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IN-LINE SKATING INJURY: A REVIEW OF THE LITERATURE

by

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In-line Skating Injury: A Review of the Literature

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Abstract:

The aim of this report is to critically review both formal research literature and informal sources of information that describe preventive strategies and countermeasures to in-line skating injury. The increase in popularity of in-line skating has led to a concomitant increase in skating injuries. Most of the injuries occur in older children (aged 10-14 years). In-line skating injuries contribute 1.4% of injuries presenting to hospital emergency departments for this age group of children in Victoria. Hospital admission rates in Australia for in-line skating injuries range from 15%-28% of hospital emergency department presentations, reflecting their serious nature. Falls cause more than three-quarters of these injuries. The most typical fall involves young novice or beginner skaters wearing little or no safety gear, who either spontaneously lose their balance while skating outdoors or fall after striking a road defect or some debris. The fall usually occurs on an outstretched arm onto a hard surface, with the wrist sustaining the injury. The main risk factors for injury are the speed at which skaters travel, obstacles in pathways, and hard landing surfaces. Measures to prevent in-line skating injury recommended in the literature include the following:

- wearing personal protective equipment (for example, wrist guards);
- improving environmental conditions for skaters;
- developing training and certification for skating instructors and providing lessons, particularly for novice skaters;
- encouraging physical preparation, including warming-up and stretching, training and conditioning, and cooling-down;
- educating skaters about safety;
- improving equipment design and standards; and
- refining local and state government policy and regulation in consultation with skating groups

Few of these measures have been formally proven to reduce injury. More biomechanical and epidemiological research is needed, particularly in the area of wrist/forearm injury prevention. Attention should be directed towards evaluating the role of wrist guards, helmets, fall technique, and lessons in preventing in-line skating injuries. Given the rapidly increasing popularity of in-line skating and the potential for a related epidemic of moderate to serious injuries, research into in-line skating injury prevention should be a priority.

Key Words:

In-line skating, rollerblading, injury prevention, safety, countermeasures, evaluation

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

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EXECUTIVE SUMMARY

In-line skating is increasing in popularity with a concomitant increase in the number of injuries associated with this activity. Most in-line skating injuries occur in older children (aged 10-14 years), representing a significant number of injuries in that age group.

Falls from up to one metre are reported to be the direct cause of 85% of in-line skating injuries recorded in the Victorian hospital emergency department database. The most typical fall involves young novice or beginner skaters wearing little or no safety gear, who either spontaneously lose their balance while skating outdoors or fall after striking a road defect or some debris. The fall usually occurs on an outstretched arm onto a hard landing surface, with the wrist sustaining the injury.

The main risk factors for injury are the speed at which the skater travels, obstacles in pathways and hard landing surfaces. Injuries occur frequently because the skater is going too fast and/or strikes an object in the pavement, or because the skater is unskilled at braking. Injuries due to equipment failure or involvement of motor vehicles are surprisingly rare.

Hospital admission rates for in-line skating injury cases in Australia are high, ranging from 15%-28% of hospital emergency department presentations from this cause. This reflects the serious nature of in-line skating injuries.

The overall aim of this report is to critically review both formal research literature and informal sources of information that describe preventive strategies and countermeasures to in-line skating injury. This review is informed by the analysis of in-line skating injury data, which provide a context for the identification of potentially effective interventions. Potential countermeasures to injury are listed in Table 1. Few of these countermeasures have been formally evaluated.

Table 1 Countermeasures to in-line skating injury.

Primary Countermeasures	• Pre-season conditioning and fitness program • Adequate warm-up and pre-skate stretch • Cool-down and post-skate stretch • Skater code of conduct (for example, learning the rules of the road) • Wearing bright or reflective clothing if riding at night • Equipment factors (for example, ensuring proper fit and condition of skates, fit of helmet, wrist guards, knee and elbow pads) • Environmental factors (for example, keeping paths free of obstacles and debris, choosing a flat course, UV protection) • Skating instruction, especially for beginners, and training of instructors • Adequate supervision of children and novices
Secondary Countermeasures	• Wearing protective equipment (for example, helmet, wrist guards, knee and elbow pads) • Skater code of conduct (for example, obey the rules of the road, yield to pedestrians) • Keeping speed in check
Tertiary Countermeasures	• Prompt access to quality medical care and first aid • Availability of first aid equipment on site • Rest, Ice, Compression, Elevation, Referral (RICER)

GENERAL RECOMMENDATIONS

Recommendations:

- Collect in-line skating participation data for all ages
- Provide pre-season training and safety programs for skaters in the late winter or early spring and before the school holidays
- Educate carers about the need to supervise young skaters
- Supervise young skaters, especially novices, until they develop the motor and skating skills that are needed to skate safely
- Target specific injury prevention strategies to young males, who appear to be more at risk for moderate to serious injury than young females

PROTECTIVE EQUIPMENT

Falls are the most frequent cause of in-line skating injuries, accounting for up to 77% of all emergency hospital presentations recorded on the electronic Victorian Injury Surveillance System (VISS, also known as the Victorian Emergency Minimum Dataset or VEMD) hospital emergency department database. The first part of the skater's body to contact the ground sustains the greatest force of the fall. Protective equipment works to provide a hard protective barrier between the body and the ground, by absorbing or dissipating the potentially injurious energy.

The effectiveness of protective equipment in preventing in-line skating injuries has not been fully researched. Wrist guards have been subjected to some epidemiological case-control evaluations as well as some biomechanical analyses. They have been found to provide a clear protective effect against wrist fractures. There is some concern that wrist guards may transfer the force of the fall further up the arm, resulting in forearm fractures rather than wrist fractures. This hypothesis requires more thorough examination.

Recommendations:

- Promote the use of full protective gear to skaters of all ages and abilities
- Identify and address barriers to wearing protective equipment, especially among adolescents
- Refine and promote standards for helmets, both multi-purpose and specifically for in-line skating (with extended coverage to protect the back of the head)
- Encourage all rental outlets for in-line skating equipment to provide protective equipment along with skates in a package deal
- Undertake further ergonomic research into the design of protective equipment, especially to improve the effectiveness of wrist guards

PHYSICAL PREPARATION

Some of the physical stresses of in-line skating may be reduced by warming-up and stretching, which are known to improve the range of motion of the joints and increase muscle elasticity (Best and Garrett, 1993). Stretching exercises for calves, hamstrings, hips and back (before and after skating) could help to prevent overuse-type injuries to the lower extremities, although their effectiveness for in-line skating requires evaluation.

Recommendations:

- Develop and promote information about warm-up, cool-down and stretching techniques specific to in-line skating
- Identify and address barriers to warm-up, cool-down and stretching among skaters
- Undertake research into the effectiveness of warm-up, cool-down and stretching as an injury prevention measure for in-line skating

SKATING INSTRUCTION

Most injured in-line skaters have received no formal skating instruction, they have learnt to skate by trial and error. Unfortunately, the “error” can result in injury. Younger skaters, among whom the activity is most popular, are often unaware of the rules of the road, and need to be taught them. Lessons can increase skater confidence and improve skating technique, resulting in safer, more enjoyable skating. The International In-line Skating Association (IISA) offers certification training for in-line skating instructors, and there are currently three certified instructors in Victoria (Kropp, personal communication). Certification exams must be sat overseas, making it difficult for Australian instructors to access training. Skating outlets do not demand that their instructors be certified.

Skating instruction by certified instructors should be available to skaters through hiring outlets and schools. Skaters should learn proper stopping techniques, and safe skating practices (for example, rules of the road, how to fall safely) before venturing out into public places. More experienced skaters can also benefit from lessons, to help refine their skills. Local certification training should be provided to in-line skating instructors in Australia. Skating outlets should demand certified training qualification of their instructors. A National Skate Patrol should be developed so that in-line skating instruction can be made available to skaters at places where they skate.

Recommendations:

- Explore the possibility of developing National Skate Patrol chapters in Victoria
- Provide local certification training for in-line skating instructors in Victoria and Australia
- Provide all skaters with the opportunity to take lessons given by accredited instructors, for example, through rental outlets and schools
- Determine the best technique for in-line skaters to use when falling, in order to minimise injury
- Undertake more research into the effectiveness of skating instruction, including safe falling technique, as an injury prevention measure

SKATE TECHNOLOGY

Skate technology has improved rapidly over recent years. The technical innovations have focused greatly on increasing the speed of the skate and improving braking technology. It seems that the improvements in speed have out-performed the improvements in braking, making it challenging for the skater to stop.

The improvements in skate and wheel technology have resulted in a very fast skate, which requires a certain amount of skill to control. Many novice skaters are overwhelmed by the speed of the in-line wheels and are unable to slow down or stop in time to avoid collisions and/or falling. The in-line alignment of the wheels as well as the heel brake mechanism make it difficult for novice skaters to retain their balance, especially when turning or braking.

Recommendations:

- Undertake ergonomic research to improve the skate braking mechanism to allow the skater to slow down and stop while keeping all wheels on the ground
- Teach skaters to use their heel brakes, as well as alternative methods of stopping
- Undertake more field and laboratory research to improve the effectiveness of each new braking system in preventing in-line skating injuries
- Improve the fit of equipment (skates and protective gear) for young skaters

ENVIRONMENTAL FACTORS

The choice of an appropriate skating course is an important decision that skaters take prior to setting out to skate. Skating on a designated skate or cycling trail can help to reduce the risk of injury caused by interactions with motor vehicles and pedestrians. Matching the course difficulty to the skaters' ability can ensure safer skating and a more enjoyable ride.

Recommendations:

- Create and maintain areas free of traffic, crowds, debris and surface irregularities for the use of in-line skaters
- Rate trails and areas used by skaters for degree of difficulty and clearly post rating at the start of each trail
- Educate novice skaters to skate in areas free of traffic and crowds and to avoid hills until they have gained some skating experience
- Encourage skaters to make themselves visible by either skating in daylight or wearing bright/reflective clothing if skating at night

POLICY AND REGULATION

Reckless skating and damage to public property (for example, steps and railings) has forced a few city councils (for example, Melbourne City Council and Stonnington City Council) to propose local by-laws which restrict skating in public spaces. Councils should consult with local skaters' groups in order to develop an effective "skate management plan". Good skate management plans should include provision of safe skating venues, as well as incorporate educational campaigns to teach skaters a proper code of conduct.

Recommendations:

- Local Councils should develop consistent "skate management plans" in consultation with local skater groups which includes a skater code of conduct, and safe skating facilities
- Local Councils and skating venue managers should promote and enforce the wearing of protective equipment on Council property and at skating venues

1. INTRODUCTION

In-line skates, or rollerblades, are a hybrid cross between traditional roller skates and ice skates. Instead of a metal skate blade, there are three to five urethane wheels lined up one behind the other attached to the bottom of the boot. Hence the name "in-line" skates.

In-line skating is different from roller skating. The skating technique more closely resembles ice skating, while many of the turning motions are similar to skiing. In-line skating is perfectly suited for ice skaters and skiers to use for cross training or to practise their skills during the off-season. In-line skates have come a long way since they were first used by winter athletes as a way to train during the summer months.

Today, in-line skating is one of the fastest growing recreational activities in North America and is emerging as a popular activity in Australia. Several specialised disciplines exist including Recreation/Fitness Skating, Roller Hockey, Aggressive Skating and Racing/Speed Skating. The sport is governed by the International In-line Skating Association (IISA).

Improvements in technology over the past two decades have revolutionised in-line skates. The development of lightweight polyurethane boots, lighter and stronger wheels and faster bearings have helped to push the speed of in-line skaters upward to 50 kph. The increase in popularity and speed has led to a concomitant increase in in-line skating injuries. Most of the injuries occur in older children (aged 10-14 years).

A combination of an unsteady base of support, a changing terrain with unexpected challenges (for example, debris, curbs, cracks in the pavement and hills) and an unsettling braking mechanism can contribute to falls. Add to that the high speed that can be reached by skaters, together with immature coordination skills and a lack of protective gear, and you have a recipe for injury.

2. AIMS

The aim of this report is to critically review both formal research literature and informal sources of information that describe measures to prevent in-line skating injury. In doing so, the report provides an evaluation of the extent to which these measures have been demonstrated to be effective.

Unlike other literature describing in-line skating injuries, this report does not specifically focus on the epidemiology of skating injury, nor does it provide a detailed description of its aetiology. Instead, it presents a detailed examination of the range of countermeasures promoted as preventing in-line skating injury. A brief overview of the epidemiology of in-line skating injury, particularly from an Australian perspective, is given to set the scene for the subsequent discussion of countermeasures.

3. METHOD

The sources of information used to compile this report were:

- Medline CD-ROM search for published medical literature (over the past 10 years)
- Sport Discus CD-ROM search for published sports literature (over the past 10 years)
- Austrom:Ausport (Sport) CD-ROM search for published Australian sports literature (over the past 10 years)
- Population Survey Monitor (PSM) of the Australian Bureau of Statistics
- Brian Sweeney and Associates' market research into Australians and Sport 1996
- Discussions with national and international in-line skating organisations
- Discussions with key Australian in-line skating injury researchers
- Scanning of internet and world wide web sites
- Expert comment on the draft report

This review is based largely on English-language material. Non-English language articles with English abstracts have been included in this review where appropriate.

The literature gathered for this review was critically assessed to determine the extent to which the various countermeasures had been fully evaluated and demonstrated to be effective in preventing injuries. A gradation scale for the strength of the evidence presented in the identified literature was developed. This is shown in Table 2.

Table 2 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 800 in-line skating injury cases presenting to VEMD hospital emergency departments 1996-1997.* **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 expensive research. However, case series can't 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 survey of injuries among a representative sample of in-line skaters. Most surveys are cross sectional. **Strengths and weaknesses:** Cross sectional studies examine the relationship between the condition (for example, injury) and other variables of interest (for example, age, sex, skill level, use of protective gear) by comparing the prevalence of the condition in different population subgroups and between those with or without the condition, according to the presence or absence of the variables. They examine a condition at one point in time so cannot determine cause and effect.

Stronger	**ANALYTIC (OBSERVATIONAL) STUDIES (case control and cohort)** **What are they?** These studies test hypotheses (suppositions/conjectures) about the influences which determine that one person is injured while another is not i.e., they provide strong evidence on the causes, risk and contributory factors to injury. • **Case-control studies** The researcher assembles a group of persons with the injury of interest (cases) and a comparison group without the injury under investigation (controls), *for example,* in-line skaters with and without wrist injury, and investigates the history of past (retrospective) exposure of one or more potential risk factors for the injury (for example, use of wrist guards, skating experience). **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, 10-14 year-old males would be a suitable cohort if in-line skating injury was the factor of interest) and the researcher follows up the cohort and *observes* the association between exposure (in-line skating) and outcome (injury) over a number of years. • **Strengths and weaknesses***:* Because they are generally prospective (forward-looking) the likelihood of collecting reliable and valid data is greater. Consequently, results from a well-designed cohort study carry more weight in establishing a cause than results from a case control study. However, cohort studies often involve large numbers (especially if the factor of interest is rare) and/or a long study period, and are therefore expensive. The other great problem can be the dropout rate ('loss to follow-up') which can result in biased data

<table>
<tr><td>Strongest</td><td>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 test whether or not wrist guards prevent wrist injuries subjects would be recruited into the trial and randomly allocated to treatment (wrist guard wearing) and control (non-wrist guard wearing) groups and followed up over time.

• 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, head injuries among in-line skaters) and prevalence of suspected risk factor/s (for example, non-wearing of helmets) for which an intervention has been developed are surveyed in both. The intervention (for example, compulsory wearing of helmets) is then carried out in one community and the other does not receive it. The intervention stops and the communities are surveyed again, the net difference in the incidence of the condition and prevalence of the risk factor/s is thereby associated with the intervention.

Strengths and weaknesses: Well-conducted controlled trials, where the assignment of subjects or communities to the experimental or comparison group is random, are regarded as the strongest epidemiological studies and provide the greatest justification for concluding causation. Obstacles to their use include their great expense and long-time period.</td></tr>
<tr><td colspan="2">References:
Dawson Saunders B., Trapp R.G. Basic and Clinical Biostatistics. Appleton & Lange 1990, Connecticut
Lilienfeld. D.E., Stolley P.D. Foundations of Epidemiology. Third Edition. Oxford University Press 1994, New York.
Robertson L.S. Injury Epidemiology. Oxford University Press 1992, New York.</td></tr>
</table>

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

Another important aspect of countermeasure implementation is the extent to which they are accepted or adopted by the users for whom they were intended. Countermeasures should be acceptable to those they were designed to protect. Community consultation and awareness programs must therefore be considered in any implementation process. It is also important to assess barriers towards use of injury countermeasures. 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, the literature describing these studies is also included in this review.

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

4. PARTICIPATION IN IN-LINE SKATING

By all accounts, in-line skating (rollerblading) is a hugely popular recreation activity. American Sports Data (ASD), a US sports marketing survey, estimates that 27.5 million Americans participated in in-line skating in 1996 (ASD, 1996). This reflects a 22% increase in participation since 1995, and a 630% increase since 1989 (ASD, 1996). Australian participation rates are not as well documented. However, it is estimated from the most recent Brian Sweeney and Associates capital city market research survey that 10% of the population over 15 years of age participated in in-line skating and/or roller skating in 1996 (Sweeney, 1996). This represents a 30% growth in participation from the previous year's survey (Sweeney, 1996).

It is important to note that the Sweeney surveys do not differentiate between in-line skating and traditional (quad) roller skating participation. Also, the annual Sweeney surveys are confined to participants aged over 15 years. In the US, children aged under 12 years represent the largest group of skaters (38%), while teenagers account for 25% of all in-line skaters (ASD, 1996). Unfortunately, the Australian Bureau of Statistics' Population Survey Monitor (PSM), which samples a wider cross section of the Australian population than the Sweeney survey, does not gather participation data for in-line skating (ABS, 1995-96).

Import figures for in-line skates may shed some light on their popularity, as there are no local manufacturers of in-line skates in Australia. One major distributor of in-line skates estimates that close to 500,000 pairs of all brands of skates are imported annually to Australia (Pitt, personal communication). This figure also includes ice skates and quad roller skates. However, in-line skate sales make up approximately 90% of the skate sales market in Australia (Pitt, personal communication).

In-line skating covers several specialised disciplines, including Recreation/Fitness Skating, Roller Hockey, Aggressive Skating, and Racing/Speed Skating. In the US, the Recreation/Fitness category is the largest, encompassing approximately 70% of all skaters (ASD, 1996). This group includes everyone who is not a competitive skater, such as those who skate on their local bike paths for exercise or transportation and athletes from other sports who use in-line skating as a method of cross-training.

Roller Hockey accounts for approximately 15% of the in-line skating market in the US (ASD, 1996). Roller hockey was first featured as an exhibition sport at the summer Olympic games in Barcelona in 1992. In-line Roller Hockey is gaining popularity each year, culminating in the establishment in 1996 of the first professional international Roller Hockey league. At present, there are no Victorian data available on Roller Hockey participation.

Aggressive Skating (also known as Street or Vert) accounts for approximately 10% of the in-line skating market in the US (ASD, 1996). Aggressive Skaters practise "extreme" or artistic skating, which emphasises speed, jumps, spins and other tricks. Although there are no Australian in-line Aggressive Skating participation data available, the skating venue at Queen Victoria Place in Melbourne, which offers ramps and jumps for Aggressive Skating, is one of the most popular venues for skating in the city (Shaw, personal communication). Also, Skate Magazine Australia, which has a large Aggressive Skating readership, has increased its circulation steadily since its inception in 1995 (Good, personal communication).

Competitive Speed Skating accounts for approximately 5% of in-line skaters in the US (ASD, 1996). Speed Skating comprises organised race events, including short sprints (100m to 500m) and marathons (50K to 100K). Roller Sports Australia reports that competitive Speed Skating operates in all states throughout Australia and involves approximately 1000 skaters (Currell, personal communication).

Several factors have contributed to the rapid rise in participation: the value of in-line skating for recreation, competition and transportation; its appeal to a broad range of ages; recognition that skating provides low-impact aerobic exercise; and the high quality and relatively low cost of in-line skating equipment. Participation costs are also low. The growing popularity of all disciplines of in-line skating over several years indicates that it is not just a passing fad.

4.1 RECOMMENDATION FOR COLLECTION OF PARTICIPATION DATA

- Include in-line skating in the Australian Bureau of Statistics' Population Survey Monitor
- Collect participation data for the under 16 year olds
- Standardise the format for collecting participation data in order to facilitate comparisons between data sets

5. AN OVERVIEW OF THE EPIDEMIOLOGY OF IN-LINE SKATING INJURIES

5.1 GENERAL OVERVIEW

The rapid increase in popularity of in-line skating has led to a concomitant increase in injuries. The US Consumer Product Safety Commission conducts active surveillance of injured patients treated at 91 hospital emergency rooms chosen to be nationally representative; this collection constitutes the National Electronic Injury Surveillance System (NEISS). An examination of NEISS data shows a 169% increase in emergency department injuries associated with in-line skating since 1993 (Schieber et al., 1996). An increase in the number of injuries over time is consistently reported from locations other than the US, including: Canada (Ellis et al., 1995); the UK (McGrath and Beattie, 1996); Hong Kong (Tse et al., 1987); and Australia (Towler and Brown, 1994; Routley, 1997; Heller et al., 1996; QISPP, 1996).

5.2 VICTORIAN EMERGENCY DEPARTMENT PRESENTATIONS

In Victoria, there has been a marked increase in the frequency of injuries associated with in-line skating (Heller et al., 1996). Heller (1996) studied the trend for in-line skating injuries in children aged 14 years and under, presenting to hospital emergency departments, as recorded by the Victorian Injury Surveillance System (VISS). In 1989, four campuses of the three VISS hospitals (Royal Children's Hospital, Western Hospital - Footscray and Sunshine campuses, and Preston and Northcote Community Hospital) recorded no cases of in-line skating injury. In 1992 at the same hospitals, there were 72 cases reported and in 1993 there were 147. There are no comparative data from the same three hospitals between 1994 and 1996 because of the introduction of an expanded Surveillance System in Victorian hospital emergency departments (the Victorian Emergency Minimum Dataset-VEMD). The highest number of emergency department presentations to these hospitals was recorded in 1997 (n = 135). Figure 1 illustrates the trend of in-line skating emergency department presentations to date. The 1996 and 1997 data (VEMD) may be an under-representation of ED presentations since validation studies to determine completeness of capture in this new data system have not yet been completed.

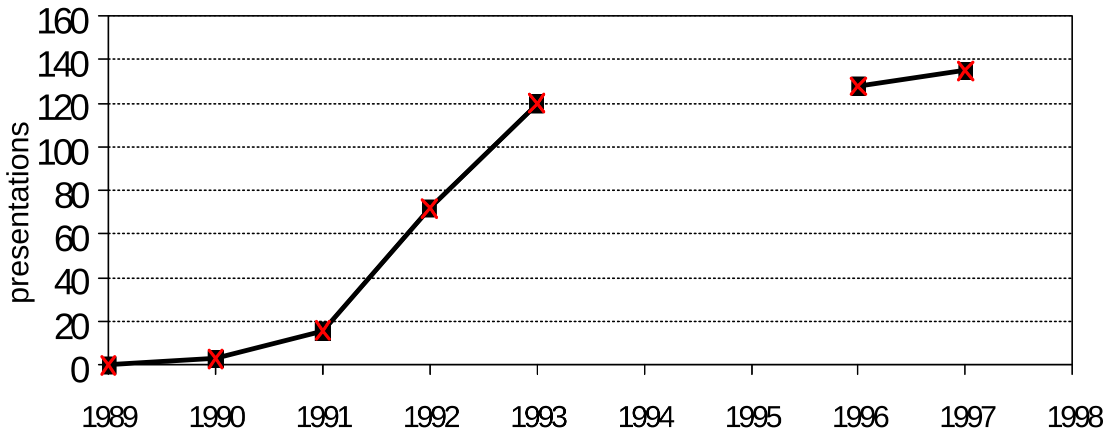

Figure 1 In-line skating emergency department presentations (1989-1997)

Source: VISS data for children <15 yrs, from Royal Children's Hospital, Western Hospital Footscray and Sunshine campuses and Preston and Northcote Community Hospital

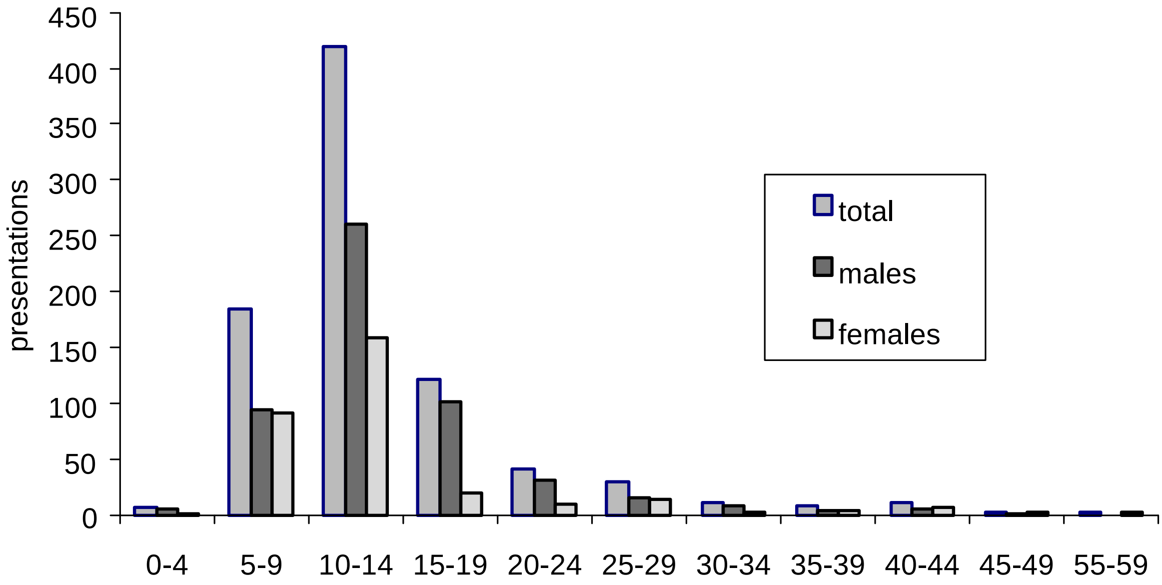

Figure 2 Age and sex distribution of in-line skating emergency department presentations

Figure 2 shows the latest in-line skating emergency hospital presentation data for VEMD hospitals. This data covers a two year period from December 1, 1995 to November 30, 1997, and represents emergency department presentations from the following nineteen hospitals: Austin and Repatriation Medical Centre, Ballarat Base Hospital, The Bendigo Hospital Campus, Box Hill Hospital, Dandenong Hospital, Echuca Base Hospital, The Geelong Hospital, Goulburn Valley Base Hospital, Mildura Base Hospital, Mornington Peninsula Hospital, Preston and Northcote Community Hospital, Royal Children's Hospital, Royal Victorian Eye and Ear Hospital, St Vincent's Public Hospital, Wangaratta Base Hospital, Warrnambool and District Base Hospital, Western Hospital, The Williamstown Hospital and Wimmera Base Hospital.

During this two year period, a total of 838 cases of injury due to in-line skating presented to nineteen emergency departments in Victoria. Most of the injuries (86.5%) occurred in children aged 5 to 19 years. The highest number of cases was in the 10-14 year age group, and the average age of those injured was 12 years. Males (63%) outnumbered females (37%), as illustrated in Figure 2. Most injuries (46%) occurred on weekends, while almost one half (48%) of all injuries occurred between 4pm and 8pm. Over one-half of all injuries (53%) were fractures, while a further 22% were sprains and strains. Seventeen percent of those presenting to emergency departments during this two year period were either admitted or transferred to another hospital.

The hospital emergency department presentation database does not provide a complete picture of in-line skating injuries because many cases would not be severe enough to warrant presentation to hospital. Nevertheless, the database generally provides information on the more serious injuries. The case narratives for the data files provide valuable information on the circumstances of the injury, including use of protective equipment, which can help guide injury prevention initiatives.

5.2.1 Injuries by body part

Figure 3 illustrates the distribution of primary in-line skating injuries by body part from the VEMD emergency department presentation database (1996-1997). Less than one percent of these cases are reported as multiple injuries, while Schieber et al. (1996) report that 13% of skaters presenting to emergency departments in the US have multiple injuries.

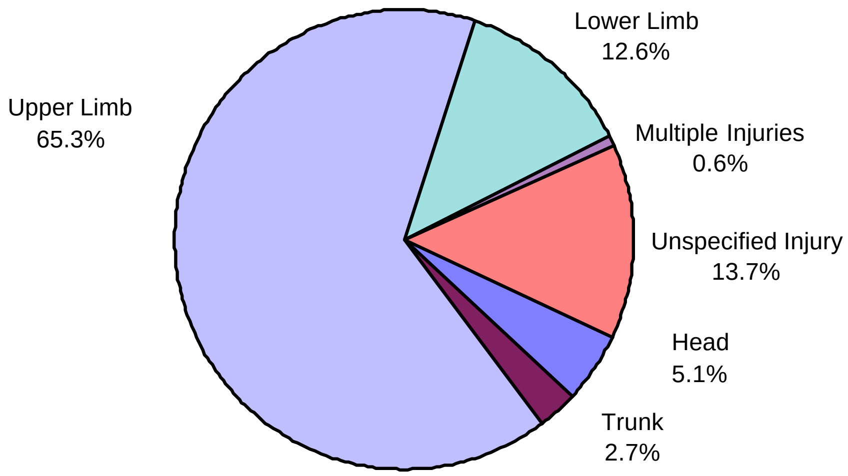

Figure 3 In-line skating injuries by body part (VEMD 1996-1997)

5.3 UPPER EXTREMITY INJURIES

Australian and overseas surveillance studies consistently indicate that there is a predominance of upper extremity injuries associated with in-line skating (Ellis et al., 1995; Heller, 1993), though the Heller hospital sample was biased towards paediatric cases. These studies report that 60-75% of injuries are to the upper limb, which comprises the shoulder, upper arm, elbow, forearm, wrist, and fingers (Ellis et al., 1995; Heller, 1993). These injuries range from abrasions, to ligament strains, to bone fractures (Ellis et al., 1995; McGrath and Beattie, 1996; Calle and Eaton, 1993). The latest VEMD data indicate that 65.2% of all in-line skating Victorian emergency hospital presentations are injuries to the upper extremity.

The upper extremity is particularly susceptible to fractures, which are variously reported to comprise between 48%-89% of all in-line skating injuries presenting to hospital emergency departments (McGrath and Beattie, 1996; Towler and Brown, 1994; Heller, 1993). Heller (1993) reports that fractures of the forearm and wrist are common and comprise 43% of all in-line skating injuries to all ages on VISS. The latest VEMD data is consistent with the literature, showing 40% of all in-line skating injuries (n=838) are fractures to the forearm and wrist. Calle and Eaton (1993) report in a review of NEISS data from 1981 to 1991 (n=444) that other upper extremity areas vulnerable to fractures during in-line skating are the shoulder (4%), fingers (8%) and elbow (11%).

Upper extremity soft tissue injuries are also common, representing between 31%-38% of in-line skating injuries presenting to hospital emergency departments (Ellis et al., 1995; McGrath and Beattie, 1996; Calle and Eaton, 1993). VEMD data shows that 12.5% of all in-line skating injuries presenting to emergency departments are soft tissue injuries to the upper limb. Soft tissue injuries may be under-reported on the hospital databases, because they are not always severe enough to warrant emergency department presentation.

5.3.1 Wrist injuries

The wrist is particularly vulnerable to injury during falls. Falls from up to one metre are reported to be the direct cause of 85% of in-line skating injuries on the former VISS database (Routley, 1997) and 77% on the replacement VEMD database. Falling skaters typically put their hands out in an attempt to break their fall, landing on an outstretched arm onto a hard surface, with the wrist sustaining the injury (Schieber et al., 1996; Heller, 1993; Calle and Eaton, 1993). US injury surveillance data consistently show that wrist fractures are the most common type of injury in in-line skating, roller skating, and skateboarding (Schieber et al., 1994).

Heller (1993) was not able to separate VISS data on forearm and wrist injuries which, as reported above, constituted 43% of all injuries to in-line skaters of all ages (Heller, 1993). Calle and Eaton (1993) report that the three most common fracture sites for in-line skating injuries are the distal radius, the scaphoid, and the radial head. Of all injuries sustained during in-line skating, between 24%-28% of emergency hospital presentations are fractures and/or dislocations of the wrist (Schieber et al., 1996; McGrath and Beattie, 1996; Schieber et al., 1994; Schieber and Branche-Dorsey, 1995). The findings from the latest VEMD data, which show that 25% of all in-line skating injuries involve the wrist, is consistent with these overseas reports.

5.4 LOWER EXTREMITY INJURIES

Injuries to the lower extremity include injuries to the hip, knee, ankle, and toes. These injuries are less common in in-line skating than those to the upper extremity (Schieber et al., 1996; Ellis et al., 1995; Heller, 1993; Calle and Eaton, 1993; Malanga and Stuart, 1995). Injuries to the lower extremity are reported to represent between 7-16% of all in-line skating injuries presenting to hospital emergency departments (Heller, 1993; Calle and Eaton, 1993; Malanga and Stuart, 1995). The latest VEMD data show that 12.6% of all in-line skating injuries presenting to Victorian hospital emergency departments are to the lower limb.

Malanga and Stuart (1995), in a retrospective review of 32 presentations to the Sports Medicine Center of the Mayo Clinic (Minnesota), found that the knee is the most commonly injured lower extremity body part, representing approximately one-half of all in-line skating injuries to the lower extremity and 9% of all reported injuries. The VEMD data shows that approximately one third of lower limb injuries (4.1% of all injuries) are to the knee and a further one third (3.6% of all injuries) are to the ankle.

Although serious injuries to the lower extremities are relatively uncommon, two case reports by Malanga and Smith (1996) highlight the potential severity of these types of injuries from in-line skating. Two cases are described in which patients suffered severe lower extremity injuries while in-line skating: one had a femoral shaft spiral fracture and the other a bilateral anterior cruciate ligament and medial collateral ligament injury (Malanga and Smith, 1996). The authors suggest that longer wheel frame lengths, such as those used for speed skating, can act as a lever arm which can apply injurious torsion forces and result in serious leg, knee, and ankle injuries (Malanga and Smith, 1996). These researchers predict that higher speeds and changing skate designs may predispose skaters to more lower extremity injuries in the future (Malanga and Smith, 1996).

5.5 HEAD INJURIES

Head injuries make up between three and seven percent of all in-line skating injuries (Ellis et al., 1995; Calle and Eaton, 1993; Schieber et al., 1994; Schieber and Branche-Dorsey, 1995). A similar pattern is seen for skateboarding and roller skating (Baker et al., 1994). VEMD data shows that 5.1% of all in-line skating injuries are to the head.

Baker et al. (1994) note that the proportion of injuries that involve the head decreases as the age of the skater increases. These authors also report that children aged 5 through 14 years incurred 77% of head injuries involving skateboards and roller skates (Baker et al., 1994). This pattern highlights the need to target younger children in injury prevention campaigns, particularly in relation to wearing protective helmets.

Weinburger and Selesnick (1994) report two cases of temporal bone fracture treated at Cornell University Medical Center which show that, although head injuries constitute a relatively small proportion of skating injuries, they can be serious, even life threatening.

5.6 OTHER INJURIES

Roller Sports Australia reports that "road burns" (second- or third- degree abrasions) are the most common injury sustained by competitive in-line speed skaters (Currell, personal communication). These relatively minor injuries may be under-reported in the hospital-based surveillance data, as they often do not require emergency hospital treatment.

5.7 AETIOLOGY OF IN-LINE SKATING INJURIES

The improvements in skate and wheel technology have resulted in a very fast skate which requires a moderate degree of skill to control. Many novice skaters are overwhelmed by the speed of the in-line wheels and are unable to slow down or stop in time to avoid collisions and/or falling. The alignment of the wheels and the heel brake mechanism make it difficult for novice skaters to retain their balance, especially when turning or braking.

Risk factors for injuries in in-line skating were identified by Schieber (1996) from a case-control study involving 161 injured in-line skaters presenting to NEISS hospital emergency departments in the US. Cases were all persons in the NEISS sample who sustained a wrist injury while in-line skating. Controls were all persons in the NEISS sample presenting to emergency departments with an in-line skating injury other than to the wrist after having fallen on their arms. Injured skaters self-reported that the main factors contributing to their injury were the speed at which they were travelling, obstacles in their pathway, and hard landing surfaces (Schieber et al., 1996). Orenstein (1996) surveyed 63 patients who had sustained an injury and presented to the emergency department of a paediatric hospital (Fairfax Hospital, Washington DC). This study found that injuries were more likely to occur because the skater was going too fast (35%), or struck an obstacle in the pavement (20%), or was unable to brake (19%) than because of equipment failure (2%) or interference from motor vehicles (3%). Schieber et al. (1994) also report that only 0.3% to 3.0% of in-line skating injuries were motor vehicle-related.

Falls from up to one metre are reported to be the direct cause of 77% of in-line skating injuries on the VEMD database. A number of research studies have shown that the most typical fall involves young novice or beginner skaters wearing little or no safety gear, who either spontaneously lose their balance while skating outdoors or fall after striking a road defect or some debris (Schieber et al., 1996; Towler and Brown, 1994; Banas et al., 1992).

Heller (1993) reports that in terms of skating ability, there are two distinct groups of injured in-line skaters. A large proportion of those injured are first-time skaters who simply lose control and fall (46%), while another major group (25%) are more experienced skaters who are injured while performing tricks, often at considerable speed (Heller, 1993). Falling skaters typically land on an outstretched arm onto a hard surface, with the wrist sustaining the injury (Schieber et al., 1996; Heller, 1993; Calle and Eaton, 1993).

A combination of an unsteady base of support, a changing terrain with unexpected challenges (for example, debris, curbs, cracks in the pavement and hills) and an unsettling braking mechanism can contribute to falls. Add to that the high speed that can be reached by skaters (up to 30-50 km/hr), together with immature coordination skills and a lack of protective gear, and you have a recipe for injury.

5.8 SEVERITY OF IN-LINE SKATING INJURIES

Australian hospital emergency department-based injury surveillance studies have reported high admission rates (ranging from 15% to 28% of emergency department presentations), reflecting the serious nature of in-line skating injuries (Towler and Brown, 1994; Routley, 1997; QISPP, 1996). In Victoria, 15% of the emergency department in-line skating presentations on the VISS database were admitted to hospital (Routley, 1997), and 17% on the VEMD database. Chong et al. (1995) report from a study of 98 skaters who sustained an injury that required hospitalisation at Wollongong Hospital in NSW, that most injured skaters (56%) give up the sport (Chong et al., 1995).

A Canadian study reports that injuries to in-line skaters are more severe and require more extensive treatment than other injuries presenting to hospital emergency departments (Ellis et al., 1995). Up to sixty percent (n=116) of injured in-line skaters presenting to ten paediatric and five general hospital emergency departments in this study required significant treatment (for example, referred to a physician or another department for further treatment) (Ellis et al., 1995). Williams-Avery and MacKinnon (1996) surveyed 217 American university students who were in-line skaters and found that most minor injuries occur during the first and second sessions of in-line skating, while the more serious injuries occur after at least 50 sessions.

The US NEISS database recorded 43 in-line skating deaths between Jan 1992 and Aug 1996. At least two thirds of the in-line skating deaths on the NEISS database were a result of head injury (Routley, 1997). To date, there have been two reported in-line skating deaths in Victoria (State Coroner's Office, Victoria, Australia). These deaths were remarkably similar, both involving young males struck by motor vehicles while skating across the road at night.

5.9 LOCATION OF INJURY EVENTS

In the US, the NEISS emergency department hospital data show that 10-15% of skating injuries occur in street settings, while only 0.3% to 3.0% are motor vehicle related (Schieber et al., 1994). Although there is a remarkably low number of motor vehicle related in-line skating accidents, these incidents often result in very serious injuries to the skater.

In-line skating injuries are sustained in similar locations to skateboarding and roller skating injuries, predominantly on public roads and footpaths or outside the home (Heller et al., 1996). A review of Queensland hospital emergency department injury surveillance data showed that one third of in-line skating injuries occurred on public roads, footpaths, parking areas or bikeways and 13% occurred in public parks. A further one third of in-line skating injuries occurred in private homes, private roads or driveways (QISPP, 1996).

In Victoria, approximately one-half (49%) of all in-line skating injuries on the VISS database to 1992 occurred in areas used for transport, especially footpaths (22%) (Heller, 1993). Relatively few injuries occurred in "safe" areas such as playgrounds (5%), parks (3.5%) and skating rinks (3.5%) (Heller, 1993). The more recently collected VEMD data still shows a high proportion of injuries occurring in areas used for transport (27%), but an increasing number of injuries occurring in places used for recreation, including playgrounds and public parks (23.4%). As the popularity of aggressive skating increases it is possible that there will be a general shift in skating from the footpaths and roads to parks.

Recommendations:

- Make in-line skaters aware of the rules of the road and enforce compliance
- Teach skaters the importance of making themselves visible by skating in daylight or wearing bright and reflective clothing if skating at night
- Teach motorists to watch out for skaters
- Designate and maintain areas free of traffic, crowds, debris and surface irregularities for the use of in-line skaters
- Display educational safety information in parks frequented by skaters

5.10 SEASONAL TRENDS

It has been reported from the US that in-line skating injuries occur more frequently during the spring (45%) and summer (28%) (Schieber and Branche-Dorsey, 1995). An analysis of the distribution of in-line skating injuries in Queensland over a 6 month period in 1996 shows peaks in January and April, which may coincide with times when children are on holidays from school (QISPP, 1996).

In Victoria, seasonal variations are evident in the number of emergency department hospital presentations, as illustrated in Figure 4. There is a clear decrease in the number of emergency department hospital presentations in the winter months of May, June, July and August.

According to North American injury surveillance data, thirty-nine percent of all injuries occur during the weekend, mostly on Sundays (25.3%) (Ellis et al., 1995). This trend is also seen in the Victorian database (VEMD), where 46.4% of injuries occur on a weekend, mostly on a Sunday (26.8%). Other US studies report that injuries tended to happen later in the day, suggesting that fatigue may also be a risk factor (Calle, 1994; Kvidera and Frankel, 1983). The VEMD data indicate that one half of all injuries occur between 4pm and 8pm.

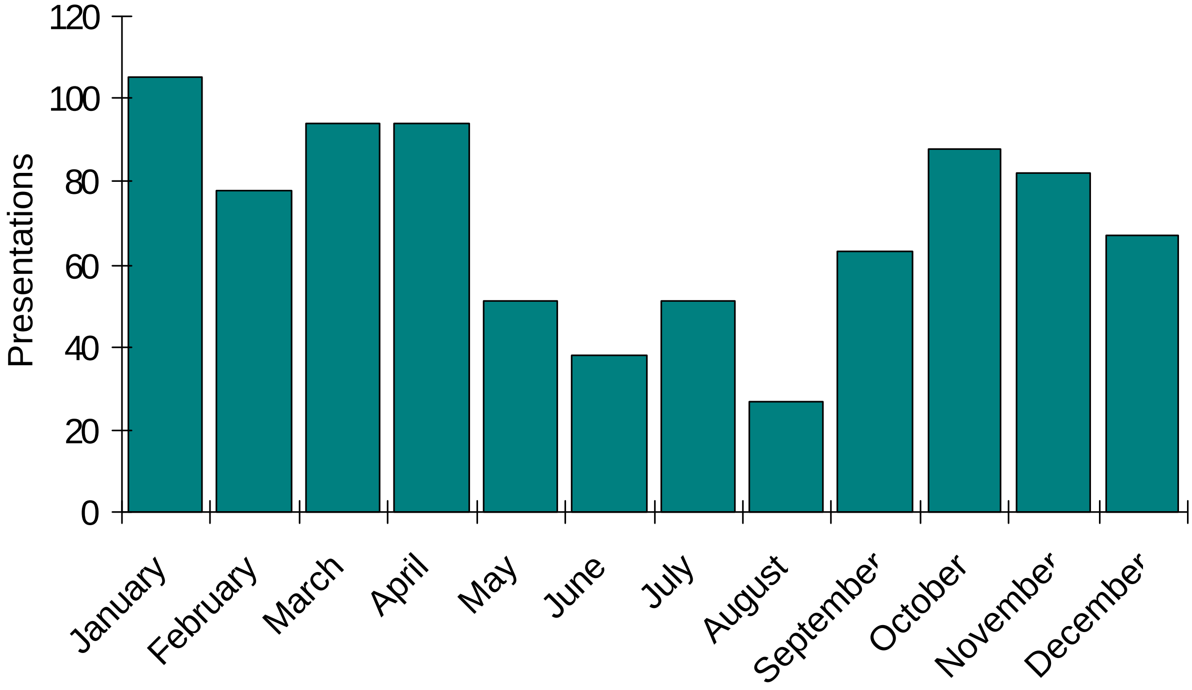

Figure 4 Seasonal variation of in-line skating emergency department presentations (VEMD 1996-1997)

Recommendations:

- Encourage skaters to make themselves visible by either skating in daylight or wearing bright and reflective clothing if skating at night
- Target "safe skating" programs to young skaters just prior to school holidays
- Teach skaters to recognise the signs of fatigue and to stop skating when they are tired
- Introduce pre-season training programs to skaters in the late winter or early spring

6. PROFILE OF INJURED IN-LINE SKATERS

6.1 AGE

Several studies report that the largest age group represented in in-line skating injuries is children aged 10-14 years (Ellis et al., 1995; McGrath and Beattie, 1996; Heller et al., 1996; QISPP, 1996; Calle and Eaton, 1993). Two of these report that the average age of injured skaters is approximately 11 years (Ellis et al., 1995; Calle and Eaton, 1993) which suggests that injuries are concentrated at the younger end of the 10-14 year age group.

In Victoria, 10-14 year olds sustained the most injuries (59%) of any age group of in-line skaters recorded on the VISS database from 1988 to 1992 (Heller et al., 1996), though this hospital sample is biased towards paediatric cases. The new VEMD database indicates that 87% of injury cases are 5-19 years old, while children aged 10-14 years old account for 50% of all cases.

Watson (1984) analysed data from the school injury reports on 6,799 Irish school children and identified a number of factors which appear to play a "major" part in children's sporting injuries, although no statistical tests were performed. The contributing factors include: poor supervision; lack of adequate warm-up; poor footwear or sports gear; lack of, or defective, protective gear; poor playing area; and the recklessness of the injured party (Watson, 1984). A number of intrinsic factors may also predispose children to sporting injuries. Weiss et al. (1993) report that children are at various stages of development in terms of balance and co-ordination, and also have immature proprioreception (position sense) and praxis (spatial sense) skills. The authors conclude that younger children (under 7 years) may have difficulty coordinating both sides of the body, as well as performing more complex motor tasks, while older children (8-12 years) are unable to selectively attend to movement characteristics, for example, avoiding collisions (Weiss et al., 1993). Injury prevention strategies should take into account these developmental factors that put younger skaters more at risk for injury.

Recommendations:

- Create and maintain safe areas for in-line skating, free of traffic and debris, especially for young and novice skaters
- Supervise young skaters, especially novices, until they develop the motor and skating skills necessary to skate safely
- Teach balancing and braking techniques to younger skaters before allowing them to skate on anything but a flat surface
- Teach children the rules of the road, encourage and enforce compliance
- Improve the fit of equipment (skates and protective gear) for young skaters
- Teach young skaters the importance of wearing protective gear while skating
- Make protective equipment "cool" (attractive) for children to wear

6.2 GENDER

Injury surveillance data consistently indicates that males are injured more often than females in in-line skating (Ellis et al., 1995; Towler and Brown, 1994; Routley, 1997; QISPP, 1996; Schieber and Branche-Dorsey, 1995). This difference may be more pronounced among adolescents. Schieber (1995) reports that the male:female ratio of injured teenagers (1.9:1) is higher than that for all ages (1.3:1) of injured skaters. The difference in the male:female ratio of injury for teenagers (aged 13 to 19 years) is even more pronounced in data from the VEMD database. The Victorian data shows that the male:female injury ratio among teenagers is 3.4:1, substantially higher than that for all ages (1.7:1) of injured skaters.

Tse et al. (1987) note that males are also injured more often than females in roller skating, despite the fact that more women than men participate in that activity (Tse et al., 1987). In an earlier study, Ferkel et al. (1981) report that males who sustain an injury while roller skating are three times more likely to require surgery than injured female roller skaters which suggests that males are injured more severely than their female counterparts. Victorian (VEMD) data indicate that males who are injured while in-line skating are admitted to hospital more often than their female counterparts ($P<0.05$).

Recommendations:

- Promote media images of skating role models wearing protective equipment
- Target specific injury prevention strategies to young males, who may be more at risk for serious injury than young females.

6.3 TRAINING AND EXPERIENCE

Novice in-line skaters appear to be more prone to injury. Several research studies indicate that the average skating experience at the time of injury is less than 6 months (Schieber et al., 1996; Heller et al., 1996; Calle and Eaton, 1993; Banas et al., 1992). Heller (1993) reports that in terms of ability, there are two distinct groups of injured in-line skaters. It is reported that a large proportion of those injured (46%) are first-time skaters who simply lose control and fall, while the other major group (25%) are more experienced skaters who are injured while performing tricks, often at considerable speed (Heller, 1993).

The disproportionate number of injuries to novice skaters is also reported for roller skating (Kvidera and Frankel, 1983; Ferkel et al., 1981). In a retrospective survey of 186 injured roller skaters, Ferkel (1981) notes that inexperienced skaters are involved in 77% of all roller skating accidents. From the same study, Ferkel reports that injuries to more experienced skaters, although less common, are more severe and require surgery twice as often as injuries to novice skaters. This observation may be due to the high speeds and more dangerous manoeuvres attempted by more experienced skaters.

Falling while standing still can cause serious injury (Ferkel et al., 1981) but falling at a high speed can have devastating consequences. The smoothness of the wheels and their alignment produces the potential to move at greater speeds than with traditional roller skates. Keeping speed in check and stopping are the most important skills skaters must learn before venturing out onto the public road, footpaths, or bicycle paths (Nesbitt, 1993).

The International In-Line Skating Association (IISA) recommends formal training by certified instructors to increase competency and decrease fear and reports anecdotal evidence that training results in safer and more enjoyable skating. Lessons in in-line skating by certified instructors are not readily available in Victoria, however RollerSports Australia conduct “Learn To Skate” classes through its clubs. Issues around training are discussed in more detail in section 8.3.

Recommendations:

- Promote skating instruction by certified instructors in order to teach stopping techniques, and safe skating practices (for example, rules of the road, wearing protective gear, how to fall safely)
- Teach in-line skaters, especially children, the rules of the road and monitor their compliance
- Offer more experienced skaters lessons to refine their skating skills
- Undertake more research into the effectiveness of in-line skating instruction in the prevention of in-line skating injury

7. AN OVERVIEW OF IN-LINE SKATING INJURY COUNTERMEASURES

Injuries are considered to result from a culmination of a set of circumstances and pre-existing conditions that may best be understood as a chain of events: pre-event, event, and post-event (Robertson, 1983). Measures to prevent or control injury (ie. countermeasures) should be targeted at the links in this chain and equate to primary (pre-event), secondary (event), and tertiary (post-event) prevention (Haddon, 1972; Ozanne-Smith and Vulcan, 1990; Watt and Finch, 1996).

7.1 PRIMARY COUNTERMEASURES

Primary countermeasures are preventive actions taken before an event or incident that could potentially lead to injury. Table 3 lists some of the major primary countermeasures to in-line skating injury.

Table 3 Primary countermeasures to in-line skating injury

- Pre-season conditioning and fitness program
- Adequate warm-up and pre-skate stretch
- Cool-down and post-skate stretch
- Equipment factors (for example, ensuring proper fit and condition of skates, fit of helmet, wrist guards, knee and elbow pads)
- Environmental factors (for example, keeping paths free of obstacles and debris, choosing a flat course, UV protection)
- Skating instruction and expertise of instructors
- Skater code of conduct (for example, obey the rules of the road, yield to pedestrians)
- Wearing bright or reflective clothing if riding at night
- Adequate supervision of children and novices

7.2 SECONDARY COUNTERMEASURES

Secondary countermeasures act during the event or incident to prevent the injury occurring or to reduce the severity of the injury. Table 4 lists some of the major secondary countermeasures to in-line skating injury.

Table 4 Secondary countermeasures to in-line skating injury

- Wearing protective equipment (for example, helmet, wrist guards, knee and elbow pads)
- Keeping speed in check

7.3 TERTIARY COUNTERMEASURES

Tertiary countermeasures act after the injury has occurred and help to minimise the consequences of injury. Table 5 lists some of the major tertiary countermeasures to in-line skating injury.

Table 5 Tertiary countermeasures to in-line skating injury

- Prompt access to quality first aid and medical care
- Availability of first aid equipment on site
- Rest, Ice, Compression, Elevation, Referral (RICER)

8. COUNTERMEASURES IN DETAIL

8.1 PROTECTIVE EQUIPMENT

Use of protective equipment by injured skaters is reportedly associated with a decreased likelihood of hospitalisation (Adams et al., 1996). It is for this reason that the American Academy of Orthopaedic Surgeons strongly urges in-line skaters to wear a helmet, wrist protectors, knee and elbow pads (Harman, 1995). The US Consumer Product Safety Commission (CPSC) warns that in-line skating can be hazardous if recreational skaters do not wear helmets and other safety gear (CPSC, 1995). Roller Sports Australia states that under the Rules of the Sport for competitive in-line speed skating, it is compulsory for all competitors to wear an approved cycle helmet as well as cycle gloves to protect the hands from skin burns and abrasions (Currell, personal communication).

8.1.1 Prevalence of protective equipment use

A number of Australian and overseas observational and epidemiological studies indicate that very few in-line skaters wear protective gear while skating. Most skaters (76%-88%) who present to hospital emergency departments with injuries wear no safety equipment at all (Ellis et al., 1995; Heller, 1993; Calle and Eaton, 1993), although usage rates in the community may be higher if skaters presenting with injuries are those less likely to be wearing gear (Adams et al., 1996). Orenstein (1996) reports that 59% of injured skaters (n=137) presenting to the emergency department of a Washington DC paediatric hospital from May 1992 to October 1993, owned their own protective gear, but less than one quarter of injured skaters actually wore some form of protective gear at the time of their injury. Heller (1996) also found a low rate of protective equipment use at the time of injury by skaters presenting to the Royal Children's' Hospital emergency department in Victoria. A number of studies have shown that even fewer skaters (1.4%-7%) self-report that they wear full protective gear (helmet, wrist guards, knee and elbow pads) while skating (Schieber et al., 1996; Adams et al., 1996; Williams-Avery and MacKinnon, 1996).

A larger proportion of women than men report wearing protective gear consistently (Adams et al., 1996; Williams-Avery and MacKinnon, 1996). It also appears that slightly more children than adults wear some form of protective gear (Towler and Brown, 1994). Experienced skaters are reported to be less likely to wear protective gear (Williams-Avery and MacKinnon, 1996; Young and Mark, 1995). Williams-Avery and MacKinnon (1996) surveyed 217 US college students who were skaters and had volunteered to participate in the study. The authors found that in-line skaters who had skated at least 6 times were less likely to wear protective gear than their less experienced counterparts.

Young and Mark (1995) report from an observational study of 1,548 recreational skaters over a 3-month period in Wisconsin that peer influence seems to be an important factor in the decision to wear protective equipment. The authors observed that skaters, especially adolescents, in groups of two or three had a significantly increased likelihood of all group members either wearing or not wearing equipment (Young and Mark, 1995). The most common reason given for not wearing protective gear is that it is perceived to be unnecessary (14.4%) (Williams-Avery and MacKinnon, 1996). Other reasons given by in-line skaters for not wearing protective equipment are: the gear is uncomfortable, it looks foolish, is inconvenient, is an added expense, and peers do not approve (Williams-Avery and MacKinnon, 1996).

It is important that younger skaters get a positive image of skaters wearing safety gear. Competitive skaters are role models for younger skaters and should act responsibly (wear protective gear) in order to ensure the safety of their sport. Professionally sponsored skaters could have a clause written into their contracts that makes the wearing of protective gear mandatory. In addition, media presenting images of in-line skaters should make it an editorial policy to only publish photos of skaters who are wearing protective equipment.

Observational data on the wearing rates for in-line skaters post-injury are not available, however, follow-up surveys of injured skaters in Victoria and in the US indicate that a skater is significantly more likely to wear protective gear after having sustained an injury (Heller et al., 1996; Banas et al., 1992).

8.1.2 Wrist guards

Use

The use of wrist guards by injured in-line skaters is reportedly low, ranging from zero use to thirty-three percent (Schieber et al., 1996; Heller, 1993; Banas et al., 1992). Adams et al. (1996) report that significantly more skaters are observed wearing wrist guards “in the field” (60%), than those who present to hospital emergency departments (44%, $p<0.01$)). This finding suggests a protective effect for wrist guards. In a Victorian follow-up survey of injured skaters, Heller et al. (1996) found that significantly more skaters wore wrist guards after sustaining their injuries than before (48% vs 5%).

Effectiveness

Although the use of wrist guards is recommended as a countermeasure to wrist injuries during in-line skating, there is some concern that wrist guards may transfer the force of the fall further up the arm, resulting in forearm fractures rather than wrist fractures. This hypothesis requires more thorough examination. Recent research studies on wrist guard effectiveness indicate that this transference may happen. The results of these studies are summarised in Appendix A.

Reviews of injury surveillance data report that the risk of wrist fractures is greater among skaters not wearing wrist guards (Schieber et al., 1996; Calle and Eaton, 1993; Adams et al., 1996; Orenstein, 1996). Although surveillance studies in Australia and overseas suggest a protective effect for wrist guards, only two (Schieber et al., 1996; Kristen, 1997) provide strong statistical evidence that wrist guards protect against injury.

In a well-designed case-control study using NEISS data, Schieber et al. (1996) report that the odds ratio for wrist injury, adjusted for age and sex, for those who did not wear wrist guards, compared to those who did, was 10.4:1. In calculations of population-attributable risk, the non-use of wrist guards accounted for 87 percent of all wrist injuries. This study was duplicated in Vienna by Kristen (1997), who found that those skaters wearing wrist guards sustained fewer wrist and forearm fractures than those skaters who did not wear wrist guards. The difference was statistically significant (Kristen, 1997).

Although it is generally accepted that wrist guards do not completely eliminate the possibility of sustaining wrist fractures, there is some debate over whether wrist guards reduce the severity of arm injuries (Chong et al., 1995; Cheng et al., 1995). There is evidence to suggest that guards may displace fractures along the arm and that these fractures are less easily treated (Chong et al., 1995; Cheng et al., 1995). Chong et al. (1995) report from a case-series study of 98 injured in-line skaters at a single Sydney hospital that the chance of forearm fracture was higher than that of wrist fracture when wrist guards were used (Chong et al., 1995). Cheng et al. (1995) also report four cases of “splint-top” fracture of the forearm in in-line skaters who were wearing wrist guards. These authors hypothesise that the rigid plastic insert of the wrist splints may transfer the energy of impact from the hand to the mid-forearm. Furthermore, the torque resulting from the force of the fall on the hand and wrist may be multiplied by the length of the splint, which acts as a lever, and causes a more serious injury (Cheng et al., 1995).

In a case-control study of 532 injured Viennese skaters, Kristen (1997) found that those skaters wearing wrist guards at the time of their injury had significantly more fractures of the hand than those not wearing wrist guards. These findings suggest that although wrist guards do protect the area directly covered by the splint, the areas directly proximal and distal to the splint may be more at risk for injury. However, observational evidence from two studies suggests that forearm fractures with wrist guards were less severe and required less orthopaedic manipulation than fractures sustained when wrist guards were not worn (Calle and Eaton, 1993; Orenstein, 1996).

An added risk factor to injury, reported by Calle and Eaton (1993), is that in-line skaters wearing wrist guards tended to travel faster (~5mph) than those without protective gear. It is possible that wearing protective gear gives skaters a heightened sense of security, thereby putting them at risk of higher energy incidents.

Studies using matched cadaveric arms to test the effectiveness of wrist guards are also inconclusive. One in vitro study concluded that wrist guards are not effective in preventing wrist fractures or diminishing their severity (Giacobetti et al., 1997). A second similar experiment conducted by Lewis et al. (1997) provided biomechanical evidence of the protective effect of wrist guards. This study reported that wrist guards are associated with a significant increase in the number of drops, mean drop height, mean kinetic energy, and summed impulse required to cause a fracture. The fractures also tended to be less severe when wrist guards were used (Lewis et al., 1997). The only apparent difference in these two studies, which may account for the conflicting results, is the method by which the fall was simulated. Giacobetti used a Instron Servohydraulic Material Testing system, where a weight is dropped onto the hand in order to fracture the wrist and Lewis used a free-falling drop device, where the forearm is fractured by dropping it onto a fixed surface. Neither test is ideal, but the Lewis test, which supports the protective effect of wrist guards, seems to better simulate the dynamic variables involved in a fall onto an outstretched arm.

Recommendations drawn from the above-mentioned studies range from mandatory use of wrist guards to prevent severe wrist fractures to investigating and improving wrist guard design. None of the researchers discourage in-line skaters from wearing wrist guards.

The current design of wrist guards may not be practical for use in roller hockey as the guards may interfere with the players’ ability to hold the hockey stick and to make a wrist shot. Further attention to the design of wrist guards for roller hockey is warranted given the emerging popularity of the sport and the potential for injury (Schieber et al., 1996).

8.1.3 Helmets

Head injuries are reported to be sustained by between three and seven percent of all injured in-line skaters (Ellis et al., 1995; Calle and Eaton, 1993; Schieber et al., 1994; Schieber and

Branche-Dorsey, 1995). Baker et al. (1994) note that the proportion of injuries that involve the head decreases as the age of the skater increases.

Helmet use is promoted primarily to decrease scalp lacerations and to reduce the potential for intracranial trauma (Calle and Eaton, 1993). Helmet use reportedly ranges from “no use” to less than 10% use (Schieber et al., 1996; Ellis et al., 1995; Calle and Eaton, 1993; Jacques and Grzesiak, 1994). Overall, helmets are the least commonly observed form of protective gear worn by skaters (Jacques and Grzesiak, 1994).

One study into the effectiveness of helmets lacked sufficient power to detect a significant association between head injury and helmet use because the number with head injury in the study (n=5) was low (Schieber et al., 1996). This problem besets all studies of rare events.

At least one helmet manufacturer has introduced a helmet designed specifically for in-line skating, which offers extended coverage to protect the back of the head. Its effectiveness “in the field” has not yet been tested. Multipurpose helmets may help to reduce the cost of outfitting a child with a single-purpose helmet for each hazardous activity. Such helmets should be designed to incorporate the protective needs of in-line skaters. The availability of multipurpose helmets may serve to encourage participants to wear a helmet when trying out a new activity, where inexperience may be an added risk factor for injury (Baker et al., 1994).

8.1.4 Knee pads

Knee pads are important for protecting the knees from injury when a fall occurs. If safe falling technique is adopted then the knees are the part of the body which contact the ground first. Knee pads are necessary to protect the knee joint from the force of the fall, and the knee from abrasions. Knee pads are also important as they give the skater the confidence to drop to their knees when falling, thus protecting their upper extremity from potential injury.

Elbow and knee pads are reported from observational studies to be the most common piece of protective equipment worn, used by up to forty-five percent of skaters (Williams-Avery and MacKinnon, 1996). Schieber et al. (1996) report a protective effect for knee pads, but this was not a statistically significant finding because of the small number of knee injuries that presented. Researchers estimate that failure to use knee pads accounts for 32 percent of all knee injuries (Schieber et al., 1996).

Pads should be made of high-grade polyurethane in order to withstand the force of falling. They should fit properly and not slide off the knee during skating.

8.1.5 Elbow pads

Schieber et al. (1996) report that up to 28 percent of skaters wear elbow pads while skating. The odds ratio for elbow injury, adjusted for the number of lessons skaters had taken and whether they performed trick skating, was 9.5:1 for those who did not wear elbow pads. Failure to use elbow pads accounted for 82 percent of all elbow injuries (Schieber et al., 1996).

Elbow pads protect the elbow from the forces of impact with the ground. Elbow pads, like knee pads, should be made of high grade polyurethane in order to withstand the force of falling. They should fit properly and not slide down off the elbow during skating.

Recommendations:

- Promote the use of full protective gear to skaters of all ages and abilities
- Identify and address barriers to wearing protective equipment, especially among adolescents
- Refine and promote standards for helmets, both multi-purpose and specifically for in-line skating (with extended coverage to protect the back of the head)
- Encourage all rental outlets for in-line skating equipment to provide protective equipment as well as skates in a package deal
- Undertake further biomechanical and ergonomic research into the design of protective equipment, especially to improve the effectiveness of wrist guards
- Encourage competitive skaters to wear protective gear by writing a clause into their contracts making the wearing of protective gear mandatory
- Lobby media presenting images of in-line skaters to adopt an editorial policy to only publish photos of skaters who are wearing protective equipment

8.2 PHYSICAL PREPARATION

"Warming-up" is a term which covers activities such as light exercise, stretching and psychological preparation for physical activity (Best and Garrett, 1993). The Australian Sports Commission, in association with Sports Medicine Australia, recommend warming-up, stretching and cooling down to help prevent musculoskeletal injuries during physical activity (SMA, 1997). Some of the physical stresses of in-line skating may be reduced by warming-up and stretching, which are known to improve the range of motion of the joints and increase muscle elasticity (Best and Garrett, 1993). Stretching exercises for calves, hamstrings, hips and back (before and after skating) could help to prevent overuse-type injuries to the lower extremities (Nesbitt, 1993). However, there is no epidemiological or experimental evidence to support this hypothesis for in-line skating.

Recommendations:

- Develop and promote information about warm-up, cool-down and stretching techniques specific to in-line skating
- Identify and address barriers to warm-up, cool-down and stretching among skaters
- Undertake research into the effectiveness of warm-up, cool-down and stretching as an injury prevention measure for in-line skating

8.3 SKATING INSTRUCTION

Follow-up interviews of injured in-line skaters indicate that most (75-78%) learn to skate by trial and error (Heller et al., 1996; Heller, 1993). This is supported by studies that found that only two percent of in-line skaters had taken any formal instruction (Adams et al., 1996). The International In-Line Skating Association (IISA), the Consumer Product Safety Commission (CPSC) and the Canadian In-Line & Roller Skating Association (CIRSA) all recommend skating instruction to skaters before they venture out on their own (CPSC, 1995; CIRSA, 1996; IISA, 1993).

The International In-Line Skating Association (IISA) offers certification training for in-line skating instructors, emphasising skill development and proper technique for braking, keeping speed under control, and falling safely. IISA provides anecdotal evidence that proper skating technique leads to increased skater confidence and decreased skater fear, resulting in safer, more enjoyable skating (IISA, 1993).

There are currently three levels of IISA Certification: Level 1 Certification is for the entry-level instructor who wants to teach the fundamentals of in-line skating based on a standardised format of teaching. Instructors are qualified to teach such things as moving, stopping and turning. Level 2 Certification is for the experienced Level 1 Instructor who wishes to enhance class-handling skills, problem solving and intermediate-level skill development. Level 2 Instructors teach skills such as backward movement, alternative stopping, cross-overs and street-skating awareness. Level 3 Certification includes certifications in high skill areas such as in-line hockey, racing, skate-to-ski, freestyle dance, street vert and ramp.

As previously mentioned, there are only three IISA-certified instructors in Victoria (Kropp, personal communication). Certification exams must be sat overseas, making it difficult for Australian instructors to access training. RollerSports Australia provide education and accreditation through the Australian Coaching Council for Level 1 and 2 coaches, although the current accreditation scheme only includes coaching of roller in-line hockey and in-line speed skating (Currell, personal communication). RollerSports Australia is in the process of developing beginner coaching courses to complement their Learn To Skate programs. These programs aim to provide basic skills to enable participants to progress into competitive disciplines, and appear less suited to recreational skaters.

The overwhelming majority of skating outlets do not demand that their instructors be certified (Kropp, personal communication). In-line skating instruction should help to prevent skating injury, especially amongst novice skaters, however this has not been formally proven.

As the sport has grown, there is an increased need for park systems to provide “on-the-spot” basic skills instruction which helps skaters to better coexist with cyclists, pedestrians and other park users. The National Skate Patrol was developed in 1992 by the New York Road Skaters Association (NYRSA) and IISA. Upon completion of a one-day training certification, the National Skate Patrol volunteers are provided with NSP jackets, T-shirts, and name tags for easy identification. First Aid/CPR training is also provided. Patrollers roam the park, and when they come across novice skaters who have trouble using their heel brake they either give them an on-the-spot stopping lesson or direct them to a stopping clinic located in the park. Skate Patrollers dispense antiseptic wipes, bandages, and gauze pads to skaters who have skinned their knees or elbows. When dealing with more serious injuries such as a possible broken bone or head injury, they radio a call to emergency paramedics who are able to give more extensive medical attention. Patrollers hand out written material and maps to people looking for directions and places to skate in the park. The National Skate Patrol has certified chapters in the US, UK, Canada, and Switzerland. There are no chapters in Australia.

8.3.1 Safe falling technique

In sports such as skiing, one effective countermeasure to injury is to teach a safe falling technique which is likely to minimise injury (Kelsall and Finch, 1996). Surprisingly for in-line skating, where falls constitute a major mechanism of injury, this countermeasure is rarely mentioned in the literature.

One certified instructor has observed that novice in-line skaters are especially at risk for injuries to the back of the head because they often skate straight-legged with their weight over their heels, resulting in a tendency to fall backwards (Miller, 1997). Novice skaters must be instructed to keep their knees bent and their weight forward (over their toes rather than their heels), thus allowing them to fall forwards rather than backwards. These techniques may require some practice, but could prove effective in minimising injuries from falls.

Most skaters sense when they are about to fall and in these circumstances they should be trained to use a safe falling technique, or at least to look for a soft surface to land on (for example, grass, sand). A safe landing technique for in-line skating might include dropping to the knees first instead of reaching out to break a fall with the hands. This way, the force of the fall is absorbed by the durable knee pads, rather than by the vulnerable wrists.

Recommendations:

- Explore the possibility of developing National Skate Patrol chapters in Victoria
- Provide all skaters with the opportunity to take lessons given by accredited instructors, for example, through rental outlets and schools
- Determine the best technique for in-line skaters to use when falling, in order to minimise injury
- Teach safe falling techniques along with other fundamental skating skills
- Provide soft shoulders to fall onto when designing skating trails
- Provide local certification training for in-line skating instructors in Victoria and Australia
- Undertake more research into the effectiveness of skating instruction including safe falling technique as an injury prevention measure

8.4 EQUIPMENT DESIGN

8.4.1 Skate fit

Correct fit of skates is vital to the skater's comfort (Choice, 1992). If the boot is too tight, the skater could get cramps; if the boot is too loose, the foot could blister (Choice, 1992). This is an important consideration when skates are hired or when skates are bought as a gift. It is wise to bring the skater along when purchasing skates to ensure a good fit. At least one skate manufacturer has introduced an adjustable skate to compensate for the rapid growth of children's feet. This design provides a full four-size fitting range to comfortably accommodate foot growth in children.

8.4.2 Skate braking systems

The smoothness of the wheels and their in-line alignment produce the potential to move at greater speeds than with traditional roller skates. Falling at high speeds can cause serious injury. The most important skills for in-line skaters to learn before they venture out into public places is to keep speed in check and stopping techniques (Nesbitt, 1993). Many novice skaters have difficulty in applying the traditional simple friction brake as it requires that the skater has sufficient balance to be able to skate on one foot whilst simultaneously angling the other skate upwards. It can also be difficult to use as the brake pad may catch on cracks or gaps on the skating surface, thus unbalancing beginners and advanced skaters alike. Further, as the brake wears, the distance between the brake pad and the skating surface increases, requiring the skate to be angled more aggressively in order to stop.

The need for a braking system, which allows all wheels to remain in contact with the skating surface, has led to the development of the next generation of in-line braking technology. Most major skate manufacturers have at least two types of braking systems on the market, a simple friction braking system and an "advanced" system. "Advanced" braking systems include the Disk Brake System (from UltraWheels), the Power Braking System (from Oxygen), the Force Multiplier System (from Bauer), and Advanced Braking Technology (from Rollerblade). Each system has unique features which can make choice difficult. It is best for skaters to try out each type of brake and decide which one is best for them tailoring their choice to their skating ability, intended use and budget.

It is important to note that there are other ways of stopping besides using brakes (such as using a "T-stop" or a "spin stop"). A skater should learn as many methods as possible in order to stop in a variety of situations. Learning these methods should not be thought of as a substitute for learning to use the heel brake, as no other method works better than a properly applied heel brake when stopping at high speeds.

Another way of keeping speed in check is to outfit skates with "s
which are small and/or soft. The new fast wheels that come with skates can be replaced by the retailer with cheap new or slower used wheels. This is akin to putting training wheels on a bicycle. The fast wheels can be refitted once the requisite braking skills have been acquired.

Recommendations:

- Teach all skaters to stop using the heel brake
- Encourage skaters to learn more than one method of stopping
- Encourage new skaters to start off with "slow" wheels
- Train and encourage salespersons and personnel in shops to correctly fit skates
- Assist skaters to choose the best braking system and wheels to suit their skating needs
- Encourage manufacturers to continue to improve brake technology
- Undertake more research into the effectiveness of each new braking system in preventing in-line skating injuries

8.5 SKATING ENVIRONMENT

The choice of an appropriate skating course is an important safety consideration and can help to ensure safer skating and a more enjoyable ride. Although skating on designated skate or cycle trails is preferred, it is not always possible. Skaters who do share the road with motor vehicles must obey the rules of the road, including using bicycle hand signals to indicate their actions when turning and stopping.

Skating on a designated trail can help to reduce the risk of injury caused by interactions with motor vehicles and pedestrians. Signs, which indicate course difficulty, allow skaters to match the course conditions to their ability. Local Councils should also ensure that footpaths and other trails used by skaters are kept in good repair and free of debris. Where possible, trail shoulders should be designed to provide a soft hazard-free landing.

8.5.1 Skate trail rating system

Trail difficulty depends on several factors including: trail width; trail gradient (for example, flat vs hilly); trail surface (for example, smooth vs textured); obstacles (for example, debris, curbs, bridges); curves (for example, wide gentle curves vs right angles); and drainage (for example, puddles, dirt and sand). Some overseas parks now display a skate trail rating guide, similar to a skiing trail rating guide (for example, green for beginner, blue for intermediate, and black for expert). The colour-coded marker is posted at the beginning of a trail, informing the skater of the condition of the path ahead. A skater can then determine whether the trail is suitable for his/her ability, thus reducing the chance of encountering any unexpected obstacles.

Recommendations:

- Teach skaters bicycle hand signals for times when they cannot avoid skating in traffic
- Provide skating trails separating skaters from other traffic (for example, cars, pedestrians)
- Maintain trails and clear them of any debris such as branches, sand, stones, and rubbish
- Rate skating trails for difficulty and post rating clearly at the start of each trail

8.6 POLICY AND REGULATION

Reckless skating and damage to public property (for example, steps and railings) have forced a few city councils (for example, Melbourne City Council and Stonnington City Council) to propose local by-laws which restrict skating in public spaces. The Melbourne City Council originally banned all skating activity from the Central Business District (CBD) between 7 am and 7pm. In October 1996, the Council advertised an amendment to its existing law, proposing an extension which would, in effect, introduce a 24 hour skating ban in the downtown area. Submissions were called for and the overwhelming response was opposition to the proposed ban.

After consulting with skaters groups and city traders, the Council decided to take a pro-active approach and tabled a six-point “Skate Management Plan”. The plan comprises the following initiatives:

i) offering skaters the use of off-street facilities (Queen Victoria Place);

ii) providing a map showing preferred access routes and no-go streets in the CBD;

iii) instituting a Code of Conduct to ensure responsible skating behaviour in the CBD (for example, skate to the left, pass on the right);

iv) providing an education and awareness campaign to inform the general public about the skate management plan initiatives;

v) developing physical measures around sensitive buildings to protect property; and

vi) passing Local Laws which prohibit reckless skating, unsafe behaviour and damage to property.

Early indications of the effectiveness of this plan are good. A recent survey of in-line skaters in Melbourne CBD found that skaters are using the City off-street skate venue more, and the streets less (Shaw, personal communication). The introduction of the skating venue has also resulted in a reported decrease in the number of conflicts between pedestrians and skaters in the CBD (Shaw, personal communication). Skating events at the venue attract large numbers of participants and onlookers and provide a good opportunity to distribute educational information to the skating community.

In an annual review of the program, it was decided that the skate park develop a Safety Plan. This plan will incorporate such things as provision of shade and water and encourage use of safety gear, training and education (Shaw, personal communication). The City of Melbourne (via the SkateSafe committee) is currently developing this Safety Plan.

Other Australian capital cities, including Brisbane, Canberra, and Hobart, and other Victorian local governments are interested in using the City of Melbourne's Skating Management Plan as a model for developing their own strategies (Shaw, personal communication).

Recommendations:

- Local Councils should develop consistent "skate management plans" in consultation with local skater groups which include a skater code of conduct, and safe skating facilities
- Local Councils and skating venue managers should promote and enforce wearing of protective equipment on Council property and at skating venues

9. SUMMARY AND CONCLUSIONS

In-line skating is an increasingly popular recreational activity. The increase in popularity has been associated with an increase in injuries. In-line skating appeals to all ages, however the majority of participants and those injured are adolescents (10-14 years). In-line skating injuries can be serious and disabling, and deaths have been reported both here and overseas.

The improvements in skate and wheel technology have resulted in a very fast skate which requires a certain amount of skill to control. Many novice skaters are overwhelmed by the speed of the in-line wheels and are unable to slow down or stop in time to avoid collisions and/or falling. The in-line alignment of the wheels and the heel brake mechanism make it difficult for the novice skater to retain their balance, especially when turning or braking.

The unsteady base of support, a changing terrain with unexpected challenges (for example, debris, curbs, cracks in the pavement and hills) and an unsettling braking mechanism can contribute to some falls. Add to that the high speed of the skater together with a lack of protective gear and you have a recipe for injury.

It is inevitable that even the most skilful in-line skater will fall eventually. The best protection against injuries from falling is equipment that protects the body at the point of contact with the ground. This includes knee pads, wrist guards, elbow pads, and helmets. When worn properly (for example, adjusted to provide a good fit) these devices help to reduce the number and severity of in-line skating injuries. **Full protective equipment (knee pads, wrist guards, elbow pads, and helmets) should be worn by all skaters, young and old, beginner and expert, at all times.**

Very few in-line skaters wear full protective gear and more research is needed to identify the barriers to implementing this safety measure. Safety equipment needs to be presented as “cool” so that children will wear it. Outlets that hire skating equipment should offer hire packages which include in-line skates and full protective gear at one all-inclusive price. Since more than one-half of those injured while skating give up the sport, it is within the interest of the hiring outlets to ensure the well-being of their clientele.

Organisers of skating competitions and skate park operators should make the use of full protective gear mandatory for participants. They should also ensure that skaters are wearing their gear properly (for example, adjusted to fit, fastened helmet) when competing. These competitive skaters are role models for younger skaters and should act responsibly in order to ensure the safety of the sport. In addition, media presenting images of in-line skaters should make it an editorial policy to only publish photos of skaters who are wearing protective equipment.

Skating instruction by certified instructors should be available to skaters through hiring outlets and schools. Skaters must learn proper stopping techniques, and safe skating practices (for example, rules of the road, how to fall safely) before venturing out onto the roads. More experienced skaters can also benefit from lessons, to help refine their skating skills and ability. Local certification training must be made available to in-line skating instructors in Australia. Skating outlets must demand certified training qualification of their instructors. The feasibility of a National Skate Patrol should be explored so that in-line skating instruction can be made available to skaters where they skate.

Finally, local Councils should consult with local skaters’ groups in order to develop an effective “skate management plan”. Good skate management plans should include provision of safe skating venues, as well as incorporate educational campaigns to teach skaters the proper code of conduct.

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APPENDIX A
REVIEW OF PROTECTIVE EQUIPMENT STUDIES

Authors	Study design and target population	Intervention	Outcomes	Results	Study quality and conclusions
Schieber et al., 1996b	Case-control study. Population: Subjects treated for in-line skating injuries at emergency departments participating in the National Electronic Injury Surveillance System (NEISS). Time period: 12/92-7/93 (N=161)	Wrist guards, elbow pads, knee pads, helmets	Wrist, elbow, knee or head injury. Cases: Skaters with injuries to wrists, elbows, knees, or head. Controls: Skaters with injuries to other parts of the body.	Wrist injuries most common, 37% of all skating injuries, 2/3 of wrist injuries are fractures. Use of protective devices low among injured patients. Odds ratio for wrist injury comparing those wearing wrist guards to those without is 0.10 (0.03-0.34) adjusted for age and sex. Odds ratio for elbow injury comparing wearers of protective equipment to those with no protection is 0.11 (0.03-0.38) adjusted for number of lessons and trick skating. Odds ratio for knee injury for those wearing knee pads was 0.45 (0.14-1.4)	Wrist guards and elbow pads are effective in protecting in-line skaters against injuries. The effectiveness of helmets could not be assessed because of the small number of head injuries. Well-designed case control study. SUDAAN statistical software used to account for complex sampling, and logistic regression was used to adjust for confounding factors.

Authors	Study design and target population	Intervention	Outcomes	Results	Study quality and conclusions
Lewis et al., 1997	Laboratory biomechanical analysis Population: Thirty paired arms were harvested from 15 cadaveric specimens	Wrist guards	Forearms from each cadaver, one with a wrist guard and one without, were fractured using a free-falling drop device. The number of drops, mean drop height, mean kinetic energy, and summed impulse required to cause fracture with and without wrist guards were noted. Severity of fractures were compared using an ordinal ranking system.	Wrist guards were associated with a significant increase in the number of drops, mean drop height, mean kinetic energy, and summed impulse required to cause fracture. Fractures also tended to be less severe when wrist guards were used.	This study presents biomechanical evidence of a protective effect of wrist guards. The in vitro testing conditions are limited, however the “free-falling” test model may better simulate the dynamic variables involved in a fall onto outstretched hands.

Authors	Study design and target population	Intervention	Outcomes	Results	Study quality and conclusions
Giacobetti et al., 1997	Laboratory biomechanical analysis Population: Forty paired arms were harvested from 20 cadaveric specimens	Wrist guards	The forearms from each cadaver, one with a wrist guard and one without, were fractured using an Instron Servohydraulic Material Testing system. Force values needed to fracture wrists with and without wrist guards were noted. Severity of fractures using Frykman classification system were compared.	The group of forearms tested to failure without wrist guards failed at an average force of 2245 N, while the group tested with wrist guards failed at an average force of 2285 N, revealing no statistical difference. Fracture patterns (severity) were not noted to be different in the two groups.	The wrist guards tested were not effective in preventing wrist fractures, or in diminishing their severity. The in vitro testing conditions may not precisely simulate the dynamic variables involved in a fall onto outstretched hands.

Authors	Study design and target population	Intervention	Outcomes	Results	Study quality and conclusions
Cheng et al., 1995	Case series Population: Four patients with open fractures of both bones of the forearm sustained while in-line skating, presented at the emergency departments of Sunnybrook Health Sciences Center (Toronto, Canada) and New York University Medical Center (NY, USA). All four subjects were wearing wrist guards at the time of their injuries.	Wrist guards	Location of forearm fracture	Four patients sustained open forearm fractures located immediately proximal to the wrist guards, occurring as a result of falling while in-line skating at a low velocity.	The authors hypothesise that the rigid plastic insert of the wrist splints may transfer the energy of impact from the hand to the mid-forearm. Furthermore, the torque resulting from the force of the fall on the hand and wrist may be multiplied by the length of the splint, acting as a lever. There was no control group in this case series of only a few (n=4) patients. The hypothesis mentioned above was not tested, and although interesting, this study is inconclusive