches should undergo the regular training and re-accreditation program provided through Volleyball Australia and state divisions.

For further research, development and implementation

- Continuous systematic evaluation of the effectiveness of coach education/training programs should be maintained.

8.4 MODIFIED GAMES FOR CHILDREN

Sports catering to children must take into account the differences in skill level, physical and psychological maturity and self-knowledge of their physical capabilities in children compared to adults. Several skills development programs and scaled-down versions of the game of volleyball have been developed for child participants in Victoria (for example, the Sport Education in Physical Education Program (SEPEP) for Volleyball and the Volleystars and mini-volleyball games). These modified games allow for the gradual introduction to the full game to children as they mature and their skills develop.

To date has been no direct evaluation of the effectiveness of modified volleyball games in preventing injuries in children (although there is evidence that they are effective in reducing child injury in Australian Rules football). However, it is reasonable to assume that modified rules that aim to reduce the intensity and physical stresses of the game and gradually develop the skills and techniques of child players should enhance the safety of the sport. Data on the frequency and pattern of child injuries in volleyball is sparse.

Recommendations

For player safety

- Volleyball Victoria should continue to promote the adoption of modified rules volleyball games for children in schools, recreation venues and junior volleyball clubs.

For further research, development and implementation

- Research to determine the appropriate age/stage of physical and skills development for children to graduate from modified to full participation in volleyball.

- The pattern of child injury in volleyball needs to be better reported and monitored to enable the development and evaluation of current skills development and modified rules programs.

8.5 TREATMENT AND REHABILITATION OF INJURY

Despite the best preventive measures, there is always the chance of injury among volleyball participants. Many injuries are re-injuries or aggravations of existing injury, therefore, proper treatment and adequate rehabilitation of any new injury is especially important. The causes of volleyball injuries are diverse and may be multifactorial so a combination of procedures may need to be administered to prevent recurrence. Overall, the treatment goals are pain relief, promotion of healing, decreased inflammation, and a return to functional and sports activities as soon as possible (National Sports' Trainers Scheme 1994).

8.5.1 Sports first aid

The provision of accessible and appropriate sports first aid is an important injury countermeasure. The initial treatment provided to the injured person is a crucial determinant of the rate and likelihood of recovery and return to play.

First aid for an injury to a muscle, tendon or ligament usually involves following the well-recognised regime of rest, ice, compression, elevation and referral (RICER) (Knight, 1985; Larkins, 1990). This procedure is promoted by Sports Medicine Australia and used by sports medicine practitioners but there are no recent investigations of its effectiveness. Ice burns from the application of ice/ice packs have been reported in the literature (O'Toole & Rayatt, 1999) so care should be taken to follow recommended procedures on icing - apply ice or commercial cold packs only for 20 minutes every 2 hours and ice and packs should be wrapped to prevent ice burns.

In addition to the RICER procedure, NO HARM is also advocated for the treatment of injury: no Heat, no Alcohol, no Running and no Massage during the first 48-72 hours after an injury. After the initial period of icing, alternate hot and cold bathing is recommended to decrease bleeding and swelling (3 minutes of each repeated 3 times, once a day). Massage is believed to aid rehabilitation, but it is not recommended in the initial 72 hours of injury (Cook, 1989). Consultation with a medical practitioner or a sports medicine specialist may also be required and further treatment and/or rehabilitation prescribed.

A survey of 993 Victorian secondary school children conducted in 1994 indicated that only one-third had received any formal first aid training via qualified instructors (for example, St John's Ambulance officers) (Finch et al., 1999). Only 28% of the students reported that they had heard of the acronym RICER/NO HARM in relation to sports injury but a much higher proportion (76%) showed some knowledge of the initial four components of the RICER regime. This knowledge was gained through school. The final component of RICER (referral) and all aspects of NO HARM were poorly understood. The incomplete knowledge of RICER, NO HARM among students (64% of whom were active community sports participants) indicates that an education campaign should be established through schools and sports associations to educate players in the RICER, NO HARM regime.

Sports Medicine Australia (SMA) organises a number of sports first aid courses at various levels and intensities targeted to school teachers, coaches, parents, club officials, athletes or anyone interested in providing a valuable, often voluntary, contribution to sport. The

RICER, NO HARM technique is endorsed in the SMA ‘Sports First Aid Course’ because it is believed to reduce the severity of injury, haematoma and swelling; limit tissue damage; and lessen recovery time (National Sports Trainers Scheme 1994).

First aid or medical assistance should be available at all volleyball matches, not only at tournaments and elite level events. At the local level, rendering first-line assistance to injured players is often left to parents or club associates who may little or no sports medicine or first aid training. It is the responsibility of clubs and associations to ensure that there are personnel qualified in first-aid in attendance at all training sessions, matches and tournaments and that first aid equipment and supplies, including ice packs, are readily available.

8.5.2 Rehabilitation

Rehabilitation of an injured athlete should restrict the athlete from re-starting activities too soon (Van Mechelen, 1992). A rehabilitation program cannot be regarded as complete 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. Rehabilitation may mean complete cessation of volleyball for a given period or a reduction in training.

It is generally recommended that ‘range of motion’ exercises are beneficial during the acute phase of an injury to reduce swelling and maintain joint mobility during rehabilitation. This should be done within the confines of a compression dressing such as athletic tape or elastic bandages to protect the injured area without restricting active movement (Hess et al. 1989). Other rehabilitation measures include the application of a contrast program of heat and cold and massage, which should be performed under supervision. There is a lack of knowledge on optimal rehabilitation regimes, especially for chronic tendinitis/tendonosis (jumper's knee and shoulder pain syndromes). Players should undergo appropriate fitness testing prior to return to full play after injury

The appropriate use and relative merits of prophylactic and rehabilitative taping and bracing for ankle knee and finger injuries are discussed in chapter 9.

Recommendations

For player safety

- All players should be taught the RICER, NO HARM regime, through schools and volleyball associations and clubs.

- Players should seek prompt attention for injuries from a sports medicine practitioner and allow sufficient time for full rehabilitation before returning to their pre-injury level of activity.

- Event organisers and clubs should ensure that there are qualified first aid personnel/sports trainers in attendance at all training, competition match days and events.

- Clubs should have a well-stocked first aid kit and a supply of ice-packs.

For further research, development and implementation

- Further research and evaluation of first aid and rehabilitation programs are required to develop optimal regimes for recovery and return to play.

9. SPECIFIC COUNTERMEASURES TO ANKLE, KNEE, HAND/FINGER AND SHOULDER INJURIES

Evidence from player surveys and observational studies identify ankle, knee, hand/finger and shoulder injuries as the most frequent injuries in volleyball. The literature search identified only a few trials of injury prevention strategies in volleyball so information from these has been supplemented by findings from trials in other sports. Generally, the evidence on the effectiveness of the various prevention measures is inconclusive. Therefore, promising intervention strategies should continue to be implemented, assessed and improved.

9.1 PREVENTING ANKLE INJURIES

Ankle injuries, mostly lateral ligament sprains, are the most common injury in volleyball and most other sports. A number of preventive measures are suggested in the literature including a rule change to prevent foot conflict at the net, prophylactic ankle taping and bracing, attention to take off and landing techniques and ankle disc training.

9.1.1 A multi-strategy intervention to prevent ankle injuries: information, balance board training and skills training

The literature search found only one intervention study (a pre- and post- evaluation) that was targeted specifically at preventing ankle injuries in volleyball. This multi-strategy intervention, conducted by Bahr and colleagues, was the third phase of a staged research program involving 719 players competing in the two top men's and women's divisions of the Norwegian Volleyball Association (Bahr et al., 1997). Injury data were studied retrospectively in the 1991-92 season and prospectively in the 1992-93 season (to inform preventive measures and to form the baseline for the evaluation). The intervention program was introduced during the 1993-94 season, and injury data from the 1994-95 season were used to evaluate the effects of the preventive program (Bahr et al., 1994; Bahr & Bahr, 1997; Bahr et al., 1997).

9.1.1.1 Planning stage considerations

Bahr and co-researchers (1997) considered four potential prevention strategies when formulating their multi-strategy intervention:

(1) *Introduction/enforcement of a stricter netline violation rule*: This measure was recommended in a number of earlier research reports with the aim of reducing the foot conflict zone under the net where an attacker may land on a blocker's foot or vice versa. The researchers piloted a stricter rule during a pre-season tournament but found it resulted in an unacceptably high level of game interruptions. They decided not to include it in their intervention.

(2) *Use of tape and ankle braces as external ankle protectors*. Despite acknowledging the strength of the research evidence in support of ankle taping/bracing the researchers decided not to include this strategy. Their reasons for doing so are not explained clearly. In the introduction to the research report they state that their decision was based on research findings that showed that external ankle support was mostly effective in the prevention of re-injuries (yet their pre-intervention

research found that 79% of ankle injuries in their proposed intervention population were re-injuries). In later discussion they state that the basis for the decision was they wanted to design an inexpensive intervention that could be implemented by coaches and players without the use of trained medical personnel. They considered balance board (ankle disc) training a more attractive option than prophylactic bracing.

(3) *Intensive balance board (ankle disc) training*. This strategy was included only for previously injured players to restore proprioceptive function (awareness of foot position on landing) and strengthen ankle ligaments. The decision to include this measure was influenced for the promising results from an early trial of a balance board training program conducted in Swedish soccer players. The trial showed a reduction of functional ankle instability in players who trained with a balance board (Tropp et al., 1985).

(4) *Specific technical training on take-off and landing techniques during attack and blocks*. The research group designed training drills to address the major mechanisms of ankle injury and predisposing factors identified in their preparatory research. They were encouraged by an earlier study that showed that a combination of technical training and player education reduced ankle injuries in soccer (Ekstrand, 1983).

The eventual technical training component focussed on two areas:

- drills that trained attacking players to use a quick and long last step when trying to reach a 'tight' set rather than trying to 'outjump' the ball (which carries a higher risk of foot conflict under the net with opposing players); and

- drills with an emphasis on side-to-side movement and take-off technique when setting one-man and two-man blocks (these were not well described in the report)

9.1.1.2 Implementation and evaluation stages

The intervention ultimately consisted of a 1-hour awareness raising session for coaches and players on the risk factors for ankle injuries conducted by the researchers and a 1.5-2 hour practical session also conducted by the research team. The practical session covered technical training as described above for all players, and practical demonstration and practice in the correct use of ankle discs (balance boards) for players with previous ankle injury. Two balance boards were given to each team and a written training program was distributed to players with previous ankle injuries.

Just before the 1994-95 season all coaches and players were given a booklet that outlined the prevention program to reinforce the information given during team visits by the research group in the 1993-94 season. No further direct contact was made with players and coaches except that coaches submitted monthly reports on acute injuries and exposure, adhering to the methods and definitions used in the pre-intervention baseline study.

9.1.1.3 Findings and discussion

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

The weak evaluation design does not allow any assessment of the relative contribution of the individual components of the trial. The three pre-season player surveys showed no significant change over time in players' stated intention to use ankle supports (bracing and taping) on a regular basis. This indicates that there was negligible 'take-up' of the advice given in the education session encouraging players with ankle instability to brace or tape their ankles. It is probable, therefore, that this measure did not contribute to the observed injury reductions.

These results also suggest that the injury reductions may be associated with the training components (jumping and landing and block formation drills and disc training) rather than the information session per se. The observed reduction of injuries caused by foot conflict suggests that the 'step in' and the block drill may have had some effect and the observed gradual decline in ankle re-injuries indicates that the ankle disc training component (which was exclusively targeted at players with ankle instability) also made a contribution.

The promising findings from this study has prompted the design of a large randomised controlled trial of ankle disc (balance board) training in volleyball in The Netherlands (Verhagen, personal communication). The planned RCT aims to test the effect and cost-effectiveness of a preventive propriocepsis and balance board training program on the risk of lateral ankle injury. It will involve second and third division players in the Dutch Volleyball Association. The training will be a combination of proprioceptive exercises on and off the balance board. The evaluation design is much stronger than in the Norwegian study by Bahr et al., and should provide a firmer base of evidence on the efficacy of balance board training. Results should be known in two to three years.

9.1.2 Transferable interventions from other sports

Thacker et al. (1999) recently conducted a thorough systematic review of published evidence on the effectiveness of the various approaches to the prevention of exercise-related ankle injuries. The authors found ten reports that compared alternative methods to preventing ankle injuries in 621 citations identified in through the literature search. The ten studies included 7 randomised trials of interventions in football (gridiron), basketball and soccer and 3 cohort studies, two in football (gridiron) and one in volleyball (Bahr et al., 1997 as outlined above). The studies investigated the effectiveness of taping, bracing and wrapping, player conditioning, shoe style, and training programs on ankle injury. They were subjected to rigorous quality assessment by three reviewers and their findings weighted accordingly. The review revealed methodological flaws in all ten studies, some major, which indicates that care should be taken in using reported findings to underpin preventive programs, without the incorporation of rigorous evaluation.

Two other recently published literature reviews on ankle injury prevention (Quinn et al., 2000; Hume and Gerrard, 1998) cover basically the same ground but the former includes only randomised controlled trials.

9.1.2.1 Taping, wrapping and bracing

Ankle supports are designed to restrict the range of motion of plantar flexion and inversion of the ankle and to increase proprioceptive input. Taping and bracing are generally considered to be integral components of the management and rehabilitation process for ankle ligament injuries. Prophylactic (preventive) taping and bracing is becoming more common at senior levels of competition in sports that have high rates of ankle inversion injury, such as netball, basketball, soccer and volleyball. Rice and Anderson (1994) recommend prophylactic taping or bracing of ankles in volleyball.

Taping and wrapping

The most quoted study that provides limited evidence that taping reduces ankle injuries is an early randomised case-control study of 2,562 US intramural university basketball players (Garrick & Requa, 1973, cited in Hume and Gerrard, 1998, Thacker et al., 1999 and Quinn et al., 2000). The study was conducted prospectively over two seasons and tested the use of high and low top shoes, with tape, J-flex (elasticised wrap) or no tape.

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

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

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

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

Bracing

Prophylactic ankle stabilisers (braces) are gaining popularity as a more convenient alternative to taping. Several studies, taken together, provide good evidence that ankle braces (orthoses) protect against ankle injury, particularly in previously injured ankles (Thacker et al., 1999; Quinn et al., 2000). The Cochrane review panel (Quinn et al., 2000) pooled the results from four randomised controlled trials that compared the use of ankle brace/orthosis with controls (Tropp et al., 1985; Ryan et al., 1994; Surve et al., 1994, Sitler et al., 1994) and found a significant reduction of number of ankle sprains in the intervention group (OR 0.49; 95% CI 0.37 to 0.66). (The Cochrane Collaboration is a network of researchers from a range of fields of medicine and health who systematically and continuously review the quality of evidence from randomised control trials in their particular area of expertise to determine the effectiveness of preventive, treatment and rehabilitative interventions.)

The strongest evidence for effectiveness comes from a large well-conducted randomised controlled trial on the effectiveness of a semi-rigid ankle stabiliser that involved 1,601 healthy US Military Academy cadets playing intermural basketball (Sitler et al., 1994). The study found that the stabilisers significantly reduced the frequency, but not the severity, of acute ankle injuries. The largest statistical reduction was seen in the previously injured ankle group but a positive effect was also evident in the group with protected healthy ankles. Ankle stabilisers were more effective for contact injuries, a finding that is particularly pertinent to volleyball. However, it is not clear whether the results from this study can be generalised to other groups of players because the army cadet population may differ from the civilian population on a number of physical attributes that may influence the risk of ankle injury.

Three other RCTs, two in soccer and one in military training (parachuting) report a positive protective effect for external ankle devices. Studies by Tropp et al. (1985) and Surve et al. (1994), both in cohorts of soccer players, found that ankle orthoses (braces) when used by players with previous ankle injury protect against re-injury. The latter study (involving 258 senior soccer players with previously injured ankles and 246 uninjured players) trialed the effectiveness of a particular brand of semi-rigid orthosis. The authors report a fivefold reduction in the incidence of recurrent ankle sprains in soccer players using the orthosis but no significant reduction of ankle sprains in players with previously uninjured ankles. The other RCT (Ryan et al., 1994) found a statistically significant reduction in ankle sprains in the group of army trainees who used an 'outside-the-boot' ankle brace in parachute training compared to trainees who did not wear braces.

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

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

9.1.2.2 Footwear

High-top vs. low-top shoes

The epidemiological evidence that high-top shoes reduce ankle sprains is equivocal. In an early case-control study in college basketballers (Garrick & Recqua, 1987, described above), players were randomly assigned to one of four groups (tape or no tape with low-top or high-top boots). The results showed that high-top shoes provided superior protection against ankle sprain compared with low-top shoes, but that low-top shoes with taping was more protective than high-top shoes without taping. The best protection was observed in high-top shoes with taping. These results suggest that taping provides most of the benefit.

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

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

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

Shoe design

In a recent review article, Robbins and Waked (1998) challenge the prevailing orthodoxy on the need for additional external support for the ankle in sports, and question whether any external device can provide sufficient structural support to the ankle to prevent sprains.

The authors claim (without citations) that epidemiological studies show that there are few ankle sprains in barefoot athletes and contend that the proliferation of ankle injuries in shod athletes is a direct result of the poorly designed modern sports footwear that decreases foot position awareness (proprioception). They argue that any apparent protective effect of ankle support devices (i.e., tape or brace) is probably due to the restoration of tactile cues on the plantar surface of the foot either by an increase in skin pressure (from taping) or skin traction (from bracing). Ankle support, therefore, enables shod players to better 'sense' correct foot position and orientation before making full contact with playing surfaces. They suggest that the best solution to ankle inversions in sport is thinner- and firmer-soled sports footwear designed to heighten the wearer's awareness of foot position.

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

9.1.2.3 Playing surface

As previously mentioned the only study to investigate the role of playing surface on volleyball knee injury found wooden surface are more forgiving than lino or concrete (Ferretti, 1986).

Steele (1990) reviewed the body of evidence that explores the association between playing surface and the frequency and type of sports injuries and concluded that definitive evidence is lacking and many aspects of the issue require further investigation. She pointed out that the evaluation of the suitability of a surface for a particular sport is a complex matter. Decision-making by sports administrators requires consideration of the functional needs of the sport and the durability and upkeep costs of the surface, along with detailed performance information on the material properties of the surface that may impact on safety and comfort.

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

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

9.1.2.4 Specific conditioning programs

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

Grana (1994) recommends a preventive ankle conditioning program consisting of:

- toe raises (40 repetitions);
- resistive exercises (40 repetitions: dorsiflexion, plantarflexion, inversion and eversion) performed by theraband program or manual resistance;
- balance activities (5 minutes) performed by single limb balancing or on balance board, plyometrics (5 minutes) hopping, skipping, stepping etc. ; and
- stretching (5 minutes).

Ankle disc training

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

Positive results from disc training have also recently been reported from a RCT of disc training to prevent ankle and knee ligament injuries in 237 Danish female handball players (Wedderkopp et al., 1999). Twenty-two teams participated in the study and were randomly assigned to the intervention and control groups. Players in the intervention group used the ankle disc for 10-15 minutes at all practice sessions, for one ten month season. The results indicated that disc training reduced the risk of injury by 80% during games and 71% during practice. In addition, the players in the control group had a 5.9 times higher risk of acquiring an injury than the players in the intervention group.

Findings from these RCTs and the prospective study conducted by Bahr et al (1997), discussed earlier, provide preliminary evidence that ankle disc (balance board) training may be effective in reducing ankle injury in volleyball players with previous ankle sprains. There has been no trial in any sport to investigate the protective effects of disc training on players with no previous history of ankle injuries.

In summary, based on available evidence it would appear that either ankle tape or braces reduce the incidence and severity of ankle sprains, but bracing may be more effective. Proprioceptive (balance board) training is also a promising preventive measure for lower limb injury. The efficacy of shoes in preventing ankle sprains is not clear and the role of the shoe, the playing surface and the shoe-surface interaction in ankle injury requires more research.

9.1.3 Recommendations

For player safety

- Associations should consider the introduction of a stricter netline violation rule to reduce foot conflict under the net.

- Players with ankle sprains should complete supervised rehabilitation before returning to competition.

- Players who have suffered a moderate or severe sprain should wear an appropriate orthosis (brace) for at least 6 months and, preferably, twelve months.

- Players with unstable ankles should consider prophylactic bracing and taping for training sessions and matches. There is evidence to suggest that bracing is more effective, cost effective and convenient than taping, and does not interfere with performance.

- Specialist blockers, particularly the middle blocker, should consider prophylactic ankle bracing (or taping).

- Coaches should introduce drills which train players in the following techniques:

  -taking a quick and long last step when trying to reach a 'tight' set rather than trying to 'outjump' the ball (which carries a higher risk of foot conflict under the net with opposing players); and

  -side-to-side movement and take-off technique when setting one-man and two-man blocks.

- Ankle disc (balance board) training should be trialed and evaluated by volleyball clubs.

- Playing shoes should be in good condition.

- Training should be conducted on sand and wooden or other synthetic 'forgiving' surfaces, not concrete or linoleum.

- Playing surfaces should be diligently maintained and regularly checked for ankle injury hazards such as hollows, cracks and wear.

For further research, development and implementation

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

9.2 PREVENTING KNEE INJURIES

There are few well-developed and evaluated preventive strategies for knee injuries in the literature. The most promising are the programs designed to reduce non-contact ACL injuries in females based on altering biomechanical risk factors through neuromuscular training.

9.2.1 Overload/overuse injuries (Jumper's knee)

Jumper's knee is the most frequent overuse injury in volleyball. The high prevalence of jumper's knee among high level volleyball players is assumed to be caused by the high number of jumps performed during training and games. Elite performers average 150 maximum effort vertical jumps per match (Schafle et al., 1990). As discussed in Chapter 6, our literature review found only one epidemiological study of jumper's knee in volleyball which reported that extrinsic factors (specifically, frequency of training and hardness of playing surface) appear more important than intrinsic factors (structural abnormalities) in the development of jumper's knee (Ferretti, 1986). A significant difference in the number of training sessions between players with and without jumper's knee was also found by Lian et al. (1996) when recruiting elite Norwegian players into a study to characterise the jump performance ability of players with jumper's knee. Various authors have made general recommendations for the prevention of knee injuries but none are well developed or evaluated.

9.2.1.1 Training regimes

The frequency of training sessions, rather than the type of training appears to influence the development of jumper's knee. Training more than four times a week increases the likelihood of jumper's knee (Ferretti et al., 1990; Lian et al., 1996). The inclusion of weight and plyometric training do not appear to be associated with any increased risk which suggests that it is the quantity rather than the type of training that has adverse effects (Ferretti et al., 1990; Lian et al., 1996). There is limited evidence-based advice in the literature on the optimal content, length and frequency of weekly training sessions to maximise performance and minimise the risk of jumper's knee.

Rice & Anderson (1994) recommend a conservative approach to jump training. The authors advise that plyometric exercises should be gradually introduced by slowly increasing the intensity and frequency of exercises over time to allow for proper adaptation of the musculoskeletal structure involved. Also, the floor should be cushioned and players should wear proper training shoes. Middle blockers and the most skilled jumpers are particularly vulnerable to jumper's knee and it is recommended that these players (and players with knee symptoms) limit the amount of time spent on jump training and pay close attention to their technique (Rice & Anderson, 1994; Richards et al., 1996; Lian et al., 1996; Briner & Kacmar, 1997).

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

9.2.1.2 Playing surface

On the basis of his research into jumper's knee, Ferretti (1990) recommends wooden parquet floors or synthetic floors with similar elastic properties to minimise the risk of jumper's knee in players. Training and playing on hard surfaces such as concrete and lino should be avoided.

9.2.1.3 Knee pads and braces

Volleyball players wear knee pads in training and games to protect against direct trauma to the knee and there was a suggestion in an early Italian-language article that they may contribute to knee overload injuries. Ferretti (1986) responded that any adverse effect of knee pads must be negligible because jumper's knee was an established injury risk in volleyball prior to the use of knee pads and is highly prevalent in other sports where knee pads are not worn.

Functional knee bracing has a place in knee rehabilitation but prophylactic bracing (braces worn on healthy knees to prevent injury) is not recommended at this time because evidence on its effectiveness is inconclusive (Moore & Frank 1994, Griffin et al., 2000).

9.2.1.4 Foot orthoses

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

Shock-absorbing shoe insoles have been shown to reduce the risk of knee injuries when running on hard surfaces (Rooser et al., 1988) and are recommended for volleyball players (Watkins, 1994). Wearing rates in volleyball players appear low (Watkins & Green, 1992).

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

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

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

9.2.1.5 Treatment and rehabilitation

Jumper's knee has the potential to become a debilitating condition if ignored. A retrospective study of the course of jumper's knee in 100 athletes, predominantly basketballers, presenting to a Melbourne sports injury clinic over a nine-year period provides some data on the clinical course of the condition (Cook et al., 1997). The sample may be biased and findings may not apply to the general population of sports participants.

The study revealed that young athletes were most affected (mean age of onset of symptoms 23.8 years, range 16-47 years). Males appeared to be more at risk than females (male to female ratio 4:1). Forty-four subjects competed at the elite or sub-elite levels (state or national representative or top domestic), the remainder were recreational athletes.

Symptoms prevented 33% of players from participating in sport for more than six months and 18% were sidelined for more than 12 months. Forty-nine per cent of subjects had two or more separate episodes of the condition. Sixty-three patients were managed conservatively using physiotherapy, rest or both treatments. Thirty-eight subjects had surgery (open patellar tenotomy), the indication for which was pain lasting for more than twelve months. Their recovery time for return to sport varied from three months to more than a year. The authors could not compare the effectiveness of treatment regimes because patients were not randomised into treatment groups.

There are no studies reporting evidence-based treatment protocols for this condition. Based on their own clinical experience, Ferreti et al (1990) recommend a progressive treatment regime for volleyball players with symptoms (table 9:1).

Table 9:1: Classification of jumper's knee and recommended treatment regimes

Stage	Symptom	Treatment
1	Pain after practice or game	• Adequate warm-up • Stretching and strengthening of quadriceps • Ice pack after training • Non steroidal anti inflammatory drugs (NSAIDs) • Physiotherapy
2	Pain after beginning of activity which disappears after warm-up and re-appears after the completion of activity	As stage 1 plus: • Gentle heat (local massage with liniment) • Local steroid injection (in limited cases because of possibility of adverse effects on tissue)
3	Pain remains during and after activity and the patient is unable to participate in sports	As stage 2 plus: • Prolonged period of rest • Reduction in sporting activity • Possible surgical solution
4	Complete rupture of patellar tendon	• Surgical treatment

Source: Ferretti et al (1990)

9.2.2 Acute injuries (ligament damage)

There is preliminary evidence to suggest that specific training and skills development programs have the potential to reduce the risk of non-contact knee ligament injuries in jumping sports, especially in women (Harmon & Ireland, 2000; Griffin et al., 2000).

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

9.2.1.1 Balance board (proprioceptive) training

Caraffa et al. (1996) investigated the possible preventive effect of a gradual proprioceptive (balance board) training program on the incidence of ACL injuries in a prospective controlled study involving 600 male soccer players in 40 semi-professional and amateur teams. Three hundred players were instructed to train 20 minutes per day in a graduated 5-phase program based on increasingly difficult skills performed initially without a balance board and progressing through the use of a series of balance boards of different designs. A control group of 300 players from comparable teams playing with similar equipment on similar fields trained 'normally' (with no balance board training).

Players were observed over three full seasons. The authors report a seven-fold reduction in ACL injuries per team per year in the intervention group compared to the control group (0.15 injuries per team per year vs. 1.15 injuries, P=0.001). These findings need to be confirmed before widespread implementation is recommended.

9.2.2.2 Plyometric (jump) training

Hewett et al. (1996) initially piloted the effect of a six-week jump training program in a preliminary biomechanical study involving eleven female volleyball players. Landing mechanics and lower extremity strength were compared with male athletes before and after training. Before training, females were found to have a marked imbalance between hamstring and quadriceps muscle strength and much lower knee flexor moments during landing from a jump than male athletes.

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

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

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

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

This study demonstrates that a specific plyometric training program may decrease knee injury risk in female athletes but this finding needs to be confirmed in larger studies where subjects or teams are randomised and other study design biases remedied. As raised by the authors, there were more volleyball players in the trained group and this may have biased this group towards lower knee ligament injury rates (there is some evidence that women's volleyball has a lower rate of knee injury than women's soccer or basketball). The study was not large enough to show if plyometric training protects against serious knee injuries in volleyball, specifically, because none of the 14 reported serious knee injuries were in volleyball.

9.2.2.3 Modifications to play techniques

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

Laboratory evidence

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

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

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

Biomechanical studies of the landing techniques of skilled netball players by Steele and associates (Steele & Milburn, 1987; Steele & Lafortune, 1989 cited in Steele et al., 1993) identified several landing technique modifications that minimise stress on the musculoskeletal system, particularly the knee. On the basis of these and other studies netball players are advised to land with the foot neutrally aligned, ensure adequate hip flexion (approximately 33 degrees when the foot initially contacts the ground and 45 degrees during the maximum landing force), flex the knee adequately (approximately 17 degrees at initial foot-ground contact and 40 degrees at the maximum landing force) and land with trunk upright (Steele et al., 1993). There are no 'real world' evaluation studies to show whether adoption of the recommended landing technique reduces the risk of knee ligament injuries in netball players.

Epidemiological evidence

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

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

The landing technique in skiing is probably of limited direct relevance to volleyball but similar advice on the importance of knee flexion on landing is given to netballers and basketballers. Preliminary evidence from a prospective study involving female college basketball players suggests that modification of landing technique is a promising countermeasure to ACL injury. After a 10 year investigation of ACL injuries (n=673) presenting to the mid-America Center for Sports Medicine, Henning et al. (1994) concluded that the majority of non-contact sports-related ACL injuries involved three common injury-producing deceleration techniques (plant and cut, straight knee landing and the one-step stop with the knee extended). The sport with the highest risk of non-contact ACL injuries was basketball (n=152).

Henning formulated a prevention program, tailored to specific sports, consisting of drills in which he had athletes practise substituting an accelerated rounded turn (off a bent knee) for the pivot and cut, flexed-knee landing for straight leg landing and the three-step stop instead of the one-step stop. His methods were instituted in a prospective study that compared knee injuries in two elite female junior college basketball teams. Preliminary data indicates that there was a significant decrease in ACL injuries when these techniques were taught prospectively (N.D.Griffis, unpublished data 1999, cited in Griffin et al., 2000).

Volleyball ranked sixth with 28 ACL non-contact injuries in the study of ACL injuries reporting to the mid-America Centre for Sports Medicine (Henning et al., 1994). More detailed investigation of these cases showed that the major mechanisms of injury were: spike attempt (10 cases; 35.7%), jumping for the ball (5 cases; 17.9%), block shot attempt (4 cases; 14.3%) and dig (10.7%). Because the majority of ACL injuries were associated with straight knee landing, the authors recommend that volleyball players are taught to land with their knees bent and to continue to bend them throughout the landing. They identified that reacting to the ball on defence was another concern and recommended that players should be drilled to keep knees bent and to push off with the inside leg when pulled out of position for a pass or during a dig situation.

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

Balance board and plyometric training programs appear to be promising interventions for the reduction of serious non-contact knee ligament injuries in volleyball players. Plyometric training should only be trialed in teams that have suitably qualified coaches and trainers, such as in schools and in the higher levels of competition, but balance board training is more accessible to the community level player. Laboratory and epidemiological studies in other sports suggest that the risk of ACL injuries may be reduced by the introduction of improved playing techniques, particularly bent knee landing.

9.2.3 Recommendations

For player safety

- Indoor volleyball should be played on wooden floors (or synthetic floors with similar elastic properties). Playing on hard surfaces (for example concrete or lino) should be avoided.

- Serious competitors should use cross training to limit the amount of training involving repetitive stresses on the knees.

- Knee pads should be worn in training and match play to prevent acute knee injuries and the acute exacerbation of overuse injuries.

- All players, especially female players, should be trained to 'land softly' on the balls of their feet with knees and hips flexed.

- Coaches should consider introducing balance board training, particularly for female players and players with knee instability.

- A plyometric (jump training), stretching and strength training program should be considered for all players to decrease peak landing forces and particularly for female players to correct imbalances between hamstring and quadriceps muscle strength. Plyometric training should be under the supervision of a trained coach and programs should be carefully evaluated.

- Players who are already proficient jumpers, middle blockers and players with knee pain are advised to decrease their jump training time and pay close attention to technique.

For further research and countermeasure development

- Population-based studies to determine gender-specific risk factors for non-contact ACL injuries.

- Further epidemiological, biomechanical and laboratory studies to clarify the role of intrinsic risk factors in non-contact ACL injuries and establish countermeasures to ACL injury.

- Research to better identify high-risk player positions and player manoeuvres for ACL injury and to develop protective neuromuscular responses when high-risk situations are encountered.

- Research to better understand the influence of playing surface and shoe-surface interaction on knee injury.

- A randomised controlled trial (in a population with no foot pain) to test the advantage of placing the foot in a supinated or neutral position rather than a pronated position when playing sport. Such a trial would have the capacity to establish the significance of pronation in overuse injury and the clinical value of an orthosis.

- Evaluation studies, preferably controlled trials, to determine the effectiveness of strategies and countermeasures to knee injuries in volleyball.

9.3 PREVENTING SHOULDER INJURIES

Shoulder overuse injuries appear to be quite common in volleyball players, especially in attackers and athletes who play frequently, but there is little detailed advice on prevention in the volleyball literature. Authors of the two small laboratory studies of shoulder problems in volleyball players recommend exercise programs to prevent and correct the imbalances and lack of flexibility that appear to characterise the dominant shoulder of volleyball players that may be associated with rotator cuff injury (Kugler et al., 1996; Wang et al., 2000). Mallon & Hawkins (1994) recommend strengthening and stretching the shoulder girdle during preseason and in-season conditioning, and thorough warm-up that includes stretching the shoulder muscles and low-intensity build-up to the sport activity. They also recommend that coaches work with players to develop techniques that minimise stress on the shoulder.

9.3.1 Shoulder flexibility and strengthening programs

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

Aargaard et al. (1997) report that shoulder injuries are more frequent in beach volleyball players than indoor players probably because there are only two players per team in beach volleyball and they are called on to serve and spike more often in a match and to hit the ball from more awkward positions. The authors suggest that beach volleyball teams should concentrate on shoulder strength and spike co-ordination training with the shoulder joint held in different rotations.

9.3.2 Shoulder rehabilitation programs

A number of shoulder rehabilitation programs that have been developed in response to shoulder overuse pathologies in throwing athletes and tennis players may also be useful for volleyball players (Meister, 2000; Chandler et al., 1992; McCann & Bigliani, 1994).

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

9.3.3 Recommendations

For player safety

- Players, especially attackers and beach volleyball players, should include specific exercises to strengthen the shoulder in external rotation and increase the flexibility of internal rotation of the rotator cuff.

- Beach volleyball players should include spike co-ordination training drills with the shoulder joint held in different rotations.

For further research and countermeasure development

- In-depth research on the incidence, patterns, mechanisms and consequences of shoulder injuries in volleyball at all levels of play with a view to developing specific countermeasures

- Controlled investigations on the optimal preventive and rehabilitative exercise programs to prevent shoulder overuse injuries.

9.4 HAND/FINGER INJURIES

Hand/finger injuries are common in volleyball players, especially juniors, and appear to be neglected in terms of prevention and adequate rehabilitation. There are only two suggestions on the prevention of hand/finger injuries in the volleyball literature: hand protection (gloves) and attention to technique (especially for young female and low level players). Recommendations on treatment and rehabilitation include immediate treatment with ice, careful assessment by a medical practitioner, adequate rehabilitation before return to play and the use of a splint or buddy taping to protect against re-injury when play is resumed.

9.4.1 Hand protection - taping and splints

Taping of finger joints (either single finger or buddy taping) is quite common among volleyball players to protect previously injured proximal interphalangeal (PIP) joints. Briner & Kacmar (1997) recommend that collateral ligament injuries to the PIP joint should be 'buddy taped' to an adjacent finger, rather than single taped, to provide the necessary degree of biomechanical support. Other authors recommend that a splint provides effective and more convenient support for acute and chronic PIP joint injuries (Benaglia et al., 1996).

Finger taping has the same drawbacks as ankle taping. The support provide by tape diminishes after about 10 minutes, skilled assistance is needed to apply tape properly and tape is costly. Benaglia et al. (1996) designed and tested a thermoplastic PIP joint splint in 20 semi-professional volleyball players all of whom had been using functional tape for chronic finger injuries and whose court position (front row) exposed them to possible re-injury. The study focused on the effectiveness, physical tolerance, and subjective acceptance of the figure-eight splint.

After some initial adjustment of the splint, all subjects reported an overall sensation of protection and stability of the joint and all found it convenient to be able to apply it without assistance. At three months follow-up (after 120 hours of play), 14 players were still using the splint for training and official games because they were still feeling a persistent 'giving-way' sensation and insecurity when playing without it, one was still using the splint as a psychological support during active competition and five subjects had stopped using it because of full remission of symptoms.

None of the 20 players experienced further injuries at the splinted joint. None of the splints had lost rigidity at the end of the test period or were deformable in extension-stress tests either at the end of each session of play or at the end of the test period. The major weakness of this study is the lack of a control group but it provides preliminary evidence that this type of splint may prevent re-injury, does not interfere with play and resolves the drawbacks of taping. The authors caution that the splint should not be used as a prophylactic device because prolonged partial immobilisation could weaken joint structures. However, support should be provided to injured hands/fingers until symptoms are resolved.

9.4.2 Ban on rings and jewelry

Bhairo et al. (1992) reported one case of serious injury leading to finger amputation caused by a player's ring being caught in the net. Jewelry should not be worn in competition and training sessions, long nails should be taped. Hands should be inspected by referees/coaches prior to play.

9.4.3 Correct playing techniques

Several authors recommend skills training and attention to technique as countermeasures to hand/finger injury but provide no detailed advice. In the case of blocking, the correct technique is the manoeuvre apparently most associated with finger injuries, particularly among high-level and elite players. Blockers spread fingers to the maximum to create a wide area for the block and ,consequently, the thumb and little finger are highly vulnerable to injury. Players are trained to aim for the fingertips of blockers when spiking to decrease the likelihood of a successful block. In these circumstances it is difficult to know what adjustment to techniques can be recommended, although skills training to improve footwork, positioning for the block and eye-hand co-ordination should be beneficial. Blocking-related hand/finger injuries are apparently less common in beach volleyball where there are fewer blocks performed because of two-person team structure (Aagaard et al., 1997).

Bhairo et al. (1992) report from their follow-up study of hand injuries that an inadequately performed 'stop' (an attempted pass or dig in the second line of defence) was the manoeuvre most associated with hand/finger injury to recreational players. Recreational players (including school children) should be progressively introduced to the correct technique for each of the basic ball hitting skills/manoeuvres, including hand/arm position and footwork. It appears that special attention should be paid to developing the skills of left-handed players, although the influence of handedness on injury, particularly hand/finger injury, needs to be confirmed by other studies.

Resources for coaches and teachers distributed by Volleyball Victoria include: the Aussie Sport Education in Physical Education Program (SEPEP) Booklet on Volleyball that introduces primary schoolchildren to the game; Volleystars (modified rules for children) Aussie Sport Lesson Plan Guide for Beginners; "Dig Set Spike" - Level One Coaches Manual, a resource for secondary students; the VVI Drills Manual for junior to advanced secondary students; and the Volleyball Sports Education Kit.

9.4.4 Proper and adequate treatment and rehabilitation

At higher levels of play, specialist blockers appear to be at increased risk of hand/finger injury, particularly the centre forward who may be called on to perform an average of 40 blocks per game. At advanced levels the ball can reach speeds up to 80mph which exposes the hand and fingers to extremely violent stresses when hands are held straight with each joint extended, a highly vulnerable position for injury.

Anecdotal evidence suggests that accumulations of minor hand/finger injuries eventually force some high-level players out of the game and that this could be partly caused by inadequate assessment, initial treatment and rehabilitation (Schafle et al., 1990). Several reports indicate that experienced players regard hand/finger injuries as minor and 'part of the game' because they can support the injured finger with sports tape and continue to play (Schafle et al., 1990; Briner & Kacmar, 1997).

Bhairo et al. (1992) exposed the folly of this attitude in their study of the long-term effects of sports-related hand injuries, although the hospital casualty series that provided the cases for telephone follow-up may have been biased towards more serious hand/finger injury cases. The authors reported that 28% of the 125 respondents interviewed by telephone (on average 5-years after initial treatment) still experienced pain, stiffness, limitation in movements (flexion and extension) and/or discomfort in using the hand. The authors could find no significant relationship between the type of injury (sprain/strain, fracture, contusion, dislocation and mallet finger) and late complaints. Only one-third (32.8%) of patients used protective tape on return to play which suggests that rehabilitation was inadequate.

The recommended treatment for acute finger injuries includes: the application of ice immediately after injury; thorough physical examination by a medical practitioner, x-ray and referral for specialist assessment (if deemed necessary) as soon as possible after the match; and rest and splinting or taping until finger has recovered full function. The rehabilitation period for finger injuries appears to be quite long. Aargaard & Jorgensen

(1996) found that symptoms persisted in elite players on average 49 days for females and 60 days for males. The mean number of days lost to play was 3 for males and 6 for females. The authors speculate that the reason for the apparent longer duration of symptoms today compared to 10 years ago (when a similar survey reported the average duration of symptoms was 26 day for males) was that players resume play earlier today, despite pain.

9.4.5 Recommendations

For player safety

- All schoolchildren and new players should be introduced to the game progressively with the proper techniques for each of the basic volleyball skills taught and practised in a controlled environment prior to full participation. Junior players should progress to regular volleyball through the modified "Volleystars" and mini-volleyball games.

- Players should not wear rings or other jewelry. Coaches and match officials should strictly enforce this ban.

- Hand/finger injuries should be immediately treated with ice and assessed by a medical practitioner within 24 hours.

- Coaches and trainers should be alert to the potential long-term adverse effects of hand/finger injuries and advise players against 'playing on' with finger injuries.

- Buddy taping or, preferably, a finger brace should be worn in both practice and games (if permitted within the rules) until symptoms resolve, which may be several months.

For further research and countermeasure development

- In-depth research on the incidence, patterns, mechanisms and consequences of hand/finger injuries in volleyball at all levels of play with a view to developing specific countermeasures.

- Controlled investigations on the optimal treatment and rehabilitation regimes for different types of hand/finger injury including the amount of rest from play that is advisable.

- Controlled trial of the most effective type of protective support for the hand/finger (tape or brace) to prevent re-injury on return to play.

10. CONCLUSION

This report presents hospital emergency department data on volleyball injury in Victoria and available data from a number of overseas studies. These sources provide an incomplete picture of the pattern of injury in volleyball in Victoria and Australia at the community and high/elite levels. There is need for an Australian prospective study to establish injury incidence and patterns for different levels of competition and for different age groups. Volleyball associations should consider the introduction of an injury database to systematically record injury cases because good quality data provides the strongest foundation for injury prevention efforts. Injury incidence report forms and associated software have been developed and trialed in Victoria and are available through Monash University Accident Research Centre. The Australian Sports Injury Data Dictionary provides guidelines for sport and recreation injury data collection and classification (http://www.ausport.gov.au/partic/datadict.html).

In general, the injury prevention strategies and countermeasures included in this report are of 'promising' rather than 'proven' effectiveness. Therefore, any planned interventions require careful evaluation 'in the field'. Many suggested countermeasures are drawn from other sports, have not been thoroughly evaluated and may have not been tested in volleyball. Also, more effort should be directed to basic scientific studies on the biomechanics of volleyball so the mechanisms of injury are better understood, to assist the design of new countermeasures.

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

- Volleyball associations should establish an injury reporting system for the documentation of volleyball injuries. All data collections should conform to national guidelines for sports injury surveillance (the Australian Sports Injury Data Dictionary).
- Action needs to be taken to improve the quality and specificity of data on sports injuries collected through the Victorian hospital system
- Further epidemiological research is needed to determine the risk factors for volleyball injury and to evaluate the effectiveness of countermeasures.
- Current work by volleyball associations on guidelines for minimum safety requirements for organised volleyball should be expedited.
- A cost of sports injury study is required to determine the overall cost of sports injury and the relative cost of injuries for different sports.

11. REFERENCES

Aagaard H and Jorgensen U. Injuries in elite volleyball. *Scand J Med Sci Sports*. 1996;6:228-232.

Aagaard H, Scavenius M, Jorgensen U. An epidemiological analysis of the injury pattern in indoor and in beach volleyball. *Int. J. Sports Med*. 1997;18:217-221.

Allingham C. The shoulder complex. In: Zuluaga et al. Eds. Sports Physiotherapy: Applied science and practice. Melbourne: Churchill Livingstone, 1995.

Arendt EA. Common musculoskeletal injuries in women. *The Physician and Sports Medicine*. 1996;24(7):39-48.

Australian Sports Commission (ASC). SportSafe Australia. A national sports safety framework. Australian Sports Commission. Canberra, 1997.

Backx FJG, Beijer HJM, Bol E, et al. Injuries in high-risk persons and high-risk sports. *Am J Sports Med.* 1991;19(2):124-128.

Bahr R and Bahr A. Incidence of acute volleyball injuries: a prospective cohort study of injury mechanisms and risk factors. *Scand J Med Sci Sports*. 1997;7:166-171.

Bahr R, Karlsen R, Lian O, et al. Incidence and mechanisms of acute ankle inversion injuries in volleyball. *Am J Sports Med*. 1994;22(5):595-600.

Bahr R, Lian O and Bahr A. A twofold reduction in the incidence of acute ankle sprains in volleyball after the introduction of an injury prevention program: a prospective cohort study. *Scand J Med Sci Sports*. 1997;7:172-177.

Bengalia PG, Sartorio F, Ingenuity R. Evaluation of a thermoplastic splint to protect the proximal interphalangeal joints of volleyball players. *Journal of Hand Therapy*. 1996;9:52-56.

Bergeron MF, Armstrong LE, Maresh CM. Fluid and electrolyte losses during tennis in the heat. *Clin Medicine* 1995;14(1): 23-32.

Best TM, Garrett WE. Warming up and cooling down.. In: Renstrom PAFH, ed. Sports injuries: Basic principles of prevention and care. London: Blackwell Scientific Publications, 1993.

Bhairo NH, Nijsten MWN, van Dalen KC, et al. Hand injuries in volleyball. *Int. J. Sports Med*. 1992;13(4):351-354.

Bigiliani LU, Kimmel J, McCann PD, Wolfe I. Repair of the rotator cuff tears in tennis players. *Am J Sports Med* 1992;20(2):112-7.

Blevins FT. Rotator cuff pathology in athletes. *Sports Med.* 1997;24(3):205-220.

Briner Jr WW and Kacmar L. Common injuries in volleyball-mechanisms of injury, prevention and rehabilitation. *Sports Med*. 1997;24(1):65.

Caraffa A, Cerulli G, Projetti M, et al. Prevention of anterior cruciate ligament injuries in soccer. A prospective controlled study of proprioceptive training. *Knee Surgery, Sports Traumatology, Athroscopy.* 1996;4(1):19-21.

Chan KM, Yuan Y, Li CK, et al. Sports causing most injuries in Hong Kong. *Br J Sports Med.* 1993;27(4).

Cook JL, Khan KM, Harcourt PR, et al. A cross sectional study of 100 athletes with jumper's knee managed conservatively and surgically. *Br J Sports Med*. 1997;31:332-336.

de Jonge J, Kingma J, van der Lei B, et al. Hand fractures in sports. An analysis of incidence and etiology across the life span. *Int J for Consumers*. 1995;2(3):143-48.

De Loes M. Epidemiology of sports injuries in the Swiss organisation "Youth and Sports" 1987-1989. *Int J Sports Med*. 1995;16:134-138.

Dixon SJ, Batt ME, Collop AC. Artificial playing surfaces research: a review of medical, engineering and biomechanical aspects. *Int J Sports Med*. 1999;20(4):209-18.

Ekstand J, Gillquist J and Liljedahl SO. Prevention of soccer injuries. Supervision by doctor and physiotherapist. *Am J Sports Med*. 1983;11(3):116-120.

Ekstrand J and Gillquist J. The avoidability of soccer injuries. *Int J Sports Med*. 1983;4:124-128.

Ellenbecker TS. Rehabilitation of shoulder and elbow injuries in tennis players. *Clinics in Sp Med.* 1995;14(1):87-100.

Ettlinger CF, Johnson R and Shealy JE. A method to help reduce the risk of serious knee sprains incurred in alpine skiing. *Am J Sports Med.* 1995;23(5):531-537.

Ferretti A, Papadnrea P, Conteduca F, et al. Knee ligament injuries in volleyball players. *Am J Sports Med*. 1992;20(2):203-207.

Ferretti A, Papandrea P and Conteduca F. Knee injuries in volleyball. *Sports Med*. 1990;10(2):132-138.

Ferretti A. Epidemiology of jumper's knee. *Sports Med.* 1986;3:289-295.

Finch CF, Mitchell D, Copeland K. Sport safe. *Sport Health, Sports Medicine Australia*. 1999;17(4):20.

Garrick J, Reque R. Role of external support in the prevention of ankle sprains. *Am. J. Sports Med.* 1973;5:200-3. Cited in Hume PA, Gerrard DF. Effectiveness of external ankle support. Bracing and taping in Rugby Union. *Sports Med* 1998;25(5):285-312.

Goodwin Gerberich S, Luhmann S, Finke C, et al. Analysis of severe injuries associated with volleyball activities. *The Physician and Sports Medicine*. 1987;15(8):75.

Grana WA. Acute ankle injuries. In Renshaw DAFH (ed). Clinical practice of sports injury prevention and care. Oxford Boston: Blackwell Scientific Publications 1994.

Greene TA and Hillman SK. Comparison of support provided by a semirigid orthosis and adhesive ankle taping before, during, and after exercise. *Am J Sports Med*. 1990;18(5):498-506.

Griffin LY, Agel J, Albohm MJ, et al. Noncontact anterior cruciate ligament injuries: risk factors and prevention strategies. *J Am Acad Othop Surg.* 2000;8(3):141-50.

Gross ML, Napoli RC. Treatment of lower extremity injuries with orthotic shoe inserts. An overview. *Sports Med*. 1993;15(1):66-70.

Gwinn DE, Wilckens JH, McDevitt ER, et al. The relative incidence of anterior cruciate ligament injury in men and women at the United States Naval Academy. *Am J Sports Med*. 2000;28(1):98-102.

Harmon KG and Ireland ML. Gender differences in noncontact anterior cruciate ligament injuries. *The Athletic Woman*. 2000;19(2):287-303.

Henning CE, Griffis ND, Vequist SW, et al. Sport-specific knee injuries. In Renshaw DAFH (ed). Clinical practice of sports injury prevention and care. Oxford Boston: Blackwell Scientific Publications 1994.

Hewett TE, Lindenfeld TN, Ricobene JV, et al. The effect of neuromuscular training on the incidence of knee injury in female athletes. A prospective study. *Am J Sports Med.* 1999;27(6):699-705.

Hewett TE, Stroupe AL, Nance TA, et al. Plyometric training in female athletes. *Am J Sports Med.* 1996;24(6):765-773.

Hume PA and Gerrard DF. Effectiveness of external ankle support. *Sports Med.* 1998;25(5):285-312.

Hume PA, Gerrard DF. Effectiveness of external ankle support. Bracing and taping in Rugby Union. *Sports Medicine* 1998;25(5):285-312.

Hutchinson MR and Ireland ML. Knee injuries in female athletes. *Sports Medicine.* 1995;19(4):288-302.

Janda DH, Loubert P. Basic Science and clinical application in the athlete's shoulder. A preventative program focusing on the glenohumeral joint. *Clin Sports Med*. 1991 Oct;10(4):955-71.

Janisse DJ. Indications and prescriptions for orthoses in sport. *Orthopedic Clin North America 1994;25(1):95-107.*

Jobe FW, Pink M. Classification and treatment of shoulder dysfunction in the overhead athlete. *JOSPT*. 1993;18(2):427-432.

Kibler WB, Chandler TJ, Uhl T, Maddux RE. A musculoskeletal approach to the preparticipation physical examination: preventing injury and improving performance. *Am J Sports Med* 1989; 17(4): 525-531.

Kibler WB, McQueen C, Uhl T. Fitness evaluations and fitness findings in competitive junior tennis players. *Clin Sports Medicine* 1988; 7(2): 403-416.

Kilmartin TE, Wallace WA. The scientific basis for the use of biomechanical foot orthoses in the treatment of lower limb sports injuries – a review of the literature. *British Columbia Sports Medicine* 1994;28(3):180-184.

Knight KL. Cryotheraphy: theory, technique and physiology. Chatanooga: Chattanooga Corporation. 1985.

Kugler A, Kruger-Franke M, Reininger S, et al. Muscular and shoulder pain in volleyball attackers. *Br J Sports Med*. 1996;30:256-259.

Kujala UM, Kvist M and Osterman K. Knee injuries in athletes. Review of exertion injuries and retrospective study of outpatient sports clinic material. *Sports Med*. 1986;3:447-460.

Kujala UM, Taimela S, Antti-Poika I, et al. Acute injuries in soccer, ice hockey, volleyball, basketball, judo and karate: analysis of national registry data. *BMJ* 1995;311(7018):1465/

Lanese RR, Strauss RH, Leizman DJ, Rotondi AM. Injury and disability in matched men's and women's intercollegiate sports. *AJPH* 1990;80(12):1459-1462.

Larkins PA. Common running problems. Canberra: Australian Sports Medicine Federation, 1990.

Lehman RC. Shoulder pain in the competitive tennis players. *Clin Sports Medicine* 1988;7(2): 309-327.

Lian O, Engebretsen L, Overbo RV, et al. Characteristics of the leg extensors in male volleyball players with jumper's knee. *Am J Sports Med*. 1996;24(3)380-385.

Mallon WJ, Hawkins RJ. Shoulder injuries. In Renshaw DAFH (ed). Clinical practice of sports injury prevention and care. Oxford Boston: Blackwell Scientific Publications

McCann PD, Bialiani LU. Shoulder pain in tennis players. *Sports Med* 1994;17(1):53-64.

McKeag DB. Preparticipation screening of the potential athlete. *Clin Sports Medicine* 1989; 8(3):373-397.

McNair PJ, Stanley SN. Effect of passive stretching and jogging on the series elastic muscle stiffness and range of motion of the ankle joint. *Br J Sports Med.* 1996;30:313-318.

McNair PJ, Prapavessis H, Callender K. Decreasing landing forces: effect of instruction. *Br J Sports Med.* 2000;34:293-296.

Meister K. Injuries to the shoulder in the throwing athlete. Part two: evaluation/treatment. *Am J Sports Med*. 2000 Jul-Aug; 28(4):587-601.

Milburn PD and Barry EB. Shoe surface interaction and the reduction of injury in rugby union. *Sports Med*. 1998;25(5):319-327.

Moeller JL and Lamb MM. Anterior Cruciate Ligament injuries in female athletes. *The Physician and Sports Med*. 1997;25(4):31-48.

Moore KW, Frank CB. Traumatic knee injuries. In Renshaw DAFH (ed). Clinical practice of sports injury prevention and care. Oxford Boston: Blackwell Scientific Publications 1994.

Murphy RJ. Heat problems in tennis players. *Clin Sports Medicine* 1988;7(2):429-34.

National Sports Trainers' Scheme. *Sports First Aid course material.* Australian Sports Medicine Federation, 1994.

Nirschl RP. Prevention and treatment of elbow and shoulder injuries in tennis players. *Clin Sports Medicine* 1988;7(2):289-308.

O'Toole G, Rayatt S. Frostbite in the gym: a case report of an ice pack burn. *Br J Sports Med* 1999; 33(4):278-9.

Pope RP, Herbert RD, Kirwan JD, et al. A randomised trial of preexercise stretching for prevention of lower-limb injury. *Medicine & Science in Sports & Exercise*. 2000;32(2):271-277.

Quinn K, Parker P and de Bie R. Interventions for preventing ankle ligament injuries (Cochrane review). In: *The Cochrane Library*. 1999, issue 1.

Razeghi M, Batt ME. Biomechanical analysis of orthotic shoe inserts. *Sports Med*. 2000 June;(29)6:425-438.

Renstrom AF. Knee pain in tennis players. *Clin Sports Medicine* 1995;14(1):163-175.

Rice EL, Anderson III KL. Volleyball. In Fu FH & Stone DA (eds). Sports injuries: mechanisms, prevention and treatment. Baltimore Md, Williams & Williams c1994 p689-700.

Richards DP, Ajemian SV, Wiley P, et al. Knee Joint Dynamics Predict Patellar Tendinitis in Elite Volleyball Players. *Am J Sports Med*. 1996;24(5):676-683.

Robbins S and Waked E. Factors associated with ankle injuries. *Sports Med*. 1998;25(1):63-72.

Rooser B, Ekbladh R, Roels J, Lidgren L. The shock absorbing effects of soles and insoles. *Internat Orthop*. 1988;12:335-8.

Rovere G, Clarke T, Yates C, et al. Retrospective comparison of taping and ankle stabilizers in preventing ankle injuries. *Am J Sports Med* 1988;16:228-33.

Safran MR, Seaber AV, Garrett W. Warm-up and muscular injury prevention. *Sports Med* 1989;8(4):239-249.

Schafle MD, Requa RK, Patton WL, et al. Injuries in the 1987 National Amateur Volleyball Tournament. *Am J Sports Med.* 1990;18(6):624.

Schafle MD. Common injuries in volleyball – Treatment, prevention and rehabilitation. *Sports Med* 1993;16(2);126-129.

Schutz LK. Volleyball. *Recreational Sports Injuries*. 1999;10(1):19.

Schwellnus MP, Jordaan G, Noakes TD. Prevention of common overuse injuries by the use of shock absorbing insoles: a prospective study. *Am J Sports Med. 1990;18(6):636*-641. Cited in Gross ML, Napoli RC. Treatment of lower extremity injuries with orthotic shoe inserts. An overview. *Sports Med* 1993;15(1):66-70.

Shrier I. Stretching before exercise does not reduce the risk of local muscle injury: a critical review of the clinical and basic science literature. *Clin J Sports Med* 1999 Oct;9(4):221-7

Sitler M, Ryan J, Wheeler B, et al. The efficacy of a semirigid ankle stabilizer to reduce acute ankle injuries in basketball. *Am J Sports Med*. 1994;22(4):454-461.

Sitler MR, Horodyski M. Effectiveness of prophylactic ankle stabilisers for prevention of ankle injuries*. Sports Med* 1995;20(1):53-57.

Solgard L, Nielsen AB, Moller-Madsen B, et al. Volleyball injuries presenting in casualty: a prospective study. *Br J Sports Med.* 1995;29(3):200-204.

Steele J. Surface selection: Considerations for player safety and comfort. Royal Australian Institute of parks and Recreation: Sports Surface Seminar. Canberra, 1990.

Stevenson MR, Hamer P, Finch CF, et al. Sport, age and sex specific incidence of sports injuries in Western Australia. *Br J Sports Med.* 2000;34:188-194.

Surve I, Schwellnus M, Noakes T, et al. A fivefold reduction in the incidence of recurrent ankle sprains in soccer players using the sport stirrup orthosis. *Am. J Sports Med* 1994;8:601-6.

Thacker SB, Stroup DF, Branche CM, et al. The prevention of ankle sprains in sports. *Am J Sports Medicine.* 1999;27(6):753-760.

Ticker JB, Fealy S, Fu FH. Instability and impingement in the athlete's shoulder. *Sports Med* 1995;19(6):418-426.

Tropp H, Askling C and Gillquist J. Prevention of ankle sprains. *Am J Sports Med*. 1985;13(4):259-262.

van Mechelen W. Running injuries: A review of the epidemiological literature. *Sports Med* 1992;14(5):320-335.

Vicenzino B, Vicenzino D. Consideration in injury prevention. In: Zuluaga et al. Eds. Sports Physiotherapy: Applied science and practice. Melbourne: Churchill Livingstone, 1995.

Wang HK, Macfarlane A, Cochrane T. Isokinetic performance and shoulder mobility in elite volleyball athletes from the United Kingdom. *Br J Sports Med*. 2000 Feb;34(1):39-43.

Watkins J and Green BN. Volleyball injuries: a survey of injuries of Scottish National League male players. *Br J Sports Med*. 1992;26(2):135

Watkins J. Injuries in volleyball. In Renshaw DAFH (ed). Clinical practice of sports injury prevention and care. Oxford Boston: Blackwell Scientific Publications 1994.

Webb J, Corry I. Injuries of the sporting knee. Br J Sports Med. 2000;34:227-228.

Wedderkopp N, Kaltoft M, Lundgaard B, et al. Prevention of injuries in young female players in European team handball. A prospective intervention study. Scand J Med Sci Sports. 1999 Feb;9(1):41-47.

Witvrouw E, Cools A, Lysens R, et al. Suprascapular neuropathy in volleyball players. Br J Sports Med. 2000 June;34(3):174-180.

Ytterstad B. The Harstad injury prevention study: the epidemiology of sports injuries. An 8 year study. *Br J Sports Med.* 1996;30:64-68.

12. APPENDIX

Appendix 1 Summary of Australian and international descriptive studies of volleyball injuries

Article, study aims, number of cases.	Study setting, duration, data source	Injury criteria	Main Findings Injury frequency and rates Gender and age pattern	 Injury site and type Other findings of interest	Comments
Community volleyball (all or mostly recreational players): children and youth					
• De Loes M (1995) • To determine acute injury rates in relation to the time of exposure in more than 30 sports played by youth aged 14-20 years n the organisation 'Youth and Sports' • 16,120 injuries overall including 618 volleyball injuries	• Switzerland (Swiss Organisation: 'Youth and Sports') • 1987-89 • Sports injury insurance registry data covering all participants, and exposure data from Swiss Sports School Macolin which documents number, age and sex of participants and time and length of participation in 'Youth and Sports' activities	• All acute injuries occurring in organised sport through Youth and Sport program, that were attended to by a physician	**Injury rates** • In male sports, volleyball had the 7^{th} highest rate of injury (3.0 injuries/10,000 hours of exposure), ranked behind ice hockey, handball, soccer, wrestling, hiking and basketball. • In female sports, volleyball had the 5^{th} highest rate of injury (3.8 injuries/10,000 hours of exposure), ranked behind handball, soccer, basketball and alpine skiing **Gender pattern** • No specific data for volleyball The overall risk of injury was slightly higher for males than females in the eleven sports practised by both males and females which included volleyball (M: 4.9/10,000 hours played; F: 3.2/10,000 hours) but higher in females than males when soccer excluded and standardisation of the incidence rates by the total exposure, (F:4.5/10,000 hours; M: 4.3/10,000 hours)	**Injury site** • No information **Injury type** • 69.1% of injuries to male volleyball players were distortions (sprains and strains); rate: 2.1 distortion injuries /10,000 hours of exposure • 75.5% of injuries to females were distortions; rate:2.9 distortion injuries/10,000 hours of exposure -distortions (73.9%) -contusions (12.1%) -fractures (5.5%) -dislocations (3.1%) -wounds (1.8%) -intracranial fractures (1.6%) -other (1.8%)	• Minor injuries may not have been reported • Individual absences not accounted for in the exposure data • Overuse injuries not included
• Backx FGH, Beijer HJM, Bol E & Erich WBM (1991) • To determine the incidence and severity of sports injuries occurring in Dutch school children (aged 8-17 years) • 399 injuries overall, frequency of injury in volleyball not reported	• The Netherlands (prospective study in schools) • 7 months of 1982/83 school year (winter and spring) • Prospective follow-up survey	• Any physical damage caused by an accident during physical education or in any sports activities outside of school either unorganised or organised • Pupils self-reported injuries to their physical education teacher and filled in questionnaire. Data was compiled at 3- and 7-month mark	**Injury frequency and rates** • No injury frequency data given for volleyball • Volleyball ranked 4^{th} of 19 organised sports and physical education with more than 15 participants calculated on injuries per 1000 young athletes/year (548/1000/year), behind basketball (998/1000/year), handball (814/1000/year), korfball (809/1000/year) • Volleyball had the highest injury incidence rate in organised sport per 1000 hours of practice but was 10^{th}	**Injury site and type** • No information given for individual sports **Other** • High risk sports for injury were characterised by contact, a high jump rate and indoor activities	• Injuries not tracked for full year, therefore may be underestimated and subject to seasonal bias • Relied on self-report for injury data (possibility of reporting and recall bias)

			highest in injury incidence per 1000 hours in games		
• Maffulli N, Bundoc RC, Chan KM and Cheng JCY (1996) • To ascertain the epidemiological characteristics of sports injuries in children (0-16 years) • 238 sports injury cases including 12 cases of volleyball injuries	• Hong Kong (one Sports Injury Clinic) • May 1994 – Dec 1990 • Retrospective review of cases seen in the Sports Injury Clinic of the Prince of Wales Hospital	• Injuries treated in Sports Injury Clinic of one hospital following referral from emergency department or another doctor • Sports injury report form filled in by patient or parent/relative and doctor	**Injury frequency and rates** • Volleyball accounted for 5.0% of injuries and was 5th ranked behind track and field, basketball, soccer, cycling based on injury frequency • No rate data	**Injury site and type** • No information for specific sports	• Small number of volleyball injury cases • No population, participation or exposure data • Population coverage not comprehensive, only one clinic included. Study does not cover injuries treated in other settings and minor injuries
• North Sydney Area Health Service (1997) • To determine the rate of sports participation and incidence and type of sports injury in 11-19 year old school children in New South Wales, Australia • 73 injuries in 826 volleyball players in previous 6 months	• Australia, New South Wales (schools survey) • Data collected at two points August 1994 (winter) and March 1995 (summer) • Retrospective survey of sports participation and sports injury in 20,000 high school children aged 11-19 years (78% response rate)	• Sports injury' subjectively defined by respondents including injury that was treated by a medical practitioner or injury resulting in stopped physical activity for at least one day or injury that resulted in loss of consciousness or awareness • Self reported data (6 months recall) from stratified sample of school children	**Injury frequency and rates** • 73 injuries to 826 volleyball participants (9% of participants injured in previous 6 months) • Volleyball ranked 30th, in terms of proportion of participants injured, in a list of 37 sports and active recreation played by high school students at club, school level and 'for fun'. • No exposure (time at risk) data included	**Injury site** -Ankle 27% -Finger 27% -Wrist 25% -Knee 19% -Back 14% -Hand 12% **Injury type** -Bruise (47%) -Muscle strain (41%) -Joint swelling/inflammation (33%) -Joint/ligament strain ((30%) -Dislocation(5%) -Bleeding (4% -Broken bone (4%) (based on most recent injury) **Other findings** • Volleyball injuries occurred most frequently in school sport (21%), training (21%), tournament (14%) and club competition (12% • 38% of injured players received first aid and 58% received later treatment from doctor, physio or parent (23% from doctor, 7% from physio and 21% from parents) and 7% received later treatment from a hospital • 26% of injured players reported time off from school and 68% reported time off from sport	• Broad definition of sport and injury • Retrospective data – recall bias (6 months recall demanded) • Injury data based on most recent injury sustained, therefore an underestimation (54% of respondents reported they had been injured more than once in previous 6 months) • Small number of volleyball injury cases

Community-level volleyball (all or mostly recreational players): all ages					
• Gerberich et al (1987) • To determine the types and severity of injuries incurred in volleyball within a select population and to identify variables that might be associated with these injuries • 106 volleyball cases treated in 7,490 persons referred to sports medicine clinic for rehabilitation	• • September 1977 – December 1984 • Retrospective case series of injuries referred to one outpatient sports medicine clinic • 106 cases drawn from general population	• Severe acute and overuse injuries referred for rehabilitation to an outpatient sports medicine clinic	**Injury frequency and rates** • Volleyball accounted for 1o6 injuries, 1.4% of referrals for rehabilitation **Gender and age** • 51.4% males, 48.6% females • mean age for males 31.2 years, females 21.0 years	**Injury site** • Lower extremity (90%) -knee 59.0% (and 97.0% of cases requiring surgery) -ankle 23.0% Shoulder 8.0% **Injury type** • Knee injuries involved mainly meniscus, ligament and patellofemoral damage • Ankle injuries, mainly sprains including torn ligaments	• Data from only one sports clinic • Only more severe and recalcitrant injuries referred and referral practices vary • Denominator data for the calculation of rates not available
• Bhairo et al. 1992 • To determine the long-term sequelae of hand injuries as a result of playing volleyball • 9,400 patients with sports injuries treated, of which 968 patients presented with 1003 injuries as a result of volleyball	• The Netherlands, hospital trauma data • Retrospective case series of volleyball injuries presenting to one trauma department over a 5-year period • 968 cases (1003 injuries) drawn from general population	• Presentations with volleyball injury to hospital trauma department	**Injury frequency and rates** • 968 patients with volleyball injuries out of 9,400 patients with sports injuries (10.3%) **Gender and age pattern** • Males 47% of injured volleyballers, females 53%.	**Injury site** -Ankle/foot (60.9%) -Hand/wrist (23.4%) -Knee (6.8%) -Head (4.3%) -Shoulder/upper arm (2.6%) -Other (2.0%) **Injury type** -Sprain and strain (73%) -Fracture (14%) -Contusion (8%) -Dislocation (4%) -Open wound (2%) -Other (3%)	• Findings based on data from only one hospital • No rate data • Overuse injuries generally do not present to ED departments

• Kujala UM, Taimwlo S, Antii-Poika I et al (1995) • To determine acute injury profile in each of six sports for all ages • 5,235 volleyball injuries (87,668 person years of exposure) in 54,186 injuries overall (621 691 person years of exposure to injury)	• Finland (national data) • 1987-91 • National sports injury insurance registry data (Compulsory sports insurance for any competitor in 4 of the six sports of interest. For volleyball, insurance was compulsory from 1987 to 1990, but not during 1991 when about 2/3 volleyball players were insured)	**Injury definition:** All traumatic, acute sports injuries that occurred in training and competitions that incurred a medical cost (including all injuries of sudden onset e.g. muscular strains)	**Injury frequency and rates** • 5,235 volleyball injuries (9.7% of all sports injuries) • Of the 6 sports volleyball had lowest injury rate per 1,000 person years of exposure (60/1000; CI 58-61), ranked behind karate (142/1000), judo (117/1000), ice hockey (94/1000); soccer (89/1000) and basketball (88/1000). **Gender and age pattern** • Males were at higher risk overall and those aged 20-24 years were at highest risk of all 5-year age groups 0->35 years. • Females were at higher risk than males in younger (0-15 years) and older (>34 years) age groups	**Injury site (volleyball)** • Lower limb (57.4%, mainly to ankle and knee) • Upper limb (22.4%, mostly upper arm and shoulder and fingers) • Other sites (20.2%, mostly back and head and neck) **Injury type (volleyball)** -Sprains and strains (74.8% , predominantly ankle and knee) -Bruises and wounds (18.3%) -Fractures, including dental (5.9%, predominantly fingers, palm and wrist and lower limb) -Dislocations (1.4%) -Other/unknown (1.8%) **Other findings** • Most volleyball injuries occurred in training (45%)	• Not all sports were included in study • Not all treated injuries report to insurance company and all minor injuries that are self treated go unreported • There was no record of hours of exposure to training and competition, higher exposure may account for some/all of the difference in injury rates in the six sports and the peak rates in males aged 20-24 years
• Schafle MD, Requa RK, Patton WL, Garrick JG (1992) • To document prospectively the injuries in the 1987 U.S. Volleyball Association's national tournament • 1,520 skilled participants in ages ranging from 17-60 years in five age/gender groups	• United States • 1987 USVA national tournament • prospective study, pre-tournament survey of all participants, injury report filled in by medical staff on presentation and telephone follow-up if necessary	• Injury presenting to the medical staff at the tournament.	**Injury frequency and rates** • 154 injuries in 1520 participants during 7812 hours of play (overall injury rate 1.97/100 hours of play) • Female injury rate higher than male (2.2/100 hours versus 1.8 per 100 hours) NS • Highest injury rate in Men's Open Division , ages 17-35 years (2.7/100 hours) and lowest in men's Golden Masters, ages 46 years and up (1.5/100 hours) • 79% of injuries occurred during the tournament and 21% were chronic injuries with an acute exacerbation	**Injury site** -ankle (17.6%) -low back (14.2%) -knee (11%) -shoulder (8.4%) **Injury type** -strains (36%) -sprains (28%) -inflammation & overuse (20.8%) **Injury severity** • few injuries required time lost from play • 8 injuries (5.2%) resulted in more than 5 days of time lost, two involved the knee and two others required surgery	• Well designed prospective study, • The pattern of injuries in a tournament may differ from pattern in volleyball league play because of intensity, number of games played over short period and skill and experience of participants • Hand (finger) injuries under-reported (anecdotal evidence) • Overuse and chronic injuries possibly under-reported, medical staff noted 'astonishing' quantity of ice used by players between and after matches with no report of these injuries
• Chan KM, Yuan Y, Chien P and Tsang G. (1993) • To identify and investigate the all-age injury pattern in the five sports most commonly associated with injury in Hong Kong • 2293 sports injury cases, including 165 cases of	• Hong Kong (one Sports Injury Clinic) • May 1994 – Dec 1990 • Prospective survey of cases seen in the Sports Injury Clinic of the Prince of Wales Hospital • 165 volleyball injury cases,	• Acute and overuse injuries, treated in Sports Injury Clinic of one hospital following referral from emergency department or another doctor • Sports injury report form filled in by patient or	**Injury frequency and rates** • Volleyball accounted for 165 sports injuries (7.4% of all sports injuries) and was the 3rd highest ranked cause of injury behind soccer (13.9%) and basketball (13.4%) , based on injury frequency data • No rate data reported	**Injury site** • Upper to lower limb ratio of 1:1.1 -Knee (27.3%) -Shoulder (23.6%) -Ankle (17.0%) -Lower spine (12.3%) **Injury type** -Sprain and strain (73.7 %) -Overuse (9.1%) -Contusion (6.1%) -Other (12.1%)	• No population, participation or exposure data • Population coverage not comprehensive, only one clinic included. Study does not cover injuries treated in other settings and minor injuries

volleyball injuries	almost equal number of amateur, recreational and team players representing their league/university/ school, few professionals.	• parent/relative and doctor			
• Solgard L, Nielson AB, Moller-Mason B et al (1995) • To describe the epidemiology and traumatology of acute injuries occurring in Danish volleyball players (aged 11-45 years) and evaluate the consequences of the injuries • 269 cases (278 injuries)	• Denmark (Arhus, two casualty departments) • 1986 • Interview study of patients presenting to casualty departments with a volleyball injury by physician in charge and post-injury mail follow-up survey (response rate 79%)	• All incidents that occurred during athletics activities at a sports area causing the athlete to consult the casualty ward within 24 hours of the accident	**Injury frequency and rates** • Volleyball accounted for 5.3% of all sports injuries recorded and was 4th in list of sports most likely to cause injury (based on injury frequency data) • Volleyball injury incidence 1.9 injuries/1,000 inhabitants per year; 89.9 injuries /1,000 club players per year (9%). • Injury rate: 6.5 injuries per 1,000 hours of practice and games. **Gender pattern** • Females: 57% of injuries; Males: 43% of injuries • Females had significantly more finger injuries than males (P<0.001) • Males had significantly more ankle and foot injuries than females (P<0.001) • Males had more knee injuries than females	**Injury site** -Hands/fingers (44.6%, mostly sprains) -Ankle and foot (36.7%, mostly sprains) -Knee (6.1%, mostly sprains) -Arm/shoulder (5.0%) -Other (7.5%) **Injury type** • Mostly sprains of hand/finger and ankle **Other findings** • School/educational players had significantly more hand/finger injuries than club players (P<0.001) • Club players had significantly more ankle injuries than school/educational players (P<0.001) • Ankle injuries occurred in players with high weekly activity (56%>5 hours per week) • Shoulder/arm, knee and hand injuries occurred in less active players (71-85%<4 hours/week)	• Survey response rate was high for a follow-up survey and allows the calculation of rates • Only acute injuries treated in emergency departments are included in the numerator for the calculation of population and participant sports injury rates so injury rate data are underestimates • Overuse injuries generally do not present to ED departments
• Ytterstad B (1996) • To describe the epidemiology of sports injuries occurring in a community (all ages) during 8 years	• Norway (Harstad) • 1 July 1985 to 30 June 1993 (8 years) • Prospective review of sports injuries in a defined population. • Hospital emergency department	• An unintentional hospital-treated injury occurring during games or physical training in an area specially designed for sports activities • Data collected by teachers and trainers, based on self report	**Injury frequency and rates** • Volleyball accounted for 6.9% of sports injuries (rate: 8.6 injuries /10,000 person-years) • Volleyball was the 4th highest–ranked sport for injury based on both frequency and population rates of injury, behind soccer (44.8%; rate 56.2/10,000 person years), handball (11.0%; rate:14.0/10,000 person-years) and downhill skiing (11.2%; rate: 13.4/10,000 person-years).	**Injury site** • No specific information for volleyball **Injury type** -Ligament ruptures (sprains) (70.3%) -Wounds and contusions (13.5%) -Fractures (9.0%) -Other internal or multiple lesions (1.3%) -Other/unknown (5.8%)	• The study was conducted in a defined population that allowed the calculation of population rates for sports injury • Population rate data not adjusted for exposure (participation and hours played), except for skiing • Geography and local cultural differences operating in Harstad (population 22,600 located 250 km north of the Arctic circle) probably limit the applicability of findings to other populations in Norway and elsewhere

First grade and elite players					
• Watkins J & Green BN (1992) • To determine the incidence and severity of injuries incurred by male volleyball players in the first division of the Scottish National League and to investigate the relative importance of injury risk factors • First grade players including current and former elite-level players that comprised 33.7% of players surveyed	• Scotland • 1989-1990 volleyball season • Postal survey to all 125 players in first division (response rate 68.8%)	**Injury definition:** An injury was defined as that degree of damage which prevented the player, due to pain or other symptoms, from training or playing for three or more consecutive days immediately after sustaining the injury.	**Injury frequency and rates** • 46 injuries in 89 players; O.53 injuries/player/year	**Injury site** - Ankle/foot (35%) - Knee (30%) - Fingers (22%) - Back (17%) - Shoulder (2%) **Injury type** - Ligament damage (39%) - Muscle damage (19%) - Tendon damage (15%) - Cartilage damage (6%) - Dislocation (2%) - Bone fracture (2%)	• A comparatively small study of high-level players. Their injury rates and patterns are probably not typical of volleyball players at club level because of increased exposure (time at play) and intensity of training and competition • Injuries may be underestimated because of recall bias and stringency of definition
• Rice & Anderson (1994) ▪ Retrospective review of musculoskeletal injuries in players in the US National Volleyball team ▪ Elite players, number of players not given, 222 injuries	• United States ▪ Injuries recorded at team's primary care clinic 1981-91 ▪ Review of medical records	Injury definition not given but study confined to musculoskeletal injuries, not including minor injuries and injuries sustained while team members were travelling	**Injury frequency** ▪ 222 injuries over an eleven-year period	**Injury site** -Ankle/foot (19.8%) -Knee (19.4%) -Leg & abdomen (8.6%) -Back (18.1%) -Shoulder (16.2%) -Arm (3.2%) -Wrist/hand (14.0%) -Head/face (4.1%)	• A small study confined to elite players. • Injuries underestimated because not all acute injuries were included and injuries that occurred while players were travelling were not included. • Number of players not reported. Rate data not given
• Aagaard H, Scavenius M, Jorgensen U. (1997) • To evaluate the injuries in indoor and in beach volleyball and to compare the injury pattern in the two different types of volleyball • 295 volleyball players overall: -Indoor-beach (119) -Indoor only (158) -Beach only (18) • Equal numbers of men and women and elite and recreational players.	• Denmark • 1993 beach volleyball season and the 1993-94 indoor volleyball season that followed • Injuries registered by coaches as they occurred, follow-up telephone survey of injured players (80% response rate)	**Injury definition:** Injuries that occur in connection of the game during training or competition, which handicap a player during play and/or which require special treatment in order to continue playing, or completely prevent a player from playing	**Injury frequency and rates** *Indoor*: 286 injuries in 277 players (1.03 injuries/player/year); 4.2/injuries/1000 volleyball hours *Beach*: 24 injuries in 137 players (0.18 injuries/player/year);4.9 injuries/1000 volleyball hours • Injury incidence higher in beach volleyball but the difference was not statistically significant (n.s.) • For indoor volleyball the difference between injury incidence in competition (4.8) and training (4.1) was small (n.s.) • Elite players (beach and indoor combined) played twice as many hours as recreational players and had	**Injury site** • Indoor -Ankle (21%, mainly from collisions between two players in landing after spiking or blocking; two-thirds were recurrent injuries) -Finger (19%, mainly from hitting ball in block) -Knee (17%, mainly overuse) -Shoulder (16%, mainly overuse) • Beach -Shoulder (42%, mainly overuse) -Knee (16%, mainly overuse) -Finger (8%, mainly from hitting ball in block) -Ankle (2%) • Overall -Shoulder injuries significantly	• Injury definition broader than in other studies • Well designed study, results tested for statistical significance

			more injuries but the injury incidence was significantly lower (p=0.02) in elite players (3.9) compared to recreational players (5.2)	more frequent in beach volleyball -Ankle injuries significantly more frequent in indoor volleyball	
• Bahr R, Bahr IA (1997) • To examine the incidence and mechanisms of acute volleyball injuries, particularly ankle injuries, among highly skilled players in one season (1992-3) • 272 male and female players competing in the top two divisions of the Norwegian Volleyball Federation competition.	• Norway • Norwegian Volleyball Federation (top two Divisions). Season 1992-3 • Prospective cohort study. Coaches submitted monthly report on exposure time and acute injuries. Injured players followed up with telephone interview	**Injury definition:** An acute injury causing a player to miss at least one playing day during the season	**Injury frequency and rates** • 89 injuries among 272 players during 51,588 player hours (45,837 hours of training and 5,751 hours of match play) • Injury rate: 1.7injuries/1000 hours of play overall • Higher rate of injuries in match play vs. training (1.5 injuries/1000 hours of training vs. 3.5 injuries/1000 hours of match play)	**Injury site** • Ankle (54%, of these 75% were recurrences) -Lower back (11%) -Knee (8%) -Shoulder (8%) -Fingers (8%) • Relative risk (RR) of injury was 3.8 ($P<0.001$) for previously injured ankles (38 of 232) vs. non-injured ankle (10 of the 234) • A reinjury was observed in 21 of the 50 ankles that had suffered an ankle sprain within the last 6 months (42+/-7.0%; risk ratio: 9.8 vs. uninjured ankles; $P<0.00001$)	• Strong prospective design but confined to highly skilled players (86% of whom consented to participate) • Response rate for injury and playing time information sheets 100%, incomplete information sheets followed up by telephone, as were all injured players. Perhaps some recall bias as report sheets filled in monthly and there was no independent validation that all injuries were captured.
• Aagaard H, Jorgensen U • To examine the incidence of acute injuries to elite Danish volleyball players during 1993-94 season • 137 elite male and female players competing in the two Danish elite divisions	• Denmark • Danish elite volleyball divisions • Player questionnaire survey (response rate, 80%)	**Injury definintion:** Injuries sustained in connection with training or matches, which handicap a player during play and/or which require special treatment (i.e., special bandaging or medical attention) in order to continue playing or which completely prevent the player from playing.	**Injury frequency and rates** • 177 injuries among 137 players (79 injuries among 70 female players and 98 injuries among 67 male players) • Overall injury incidence: 3.8 injuries/player/1,000 hours of play (male and female incidences the same)	**Injury site** -Fingers (21%, acute) -Ankles (18%, acute) -Knees (16%, overuse) -Shoulders (15%, overuse) • Shoulder injuries appeared to be a more serious problem in females • The overall rate of overuse injury reported to have increased from 16% to 47% in male elite volleyball in past decade (from 0.5 to 1.8 injuries per player per 1,000 hours played ($P<0.001$) due possibly to 50% increase in training time over the decade.	• Study confined to elite players • Study explained to players before season but data collected retrospectively • Injury and exposure data self-reported (no validation) • High response rate to player survey (80%) • Exposure data collected, injury rates calculated