ORIGINAL ARTICLE

Injury risk from popular childhood physical activities: results from an Australian primary school cohort

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Background: Children engage in various physical activities that pose different injury risks. However, the lack of adequate data on exposure has meant that these risks have not been quantified or compared in young children aged 5–12 years.
Objectives: To measure exposure to popular activities among Australian primary school children and to quantify the associated injury risks.
Method: The Childhood Injury Prevention Study prospectively followed up a cohort of randomly selected Australian primary and preschool children aged 5–12 years. Time (min) engaged in various physical activities was measured using a parent-completed 7-day diary. All injuries over 12 months were reported to the study. All data on exposure and injuries were coded using the *International classification of external causes of injury*. Injury rates per 1000 h of exposure were calculated for the most popular activities.
Results: Complete diaries and data on injuries were available for 744 children. Over 12 months, 314 injuries relating to physical activity outside of school were reported. The highest injury risks per exposure time occurred for tackle-style football (2.18/1000 h), wheeled activities (1.72/1000 h) and tennis (1.19/1000 h). Overall, boys were injured more often than girls; however, the differences were non-significant or reversed for some activities including soccer, trampolining and team ball sports.
Conclusion: Although the overall injury rate was low in this prospective cohort, the safety of some popular childhood activities can be improved so that the benefits may be enjoyed with fewer negative consequences.

Current Australian national guidelines recommend that children aged 5–12 years participate in at least 60 min of physical activity every day.[1] These guidelines are consistent with recommendations from other countries,[2 3] and physical activity in general is widely advocated for numerous health benefits.[4] Children in this age group typically participate in a variety of sports, games, leisure time pursuits and chores, which contribute to their overall physical activity.

However, all physical activity is associated with varying degrees of exposure to the risk of injury, which is a leading cause of mortality and morbidity in Australian children.[5] The top three single causes for presentation to an emergency department in Australian children aged 0–14 years are related to physical activity: sport and recreation, cycling and skateboarding, and playground use[6]; and 14% of those presenting with a sporting or recreation injury require hospitalization.[7]

Similar results have been reported internationally. For example, an injury surveillance system in Swansea, UK, reported that 36% of fractures in children were due to sport and leisure activities.[8] Physical activity and sporting-related injuries are leading causes of visits to the emergency department and hospitalizations among children from several countries including Norway,[9 10] France,[11] New Zealand[12] and the US.[13]

To date, many specifics of the physical activity-related injury problem are largely unknown.[14 15] The lack of a coordinated collection of reliable data on injury incidence means that measurement estimates are imperfect, and are often derived from descriptive case series or from injury surveillance data that involve non-representative samples.[15] In addition, reliable population-based participation rates in various activities are generally lacking or are restricted to organized sports in competitive scenarios, so that even when injuries are accurately numerated, the lack of denominator data inhibits the calculation of activity-specific injury rates per exposure time.[16]

The aims of this study were to obtain population estimates of exposure to common physical activity pursuits for children aged 5–12 years and to calculate injury incidence for these activities. Relative risk (RR) profiles for popular activities could hence be ascertained for this pediatric population. This research question was a component of a larger cohort study, the Childhood Injury Prevention Study, conducted in Brisbane, Australia, between 2001 and 2004.

PARTICIPANTS AND METHODS

Study design and setting

A detailed account of the methods of the Childhood Injury Prevention Study have been described previously.[17] It was a prospective cohort study involving a 12-month follow-up of primary school children in Brisbane, Australia. Brisbane is a metropolitan city with 1.6 million inhabitants on the eastern coast of Australia.

Participant recruitment

Participants were recruited continuously from January 2001 to April 2003 via a two-tier randomization process. On the basis of their postal codes, all public and private Brisbane primary schools were allocated to categories of low, middle or high socioeconomic status. Thirty six schools were then randomly selected for inclusion from these categories. Secondly, about 150 families with at least one child attending one of the included schools from preschool to grade six level were randomly invited to participate. Only one quasi-randomly selected child per family was subsequently included.

Variable, instruments and the data collection process

Data collection consisted of a baseline home interview, a parent-completed 7-day activity diary and a record of each injury that occurred during the 12 months after the interview. The baseline interview lasted about 45 min and information collected included the age and the sex of the child.

The prospective activity diary provided a measure of exposure to physical activity. This 1-week diary was completed for all children at the time of recruitment into the study. Excluding time spent at school, parents were asked to describe the exact location and activity details of the child for seven consecutive days. Mealtime prompts were given in the diaries to increase accuracy recall,[18] and an example page was provided as a guide for the level of detail required. Activity and location were coded according to the *International classification of external causes of injuries*,[19] which has been validated as a tool for categorizing activities.[20] Details of the coding method have been reported previously.[21]

Each injury that occurred over 12 months was registered with the study. An injury was defined as any incident for which first aid treatment was given. Any reported events that were aggravations of previous injuries were excluded. We defined a ''serious'' injury as any incident for which professional health treatment from a general practitioner, emergency department, dentist or other allied health provider was sought. All injuries were self-reported by families via an injury event questionnaire provided at the baseline interview. In addition, parents were contacted by telephone every 2 months to ensure that injuries sustained during that time had been recorded. The details of any injury that had occurred for which the study investigators had not received a completed injury event questionnaire were recorded by telephone.

The injury event questionnaire solicited information related to the location of the child and the circumstances relating to the injury event. The place of treatment was also noted on these forms. The questionnaires were coded using the same *International classification of external causes of injuries* used for the diaries.[19]

Data synthesis and analysis

All data were analysed using SPSS V.12.0. For each child, the total time (min) spent in different physical activities was calculated for the entire week. The mean weekly time spent in the 15 most popular activities (by time) by all children and then separately by both boys and by girls was calculated by totalling the individual time scores for each child and dividing by the total number of children.

Each injury was categorized according to whether or not it was attributable to physical activity. These could be any injuries that occurred while the child was participating in one of the activities defined previously as falling within the physical activity category. Physical activities that occurred during school hours were not included in the analysis because accurate exposure data for schooltime activities were not available.

Injury rates for the most popular activities were calculated using the formula below:

$$\text{Exposure specific injury rates per 1000 h} = \frac{\text{Number of specified injuries} \times 1000}{\text{Person-hours exposed to specified activity in the week} \times 52}$$

The injury rate formula assumes that the random sample of 1-week diaries distributed over the full study period represents the physical activity experience of the whole sample and can be used to derive estimates of the population experience over that period (within a defined probability of error).

Relative risk (RR) ratios with 95% confidence intervals (CIs) were calculated to compare the overall and serious injury risk profiles for each activity against the most common activity.

Sex-specific differences

Injury rates for the activities popular with both sexes were calculated separately for boys and girls. These differences were then compared by calculating odds ratios (ORs) with 95% CI for boys and girls. We were unable to compare serious injuries in this manner because of the few incident numbers.

Ethical approval for the study was provided by the Queensland Department of Education and the Catholic Education Commission and the research ethics committee of the University of Queensland. Parental written consent was obtained for all participating children.

RESULTS

Sample characteristics and exposure to physical activity

Of 3384 children who were invited to participate, 871 were registered in the study. The mean age of participating children was 8 (range 4–12) years. Diaries were returned for 767 participants; 744 (407 boys and 337 girls) of these were completed for the full week. Only data pertaining to children for whom complete diaries were returned (n = 744) were analyzed for the current study.

The mean total time spent in physically activity was 861 min/week (95% CI 831 to 891). Table 1 lists the 15 most popular activities outside of school hours according to descending order of rank by time for all children: the mean number of minutes spent by each child in each activity (with 95% CI) and the percentage of total physical activity time represented by that activity are shown. The means represent the average time spent in each activity across the whole sample and do not represent the actual time spent by one particular child. Active play, which accounted for nearly half of all activity, was defined as spontaneous, unstructured games and activities.

The top 15 activities accounted for 99% of all physical activity, with active play accounting for nearly half the accumulated time. Swimming, bicycle riding and walking

Table 1 Ranked order of most common activities by time

Rank	Activity	Mean (95% CI) min spent per week	Percentage of total physical activity time
1	Active play	421 (394 to 456)	48.9
2	Swimming	105 (91 to 118)	12.2
3	Bicycle	68 (59 to 78)	7.9
4	Walking	46 (40 to 52)	5.3
5	Outside chores	37 (31 to 42)	4.3
6	Soccer	30 (24 to 36)	3.5
7	Wheeled activities*	27 (20 to 34)	3.1
8	Trampoline	21 (17 to 25)	2.4
9	Other team ball sports†	20 (15 to 25)	2.3
10	Dancing	18 (13 to 22)	2.1
11	Cricket	18 (12 to 23)	2.1
12	Tennis	13 (10 to 16)	1.5
13	Tackle football‡	13 (9 to 16)	1.5
14	Athletics	10 (6 to 13)	1.1
15	Gymnastics	7 (5 to 10)	0.8

*Excludes bicycle riding.
†Excludes all football codes.
‡Includes rugby, Australian rules football.

(for both transport and leisure) were the next most popular activities. Soccer was the most popular team ball sport. Other team ball sports included netball, basketball, volleyball and handball. The tackle football category grouped together rugby and Australian rules football. Wheeled activities (other than bicycle riding) included skateboarding, scootering, roller skating and roller blading (inline skating).

Injuries related to physical activity

Over the study period, 504 injuries related to physical activity were recorded for the 744 participants, of which 314 (62%) occurred out of school; 94 (30%) of these were treated professionally and were therefore regarded as serious.

Most injuries were due to abrasions (n = 79), contusions (n = 108) and cuts or slices (n = 64). Compared with all other causes, professional treatment was least likely to be sought for abrasions (9%). All children who had fractures (n = 18), concussions (n = 3) or dislocations (n = 2) were treated either at an emergency department or by a general practitioner. Nearly a third of all reported injuries occurred to the head or face, although only one third of these injuries were treated professionally.

Table 2A shows the number of injuries and the injury rates per 1000 h of exposure for activities for which a minimum of four injuries were registered with the study. The activities are ranked in descending order for injury rate. RR with 95% CI for each activity compared with active play, the most common activity, are also shown. Table 2B shows the same information for serious injuries.

The highest overall injury rates occurred during tackle football, bicycle riding, other wheeled sports, tennis and soccer. Children were significantly more likely to be injured while participating in these activities than while engaging in active play. Swimming was the only activity for which significantly fewer injuries occurred than during active play. Serious injuries were more common per exposure time for tackle football, tennis, soccer and wheeled sports (excluding bicycle riding).

Sex-specific differences

On average, boys were active for a greater amount of time than girls (909 min/week; 95% CI 867 to 950; *v* 792 min/week; 95% CI 749 to 835). Boys also sustained nearly twice as many injuries related to out-of-school physical activity than girls (209 *v* 105).

Table 3 shows the RR of injury per exposure time for boys versus girls for activities for which a substantial proportion of time was accumulated for both sexes. Boys sustained injuries at a significantly higher rate than girls while participating in active play and wheeled sports (excluding bicycle riding). For all other activities, we found no statistically significant differences in injury rates between the two sexes; however, the rate for girls was higher than that for boys for soccer, trampolining and other (non-football) team ball sports.

DISCUSSION

This 12-month prospective cohort study quantified activity-specific injury risk in a randomly selected sample of Australian children aged 5–12 years. The ability to measure exposure to a range of daily recreational activities in a general pediatric population is a valuable strength of the study and adds a dimension to the epidemiology of injury related to physical activity in this age group, which was not previously available.[22]

Our list of popular activities is similar to that compiled previously from a survey of Australian adolescents, and reflects the warm climate of Brisbane that allows outdoor activity year round.[23] Children in our sample spent nearly half their active time in active play, which consisted of spontaneous, unstructured activities and games. Swimming and bicycle riding were the two most popular specific activities, and soccer was the most popular team ball sport.

Earlier studies that have included exposure measurement have mostly concentrated on organized sports in competitive scenarios,[24–31] which accounts for only a small portion of activity for children in this age group. The injury rates reported in our study, which ranged from 0.19 to 2.18 injuries per 1000 h of participation, are significantly lower than those

Table 2 Overall and serious injury rates for popular childhood activities

Rank	Activity	Number of injuries	Injury rate/1000 h (95% CI)	RR (95% CI)
A. All injuries				
1	Tackle football*	18	2.18 (1.74 to 3.10)	3.95 (2.56 to 6.10)
2	Wheeled sports†	30	1.72 (1.37 to 2.33)	3.04 (2.19 to 4.20)
3	Tennis	10	1.19 (0.97 to 1.55)	2.29 (1.26 to 4.16)
4	Soccer	20	1.03 (0.86 to 1.29)	1.91 (1.27 to 2.88)
5	Bicycle	44	1.00 (0.87 to 1.16)	1.75 (1.35 to 2.26)
6	Team ball sports‡	11	0.84 (0.68 to 1.14)	1.62 (0.92 to 2.86)
7	Trampoline	8	0.59 (0.50 to 0.73)	1.16 (0.59 to 2.28)
8	Active play	136	0.50 (0.46 to 0.54)	Reference
9	Cricket	4	0.37 (0.27 to 0.52)	0.74 (0.28 to 1.94)
10	Walking	6	0.20 (0.18 to 0.23)	0.47 (0.22 to 1.03)
11	Outside chores	5	0.21(0.18 to 0.25)	0.44 (0.19 to 1.05)
12	Swimming	13	0.19 (0.17 to 0.22)	0.44 (0.26 to 0.73)
B. Serious injuries				
1	Tackle football*	4	0.48 (0.39 to 0.69)	2.60 (1.01 to 6.67)
2	Tennis	4	0.48 (0.39 to 0.62)	2.57 (1.00 to 6.58)
3	Soccer	8	0.41 (0.34 to 0.52)	2.13 (1.12 to 4.05)
4	Wheeled sports†	7	0.41 (0.32 to 0.54)	2.14 (1.07 to 4.27)
5	Active play	48	0.18 (0.16 to 0.19)	Reference
6	Bicycle	5	0.11 (0.10 to 0.13)	0.68 (0.29 to 1.56)
7	Swimming	7	0.10 (0.09 to 0.12)	0.64 (0.32 to 1.27)

*Includes rugby and Australian rules football.
†Excludes bicycle riding.
‡Excludes all football codes.

Table 3 Injury rates for popular activities: sex-specific differences

Activity	Injury rate/1000 h		OR (95% CI) of injury risk*
	For boys	For girls	
Active play	0.58	0.40	1.42 (1.00 to 2.02)
Soccer	0.97	1.55	0.62 (0.18 to 2.13)
Tennis	1.26	1.07	1.17 (0.30 to 4.55)
Bicycle	1.08	0.85	1.26 (0.66 to 2.41)
Other wheeled sports	2.46	0.89	2.76 (1.18 to 6.43)
Other team ball	0.58	1.00	0.58 (0.15 to 2.17)
Trampoline	0.53	0.63	0.84 (0.20 to 3.50)
Swimming	0.21	0.17	1.22 (0.41 to 3.62)

*Boys compared with girls.

reported from studies conducted purely in the organized sports paradigm. This is mainly because the included populations are much more narrowly defined in these studies, and exposure is accumulated only during organized games or practice, whereas we included non-organized, informal activity in our definition of exposure.

The magnitude of injury risk for various activities in our study is, however, comparable to that in a similar study conducted on an adult cohort in Finland.[22] This study also attempted to measure exposure to a large range of daily and recreational activities, and reported an injury rate ranging from 0.19 to 18.3 per 1000 h of participation. The reported injury rates for specific activities including soccer, skating, inline skating, tennis and athletics were lower among the children in our cohort than among the Finnish cohorts, or among older children and adolescents aged from eight to 17 years of age.[32 33] This is not surprising, given that studies that have compared injury rates for different age groups during organized sports have reported an increase in injury with age and that rates are typically low in pre-adolescent children.[26 27 30 31]

The highest injury risk per exposure time, both overall and for only serious injuries, was found for tackle-style football, which included rugby and Australian rules football. Children sustained injuries that were treated in emergency departments, by general practitioners or by other health professionals more than twice as frequently as those sustained during general play. Serious injuries were also considerably more frequent per exposure time for tennis, soccer and wheeled sports including skateboarding, scootering, roller skating and roller blading.

Overall, boys were injured at a higher rate per exposure time to activity than girls. This difference was notable for wheeled activities and active play. For some activities, however, girls seemed to be injured at a higher rate than boys per exposure time, although the differences were not statistically significant. These activities included soccer, trampolining and team ball sports. Previous studies that have measured injury rates during soccer competitions have also reported higher injury rates in girls than in boys.[24 27 28]

The findings in our study extend previous Australian research suggesting that the most common reasons for visits to emergency department for children aged $\leqslant$15 years are injuries due to cycling, football, roller blading or skating, basketball, trampolining, skateboarding, cricket and netball.[5] Our results are also consistent with those of other studies that have reported higher injury rates for competitive rugby than for other competitive team sports.[25 34] Interventions to reduce injuries during these codes of football, such as modification of tackling rules for younger children, have been put in place to make the game more safe and enjoyable for this age group.

Efforts are also required to reduce serious injuries during skateboarding, scootering and roller or inline skating. Owing to the popularity of cycling, bicycle safety has been a focus of intervention efforts for many years, and several safety initiatives have been implemented in Australia and other countries, including the legislation of mandatory bicycle helmets. Meanwhile, other wheeled activities have not received the same attention, and children are not currently required to wear helmets or other safety equipment despite their ability to attain high speeds and despite product designs that entail limited stability and control. Efforts to promote safety equipment (eg, helmets or wrist guards) among users and to compel the industry to adopt safety measures in product design should be the focus of interventions to decrease these injuries.

Methodologic limitations

Several methodologic weaknesses of this study need to be overcome. Firstly, the measure of exposure was a parent-reported method, and participation in specific activities may have been under-reported or over-reported, given that parents might not be fully aware of their child's actual activity throughout the entire day. This is particularly a concern for activities with lower participation rates. Self-report or proxy-report methods of measuring physical activity

Key points

What is already known on this topic

- Physical activity is strongly recommended in children; however, many activities carry the risk of injury.
- Accurate data on exposure have been lacking for many childhood activities, and activity-specific injury rates are therefore not available for children aged 5–12 years.

What this paper adds

- Data on exposure and injury-specific rates for popular childhood activities.
- A 7-day diary was used to measure the time spent in various activities among a cohort of Australian children aged 5–12 years, and all injuries over 1 year were reported.
- Overall injury rates were low; however, injuries that were treated professionally occurred most often during tackle-style football (rugby, Australian rules football), tennis, soccer and wheeled activities (skateboarding, scootering, roller or inline skating).
- Overall, boys were injured at a higher rate than girls; however, sex-specific differences were non-significant or were reversed for several specific activities when exposure was taken into account.

have been criticized for their subjective nature,[35] and are considered to be less reliable for measuring exposure to activity than more objective methods including direct observation, pedometers or heart rate monitors. Self-report or proxy-report methods are, however, the only feasible means of collecting diverse information for large samples, and have been used previously in this context.[36 37] Prospective diaries, as used in our studies, are among the most reliable activity measures of self-report or proxy-report.[37 38]

Injuries were also reported by parents, and there was potential for either missed reporting or parental error in reporting the activity at the time of injury. We attempted to limit these errors by contacting parents at a minimum of 2-monthly intervals and by extracting information relating to how exactly each injury event occurred, so that the injury mechanism and objects, as well as the reported activity, could be determined.

Additionally, the diary might not have been completed in a typical week, and it is possible that illness, weather or school holidays may have had an effect on normal activity participation. Nonetheless, diaries were evenly distributed around the calendar year and so summer and winter activities as well as school holidays were proportionately represented across the cohort population.

This study was also limited as it measured exposure to physical activity only outside of school, and hence injuries occurring in the school environment were not included in the analysis. The school setting is governed by a social and physical environment that differs substantially from the home or neighborhood setting. Therefore, our results may not be generalizable to physical activity at school.

The low number of injury events means that the activity-specific injury rates must be interpreted with caution. These rates are useful in gauging the RR of participating in various activities; however, they are unreliable in presenting a stable injury rate. The low number of events also indicates our inability in making meaningful comparisons between competitive and non-competitive scenarios.

A final methodological weakness is related to the low participation (25%) of eligible children, which may affect generalizability of our findings to the whole population. Comparisons with census data from the school catchments imply that the more extreme levels of social disadvantage are not well represented (Dr Christina Nagle, School of Population Health, University of Queensland, personal communication, 2005).

IMPLICATIONS FOR PREVENTION

Although the overall injury rate for physical activity was relatively low, this prospective cohort study found markedly raised rates of injury that required medical treatment for children participating in tackle-style football, soccer, tennis and wheeled sports. Interventions need to focus on these activities to reduce the injury risk so that children may continue to enjoy the physical, social and emotional benefits of these activities without compromising their safety.

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